



MONITORING AND SURVEILLANCE PLAN REVISION 1

QML-0009

September 2011

BELLEKENO PROJECT



Table of Contents

1.0	Introduction	1
2.0	Water Quality Surveillance Network.....	1
3.0	Groundwater Surveillance Network.....	5
4.0	Permafrost Monitoring.....	5
5.0	Physical Inspection Plan	5
6.0	Weather Monitoring	6
6.1	Climate Overview	6
6.2	Climate Monitoring Stations	7
7.0	Noise Impacts and Sound Monitoring.....	8
8.0	Dust Abatement and Monitoring.....	8
8.1	Dust Modeling Synopsis.....	8
8.2	Potential Mill Site Dust Sources and Mitigative Measures	10
8.3	Seasonality of Sources	11
8.4	Dust Monitoring	11
8.5	Phase 1: Dustfall Monitoring	12
8.6	Phase 1 Sampling Initial Results	13
8.7	Phase 2: TSP Monitoring	13
8.8	Method of Analysis.....	13
8.9	Future Monitoring	14
9.0	Waste Rock Monitoring	15
10.0	Environmental Effects Monitoring (Under MMER)	15
10.1	Final Discharge Points	15
10.2	Effluent Monitoring	15
10.3	Environmental Effects Monitoring (EEM) Program	16
10.4	Christal Lake Characterization Study	17
11.0	Spill Contingency Plan	18
12.0	Adaptive Management Plan (AMP)	18

12.1	AMP Objectives	18
12.2	AMP Approach.....	20
13.0	Reclamation Effectiveness Monitoring Program.....	25
14.0	Reporting	26
15.0	References.....	27

List of Tables

Table 1 Current Monitoring Program Summary within the Area of the Mill and Mine	3
Table 2 Precipitation and Evapotranspiration at Select Keno Hill District Locations.....	7
Table 3 MMER Standards	16
Table 4 Overall AMP Summary	12-21

List of Figures

Figure 1 Bellekeno Surface Water Quality Monitoring Locations	4
Figure 2 Dust Monitoring Stations	9
Figure 3 Bergerhoff Deposit Dust Gauge.....	10

Appendices

Appendix A: Groundwater Monitoring Plan, Water Licence QZ09-092
Appendix B: Physical Inspections and Reporting Plan, Water Licence QZ09-092
Appendix C: Environmental Conditions Report, Section 2.1
Appendix D: Memorandum: Keno District Mill Preliminary Dustfall Monitoring Results
Appendix E: VDI 2119 Part 2: Determination of Dust Precipitation with Collecting Pots Made of Glass (Bergerhoff Method) or Plastic
Appendix F: Bellekeno Mine Cycle 1 Environmental Effects Monitoring Study Design
Appendix G: Bellekeno Adaptive Management Plan

1.0 INTRODUCTION

This plan describes the environmental monitoring programs that will be carried out to ensure that the Bellekeno mine/mill development operations are conducted in a manner that provides human and environmental protection. These programs are designed to monitor:

- Potential effects to the receiving environment through scheduled physical and environmental monitoring programs and inspection tours of the project components and receiving environment;
- Effluent discharge points and consequently operational treatment performance;
- Site facilities and incorporated design measures to ensure structural stability and prevent accidents and malfunctions;
- Mitigation success; and
- Adaptive management responses to improve procedure/process.

If monitoring indicates that physical structures, treatment systems or other mitigative measures are not performing, then maintenance measures or contingency plans can be implemented following an adaptive management approach as discussed in Section 12.

Prior to Bellekeno mine development, a number of monitoring programs and a surveillance network were already in place for care and maintenance activities and for advanced exploration and preliminary development activities at the Keno Hill Property. These programs include physical inspections, effluent treatment systems and flow monitoring, a water quality surveillance network, old mine workings monitoring, aquatic effects monitoring for benthic invertebrate populations, sediment monitoring, waste rock and mine wall sampling and/or the adaptive management plan. Monitoring and surveillance networks specific to the Bellekeno Undertaking are presented in this plan. Monitoring stations near the mill and mine areas are discussed within the following sections.

2.0 WATER QUALITY SURVEILLANCE NETWORK

The existing water quality surveillance network for the Bellekeno Project includes surface receiving waters in the Bellekeno and Christal Lake area. Most of the monitoring stations have been sampled extensively in the past. Current water quality monitoring is required in these areas under Water Licence QZ06-074 Water Licence QZ07-078, and Water Licence QZ09-092.

Table 1 outlines existing sampling frequency and schedule for internal and external lab analysis in the area of the Bellekeno Mine and in the vicinity of the Mill Site. Figure 1 shows the existing monitoring station locations. Treatment sites are monitored monthly,

daily, or daily while discharging. Surveillance sites are sampled weekly, monthly, monthly (seasonally) and quarterly as required by QZ09-092. This includes the following sites upstream of Christal Creek and upstream of Lightning Creek:

- KV-6 – Christal Creek at the Keno Highway to monitor downstream of the old Mackeno Mill and tailings location;
- KV-7 – Christal Creek at Hanson Road to monitor effects from the old Mackeno Mill;
- KV-41 - Lightning Creek at Keno City Road Crossing to monitor impacts from adit drainages and waste rock seepage reporting to this creek;
- KV-43 – Bellekeno 625 Treatment pond decant to monitor the impacts from the mine edited to be ongoing weekly sampling;
- KV-78 – Bellekeno Waste Rock Storage Facility;
- KV-52 or KV-80 – Potential mill water sources;
- KV-81 – Mill discharge (final discharge point) to monitor the mill impacts; and
- KV-2, KV-8, KV-38, KV-39 KV-40, KV-42, KV-44, KV-45, KV-49, KV-50, KV-51, KV-65, KV-72, KV-75, KV-76, KV-77 and KV-79 (refer to Table 1 for complete station descriptions) are additional upstream and downstream monitoring locations in Lightning and Christal Creek drainages.

SITE	SITE DESCRIPTION	WATER LICENCE			MMER																		PARAMETERS																EEM PROGRAM ¹		
		Q206-074	Q207-078	Q209-092	Effluent Monitoring Conditions	Effluent Characterization	Inspect	Level	Flow	pH	Temp.	Cond.	Total Zn	Ammonia	Turbidity	Total Metals	Dissolved Metals	Mercury	Ammonia-N	Nitrite	Nitrate	Total Phosphorous (colourimetric)	Sulphate	DOC	Hardness	Alkalinity	pH	Conductivity	TSS	Radium 226	Acute Lethality LC 50	Daphnia Magna	Sediment	Benthic	Sub-Lethal Toxicity						
Bellekeno Treatment Sites																																									
KV-42	Bellekeno 625 Adit	✓	✓	✓	✓	✓	D	-	C	D	D	D	D	D	D	W	W	-	W	W	W	W	W	M	W	-	W	W	W	W	-	-	-	-	-	-					
KV-43	Bellekeno 625 Settling Pond Decant	✓	✓				D	-	C	D	D	D	D	D	D	W	W	Q	W	W	W	W	W	W	Q	W	W	W	W	W/Q	M	M	-	-	SA ⁴						
KV-74 ²	Bellekeno East Decline		✓				D	-	D	D	D	D	D	D	D	M	M	-	M	-	-	-	-	M	-	M	M	M	M	-	-	-	-	-	-						
KV-75 ²	Bellekeno East Settling Pond		✓				D	-	D	D	D	D	D	D	D	M	M	-	M	-	-	-	-	M	-	M	M	M	M	-	M	-	-	-	-						
KV-82	Flame and Moth Site Collection and Sediment Pond			✓			D	D	M	M	M	M	M	M	M	M	M	-	M	M	M	M	M	M	-	M	M	M	M	M	M	M	-	-	-	-					
KV-83	Flame and Moth Treatment Plant Discharge			✓	✓	✓	D-WD	-	D-WD	D-WD	D-WD	D-WD	D-WD	D-WD	D-WD	W-WD	W-WD	Q-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/Q	M-WD	M-WD	-	-	SA ⁴					
Bellekeno Mine Development Surveillance Sites																																									
KV-1	South McQuesten River u/s Christal Creek	✓		✓			-	-	Q	Q	Q	Q	-	-	-	Q	Q	-	-	-	-	Q	Q	Q	Q	-	Q	Q	Q	Q	-	-	-	-	-	-					
KV-2	South McQuesten Rive @ Pumphouse	✓		✓			-	-	Q	Q	Q	Q	-	-	-	Q	Q	-	-	-	-	Q	Q	Q	Q	-	Q	Q	Q	Q	-	-	-	-	-	-					
KV-6	Christal Creek @ Keno Highway			✓			-	-	C	M	M	M	-	-	-	M	M	-	M	M	M	M	M	M	M	-	M	M	M	M	-	-	-	BA	BA	-					
KV-7	Christal Creek @ Hanson Road			✓			-	-	M	M	M	M	-	-	-	M	M	-	M	M	M	M	M	M	M	-	M	M	M	M	-	-	-	-	-	-					
KV-8	Christal Creek @ mouth			✓			-	-	Q	Q	Q	Q	-	-	-	M	M	-	-	-	-	M	M	M	M	-	M	M	M	M	-	-	-	-	-	-					
KV-37 ³	Lightning Creek u/s Hope Gulch	✓	✓	✓			-	-	Q	Q	Q	Q	-	-	-	Q	Q	-	-	-	-	Q	Q	Q	Q	-	Q	Q	Q	Q	-	-	-	-	-	-					
KV-38	Lightning Creek u/s Thunder Gulch	✓	✓	✓			-	-	Q	Q	Q	Q	-	-	-	Q	Q	-	-	-	-	Q	Q	Q	Q	-	Q	Q	Q	Q	-	-	-	A	-	-					
KV-39	Hope Gulch u/s Lightning Creek	✓		✓			-	-	Q	Q	Q	Q	-	-	-	Q	Q	-	-	-	-	Q	Q	Q	Q	-	Q	Q	Q	Q	-	-	-	-	-	-					
KV-40	Charity Gulch u/s Lightning Creek	✓		✓			-	-	Q	Q	Q	Q	-	-	-	Q	Q	-	-	-	-	Q	Q	Q	Q	-	Q	Q	Q	Q	-	-	-	-	-	-					
KV-41	Lightning Creek u/s Brige @ Keno City	✓	✓	✓			-	-	C	M	M	M	-	-	-	M	M	-	M	M	M	M	M	M	M	-	M	M	M	M	-	-	-	A	-	-					
KV-44 ²	Bellekeno 625 Seep		✓	✓			-	-	Ms	Ms	Ms	Ms	Ms	-	-	-	Q	-	-	Q	Q	Q	Q	Q	-	Q	Q	Q	Q	-	Q	-	-	-	-						
KV-45	Onet Adit	✓	✓	✓			-	-	Q	Q	Q	Q	-	-	-	Q	Q	-	-	-	-	Q	Q	Q	Q	-	Q	Q	Q	Q	-	-	-	-	-	-					
KV-49 ¹	Hinton Creek u/s Christal Creek	✓		✓			-	-	-	-	-	-	-	-	-	Q	Q	-	-	-	-	Q	Q	Q	Q	-	Q	Q	Q	Q	-	-	-	-	-	-					
KV-50 ¹	Christal Creek u/s Hinton Creek	✓		✓			-	-	Q ⁵	Q ⁵	Q ⁵	Q ⁵	-	-	-	Q ⁵	Q ⁵	-	-	-	-	Q ⁵	Q ⁵	Q ⁵	Q ⁵	-	Q ⁵	Q ⁵	Q ⁵	Q ⁵	-	-	-	-	-	-					
KV-51 ³	Christal Creek d/s Hinton Creek	✓		✓			-	-	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	✓		✓			-	-	M	M	M	M	-	-	-	M	M	-	-	-	-	M	M	M	M	-	M	M	M	M	-	-	-	-	-						
KV-65	Thunder Gulch u/s of Bellekeno 625	✓	✓	✓			-	-	Q	Q	Q	Q	-	-	-	M	M	-	-	-	-	M	M	M	M	-	M	M	M	M	-	-	-	-	-	-					
KV-72	South McQuesten River @ McQuesten Lake			✓			-	-	Q	Q	Q	Q	-	-	-	Q	Q	-	-	-	-	Q	Q	Q	Q	-	Q	Q	Q	Q	-	-	-	-	-	-					
KV-76	Thunder Gulch d/s Bellekeno 625		✓	✓			-	-	-	Q	Q	Q	Q	Q	Q	Q	Q	-	-	-	-	Q	Q	Q	Q	-	Q	Q	Q	Q	-	M	-	-	-	-					
KV-77	Thunder Gulch u/s Bellekeno East		✓	✓			-	-	Q	Q	Q	Q	-	-	-	Q	Q	-	-	-	-	Q	Q	Q	Q	-	Q	Q	Q	Q	-	-	-	-	-	-					
KV-78	Bellekeno East Temporary Waste Rock Storage Facility			✓			-	Ms	-	Ms	Ms	Ms	-	-	-	Q	Q	-	-	-	-	Q	Q	Q	Q	-	Q	Q	Q	Q	-	-	-	-	-	-					
KV-79	Christal Creek d/s MacKeno Tailings			✓			-	-	-	Q	Q	Q	-	-	-	Q	Q	-	-	-	-	Q	Q	Q	Q	-	Q	Q	Q	Q	-	-	-	-	-	-					
KV-80	Christal Creek u/s Mackeno Tailings			✓			-	-	-	Q	Q	Q	-	-	-	Q	Q	-	-	-	-	Q	Q	Q	Q	-	Q	Q	Q	Q	-	-	-	-	-	-					
KV-81	Lightning Creek Southwest of Mill Site			✓			-	-	-	Q	Q	Q	Q	-	-	Q	Q	-	-	-	-	Q	Q	Q	Q	-	Q	Q	Q	Q	-	-	-	-	-	-					

1. Program design currently underway
2. Station is frequently dry or not expected to produce water
3. Background station
4. Monitoring to occur semi-annually during the first three years of the study program, with the first sample collected 6 months following the start of operations, and once each year after the third year
5. Monitoring to occur monthly for the first year of operations, resuming this schedule after 12 months

C = Continuous
D = Daily
D-WD = Daily While Discharging
W = Weekly
W-WD = Weekly While Discharging
W/Q = Weekly migrating to quarterly to accord with monitoring frequency pursuant to MMER regulations
M = Monthly
Ms = Monthly (May - Oct)
Q = Quarterly
A = Annually
SA = Semi Annually (twice per year)
BA = Bi Annually (every 2 years)

Currently at Bellekeno 625, treated water (KV-43) is monitored daily through internal analysis for pH, flow, total zinc, ammonia and turbidity with monthly samples sent to an external lab. Similar monitoring is conducted for the Bellekeno East portal, with treated water (KV-75) sampled and analyzed at the same frequencies if it is discharged. The mine and mill discharge will be monitored through stations KV-43 and KV-81, respectively.

3.0 GROUNDWATER SURVEILLANCE NETWORK

A groundwater monitoring plan for the Bellekeno mine has been developed under Water Licence QZ09-092. This program outlines monitoring locations and frequency for the Keno District mill and dry stack tailings facility, the non-AML waste rock disposal area, and Keno City. The groundwater monitoring plan includes sites stipulated in Schedule B to QZ09-092, and is attached as Appendix A.

Groundwater wells are scheduled for monthly monitoring for both water level and quality for the first year after QZ09-092 came into effect to establish well conditions, followed by quarterly sampling thereafter, for the duration of the project.

4.0 PERMAFROST MONITORING

Geotechnical programs have identified areas of permafrost within operational areas of the project. Specifically, some permafrost was encountered beneath the proposed non-AML Waste Rock Storage Area (WRSA) and in the vicinity of the proposed Dry Stack Tailings Facility (DSTF). Ground temperature and permafrost monitoring is currently in place at these locations. Details on monitoring for the DSTF will be included in the DSTF OMS manual, which forms a part of the DSTF Development and Operations Plan. Details on permafrost monitoring for the WRSA are included in the Mine Development and operations Plan.

5.0 PHYSICAL INSPECTION PLAN

The purpose of the physical inspection is to observe and record sufficient information related to physical and water retaining structures to permit development of a course of action, repair or rehabilitation if it is required. Physical inspections are currently inspected under the Physical Inspections and Reporting Plan prepared for Water Licence QZ09-092. The Physical Inspections and Reporting Plan is attached as Appendix B. The Physical Inspections and Reporting Plan describes weekly and monthly physical inspections of infrastructure associated with the Bellekeno mine/mill development and operation. Information is collected through use of weekly and monthly checklists and reporting forms. 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.

In the vicinity of the Bellekeno mine, physical inspections include the Bellekeno 625 settling ponds, the Bellekeno East temporary Waste Rock Storage Facility, the non-AML Waste Rock Disposal Area, 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, and the dry stack tailings facility.

6.0 WEATHER MONITORING

6.1 Climate Overview

This section presents an overview of basic variables which affect the water balance at each of the three points of water use and discharge in this project. Data from two historical Environment Canada Atmospheric Environment Service weather stations in the Keno Hill area (Elsa townsite from 1948-1965, and 1974-1989; and Keno Hill from 1974-1982) were used to predict climatic parameters for the three site locations within the Bellekeno Mine and Mill development project.

The most important variables are average precipitation and average evaporation. These two parameters were considered the key parameters in developing the water balance for the Keno Hill area as a whole, see Section 2.1 of the Environmental Conditions Report (attached as Appendix C).

6.1.1 Precipitation and Evaporation

Two climatic variables were assessed to develop an overall water balance for the Keno Hill Silver District. The two variables are average precipitation and average evaporation. These two variables were considered the key parameters in developing the water balance for the site.

Data from various climate stations were used to characterize the climate of the Keno Hill Property. A discussion of this data including mean annual precipitation and rates of evaporation is provided in Section 2.1 of the Environmental Conditions Report (see Appendix C). This data was used to derive site hydrological conditions at the time; however based on comparisons with the latest site data, the original techniques and hydrological inputs were deemed appropriate in deriving site hydrological conditions (Clearwater Consultants Ltd, 2008; see Environmental Conditions Report). This climate data is therefore still considered valid and accurate.

Mean annual precipitation (MAP) has been shown within the Keno Hill Silver District to increase with increasing elevation. The significant relief over which the Keno Hill area spans is well represented by the two historical weather stations with Elsa at 814 m and the Keno Hill weather station at 1472 m. This spread facilitated derivation of the relationship between elevation and precipitation for the site. In combination with site evapotranspiration, calculations have been used to predict annual precipitation, evapotranspiration, and net precipitation for the Bellekeno Mine and Keno District Mill (see Table 2 below). The close proximity and similar elevation allow Elsa to be a proxy for the Flat Creek Camp.

Table 2 Precipitation and Evapotranspiration at Select Keno Hill District Locations

Site	Mean Annual Precipitation (mm)	Mean Annual Evapotranspiration (mm)	Annual Net Precipitation (mm)	Data Source
Keno Hill (1472 m Elevation)	585	205	380	AES Climate Station, UKHM Site Characterization Report, 1996
Elsa Townsite (814 m Elevation)	420	230	190	AES Climate Station, UKHM Site Characterization Report, 1996
Bellekeno Mine (1050 m Elevation)	479	221	258	Calculated based on site elevation-precipitation relationship
Keno District mill site (901m Elevation)	443	227	215	Calculated based on site elevation-precipitation relationship

These precipitation and evapotranspiration estimates have been compared to recent work done by Clearwater Consultants Ltd. (CCL, 2008) on behalf of Alexco to update the 1996 study on Hydrology for the Keno Hill Silver district (CCL, 2008). CCL found that using the latest site flow data, hydrologic inputs for their new site-wide water balance could be estimated using the original techniques presented in the 1996 Hydrology Study, provided the influences of adit flows on local hydrology were accounted for. A direct comparison between the annual net precipitation for the Keno District Site (209 mm) with the 2004-2007 MAR of the Christal Creek catchment area based on KV-7 flow data (221 mm) shows close agreement. Comparison between the estimated Bellekeno Mine Site annual net precipitation and MAR from the Lightning Creek catchment area above KV-41 shows a considerable difference (258 mm vs. 344 mm, respectively). This can be explained in the fact that the Bellekeno Mine site is quite low within the Lightning Creek catchment, and therefore receives below average precipitation for the catchment area.

6.2 Climate Monitoring Stations

As part of closure planning studies, a meteorological station was established on Galena Hill in summer 2007 by Alexco. The station measures air temperature, relative humidity, barometric pressure, rainfall, wind speed and direction, solar radiation, and soil temperature. As a condition of Type A water use licence QZ09-092, a second metrological station and snow course have been established at the Keno District mill site. The location of the mill site weather station is shown on Figure 2. A Yukon Government monitored snow

course station also exists in the area. These data will be used to update meteorological/hydrological information and water balances for the project area throughout operations and to better inform closure planning. This will include calculations of minimum and maximum for both wet and dry years.

7.0 NOISE IMPACTS AND SOUND MONITORING

Noise Impacts and sound monitoring are discussed in the Noise Abatement Plan submitted under QML-0009.

8.0 DUST ABATEMENT AND MONITORING

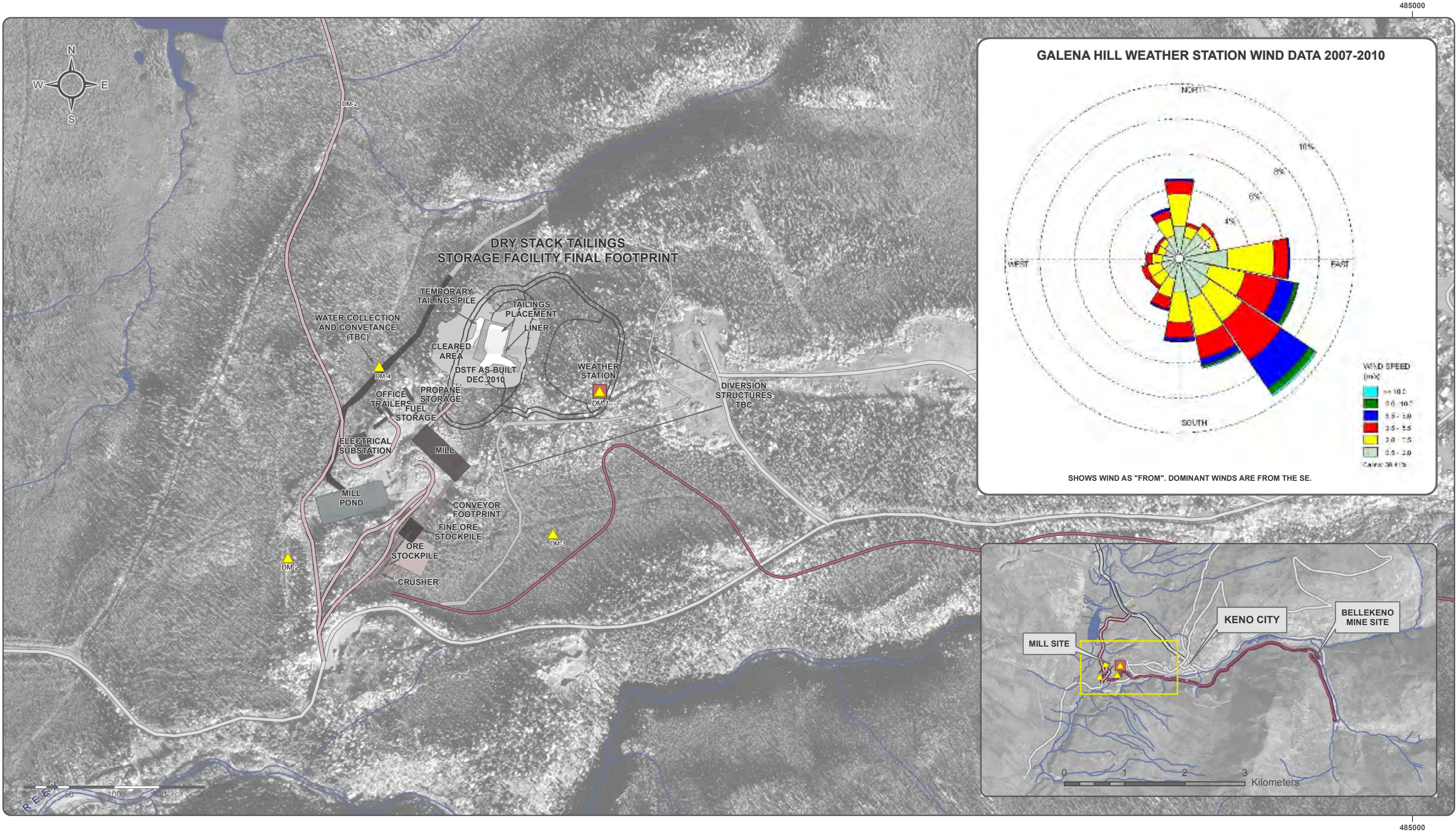
In accordance with Clause 69 of the Decision Document for the assessment for the Bellekeno Mine Project (YESAB File Number 2009-0030), dustfall monitoring was installed at two initial locations near the Keno District mill site. Bergerhoff dust monitoring gauges were selected as the appropriate instrumentation to carry out this program. The Bergerhoff deposit dust gauge is designed to measure dust deposition, which can be reported as a weight per unit area over unit time.

This section outlines the approach for dustfall monitoring for the Bellekeno Production Unit and surrounding areas.

Mill site layout and infrastructure and locations of Bergerhoff dust monitoring gauges currently in place at two locations at the edge of the mill site are shown on Figure 2.

8.1 Dust Modeling Synopsis

A dust modeling exercise using ISC3 modeling software using both simulated and real weather data from the Galena Hill weather station was undertaken by Alexco for the DSTF. The Gaussian plume model is used by this program. The results of the wind analysis predicted that any dust generated by the DSTF would rarely be transported towards Keno City. Results of the dust modeling using worst-case-scenario inputs predicted a maximum of 60 µg/m³ in Keno City, which is well below the BC objective of 150 µg/m³. The accuracy of the Gaussian model is noted to be within 20% for ground level emissions at distances less than 1 km. At distances greater than 1 km, the equation is estimated to be accurate within a factor of 2 (Reed, 2005). The dust modeling report formed Part III of the Dry Stack Tailings Facility Construction and Operation Plan and was submitted September 2010.



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 under license 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

Main Map: 1:4,000 Inset Map: 1:60,000
(when printed on 11 x17 inch paper)

- Dust Monitor Station
- Weather Station
- Mill Access Road
- Haul Road
- Local Road



MONITORING AND SURVEILLANCE PLAN QML - 0009

FIGURE 2
DUST MONITORING STATIONS

DRAWN BY MD SEPTEMBER 2011 VERIFIED BY EA

I:\ALEX-05-01\Bellekeno\GIS\mxd\Permitting\Monitoring_and_Surveillance_Plan_QML_0009\Dust_Monitoring_Stns_20110913.mxd
(Last edited by: jpan; 9/13/2011/14:39 PM)

Figure 3 Bergerhoff Deposit Dust Gauge

8.2 Potential Mill Site Dust Sources and Mitigative Measures

The single largest potential source of dust from a mining operation is considered to be windblown dust from tailings facilities. This has been a feature of slurry tailings deposits in past mining operations, where desiccated ‘beaches’ of tailings form above water line in large, valley fill tailings impoundments. The system proposed for the Bellekeno mill, however, is completely different from valley-fill slurry tailings deposits of the past. The Dry Stack technology results in a filtered, moist tailings deposit that is placed and compacted in lifts to achieve certain design compaction levels. Also, with the added feature of progressive construction and progressive reclamation, only a fraction of the total DSTF footprint will be exposed at any one time. As far as possible, each year’s dry stack after construction is covered with an evapotranspirative cover and revegetated.

Therefore, not only is the footprint minimized, but damp and compacted tails will not be subject to wind erosion. Should desiccation be observed in summer months, the Operation, Maintenance and Surveillance Manual for the Day Stack Tailings Facility submitted in September 2010 dictates procedures to be undertaken to maintain moist conditions prior to covering. These include rewetting with spray bars or trucked water.

A second potential source of dust at the mill site is from the ore crushers, conveyance equipment and fine ore and concentrate stockpiles. First quarter operations of the mill site have revealed that dust can be produced by the crushing operation during extremely cold weather (below -30 C) when most of the available moisture in the ore is frozen. Significant production of dust from crushing is generally not observed at warmer temperatures. Dust from crushing operations at cold temperatures will be controlled by installation of dust screens or temporary dust suppression structures around the crushing equipment. The fine ore stockpile is covered with a sprung structure, and no significant dusting from this pile has been observed. The ore loadout areas are sheltered within loadout bays in the mill building, and the ore loading area is covered by a sprung structure which is attached to the mill building. These structures will be effective in minimizing dust from the ore loadout area.

A third potential source of dust is from mill site traffic. This will be of primary concern in any prevailing dry periods during the summer. Traffic related dusting will be controlled on the mill site area roads by application of water as necessary and/or use of non-petroleum dust suppressants (e.g. Calcium Chloride). Under no circumstances will waste oil or other hydrocarbon product be used for dust suppression. Verification that dust control measures are effective is provided by the dust monitoring.

8.3 Seasonality of Sources

As discussed above, potential dust sources at the mill site have been identified as the Dry Stack Tailings Facility (DSTF), the tailings and concentrate loadout areas, the fine ore stockpile, the primary and secondary crushers, and fugitive dust from mill site area roads. Based on the dust modeling conducted and submitted as part of the DSTF Construction and Operation Plan and preliminary data collected to date, these potential dust sources are expected to be more likely to produce dust at different times of the year. Dust from crushing activity is most likely during periods of cold weather during the winter months, when natural water in ore is too frozen to provide natural dust suppression. Dust from other sources (DSTF, loadout areas, stockpiles, and roads) is considered more likely to be produced during the summer months during periods of dry weather.

8.4 Dust Monitoring

During the YESAA assessment, the issue of dust was highlighted by assessors and reflected in the YG Decision Document issued July 10, 2009. Clause 64 and clause 65 of the Decision Document call for dust monitoring to be conducted during operations as follows:

64. Monitoring dust conditions is an important step in controlling dust impacts. Simple TSP (dustfall) monitoring is a simple and inexpensive way to determine dust deposition at the sampling locations. This test can be done at the site by the proponent with little cost or training necessary.
65. If warranted by initial dustfall measurements indicating TSP concentrations in excess of 150 micrograms per cubic metre (the BC Air Quality Objectives and

Standards Level A criteria) at the fence line, the proponent shall conduct more sophisticated monitoring with high volume samplers and re-evaluate and improve dust suppression techniques to achieve the TSP objective.

It should be noted that TSP (total suspended particulate) monitoring is not the same as dustfall monitoring, which is a passive measurement of dust accumulation over time per unit area. The Decision Document suggests the use of BC Air Quality Objectives and Standards Level A criteria of $150 \mu\text{g}/\text{m}^3$ as a threshold for triggering phase two of the monitoring program. However, dustfall measurements (as suggested in the decision document for phase 1) will yield deposition rates (in $\text{mg}/\text{dm}^2/\text{mo}$) and will not be comparable to BC Air Quality Objectives and Standards.

Alexco believes that the intent of these clauses were to instate a two phase monitoring program in which dustfall monitoring is undertaken as the first phase, with a specified trigger upon which more sophisticated TSP monitoring would be deployed.

The Pollution Control Objectives for the Mining, Smelting and Related Industries of BC (1979), provide reasonable limits for dustfall (Phase 1) at the edge of the mill site. These parameters, which range from 1.7 to $2.9 \text{ mg}/(\text{dm}^2 \cdot \text{d})$, will be used as a trigger for phase two (TSP monitoring). If deposition rates measured at the edge of the mill site either exceed $1.7 \text{ mg}/\text{dm}^2 \cdot \text{d}$, Phase 2 of the monitoring plan will be undertaken.

8.5 Phase 1: Dustfall Monitoring

Two Bergerhoff gauges have been commissioned near the mill site. One gauge (DM-1) was installed in January, 2011 to the east of the DSTF between the mill site and Keno City. A second Bergerhoff gauge (DM-2) has been installed to the west of the mill facility and crushing facility and is located between the mill site and upper Christal Creek. The location for dust monitoring stations is shown on Figure 4.

In a meeting held between Alexco and representatives from YG Environment and YG Environmental Health, additional Bergerhoff gauges were recommended by YG Environment. Two additional dust monitoring gauges were installed by Alexco near the mill site in August, 2011. All dust monitoring locations are shown on Figure 2.

The dust monitoring station locations were selected based on results of Galena Hill Wind analysis, and the location of the most sensitive receiver (Keno City). Distance from potential dust sources was selected to be consistent with Clause 70 of the Decision Document, which states that TSP standards should be met at “the fence line”. Although there will not be a fence around the perimeter of the project, the locations are consistent with the approximate edge of the extent of the project area. DM-1 may need to be relocated slightly to the east as it lies within the final footprint of the dry stack tailings facility. However, this portion of the dry stack will be constructed as the final part of the pile construction and will not occur for several years.

8.6 Phase 1 Sampling Initial Results

Initial results of dust sampling between were taken at DM1 and DM2 for the time intervals March 6, 2011 until April 3, 2011, and between April 3, 2011 and May 10, 2011 are attached in an interpretive memo (Appendix D).

8.7 Phase 2: TSP Monitoring

Dust monitoring may be triggered to require more rigorous sampling at the site. Should the monitoring plan move into Phase 2, TSP dust monitoring equipment will be put in place, together with more rigorous dust suppression measures. Sampling equipment will consist of either a continuous duty, constant flow air monitoring system or a discrete sampler. It is anticipated that this type of equipment will require power at the site and will measure ambient concentrations (in $\mu\text{g}/\text{m}^3$). The objectives recommended during the assessment to which results from a continuous sampler were to be compared were the BC Air Quality Objectives and Standards Level A criteria of $150 \mu\text{g}/\text{m}^3$ averaged over 24 hours, or $60 \mu\text{g}/\text{m}^3$ for the annual geometric mean. Alexco is aware that Environment Yukon has recently set Ambient Air Quality Standards under the Environment Act. These standards for TSP are set at $120 \mu\text{g}/\text{m}^3$ for a 24-hour average, and $60 \mu\text{g}/\text{m}^3$ as an annual geometric mean. Should dust monitoring proceed to TSP monitoring, Alexco will compare its results to the Ambient Air Quality Standards under the Environment Act.

Should phase 2 be initiated, a single instrument will be installed at the primary receptor point (DM1 on Figure 1), and the Phase 1 instruments (Bergerhoff gauges) will be decommissioned. Once Phase 2 is initiated, the focus will be on ensuring that air quality (TSP) are maintained at or below the Ambient Air Quality Standards under the Yukon Environment Act through more rigorous and/or additional dust suppression measures.

8.7.1 Phase 2 Monitoring Schedule

Should a discrete sampler be used, the averaging period will correspond to the interval between filter changes, and with monthly filter changes, data will be comparable to annual objective. Filters will be sent to a certified laboratory for analysis.

8.8 Method of Analysis

Samples taken during Phase 1 testing will be subjected to the following procedure upon receipt by the laboratory:

Based on the outcome of the first round of dust monitoring (as described in Appendix D) the laboratory has been instructed to run dust samples for only TSS, and to keep the solids from the Total Solids and if enough sample is available (at least 1 gram) to proceed with an ICP metals analysis.

Dust will be recovered monthly from the filters and collection bottles and the rate of dust deposition will be calculated. Details on dust recovery techniques can be found in the

standard protocol developed for the Bergerhoff dust gauges (German Standard VDI 2119) which is provided as Appendix E.

8.9 Future Monitoring

Based on the results of the first round of dust monitoring under Phase 1 of the plan described herein, the following recommendations have been adopted for further dust monitoring:

- Continuation of the Phase 1 (dustfall) monitoring program as there were no exceedences of the trigger of $1.7 \text{ mg}/(\text{dm}^2 \cdot \text{d})$ for the second phase (TSP) monitoring.
- Two additional monitoring Bergerhoff dust monitoring stations (shown as DM-3 and DM-4 on Figure 2) will be installed along the northwest and southeast margins of the mill site. These additional stations will provide additional confidence that windblown dust resulting from any predominant wind direction is adequately sampled.
- Only TSS will be measured for future dust samples by the laboratory, because of its more sensitive RDL.
- A sampling period length of approximately 1 month will be carried out during the spring and summer months as other potential dust sources are exposed.
- A longer sampling period (e.g. 60 days) during winter/spring months will be carried out in order to attempt to collect a greater (measurable) sample weight which will provide a greater margin above RDLs.
- Implementation of more sophisticated field sampling procedures (including the periodic addition of deionized water to sampling jars) will be implemented during the summer months in order to prevent potentially drying out of the sample jars, which could cause loss of sample. In winter, more frequent emptying of the sampling jars (in which subsamples would be held by Alexco and combined prior to sending to the lab) may be required as necessary in order to prevent overflowing of sample jars with snow, which could prevent proper sample collection.
- Continuation of pre-emptive and reactive dust control procedures as outlined in the DSTF Construction and Operation Plan, Traffic Management Plan, and Monitoring and Surveillance Plan is recommended to help ensure that fugitive dusting does not become an issue.

9.0 WASTE ROCK MONITORING

All waste rock management facilities are subject to monitoring for physical and geochemical stability (acid rock drainage or metal leaching). A complete Waste Rock Management Plan was attached to the Construction Site Plan Revision 1 as Appendix B and includes detailed descriptions of waste rock monitoring and mine wall testing.

10.0 ENVIRONMENTAL EFFECTS MONITORING (UNDER MMER)

The MMER, governed under the Fisheries Act, was annexed on June 6, 2002 and amended on October 2006. The Bellekeno mining operation is subject to these regulations, as effluent discharge exceeds 50 m³ /day, which authorizes the deposit of a deleterious substance (allow the deposit of an effluent) from the mining and milling operation according to the following categories and conditions (MMER 2002, Metal Mining Guidance Document for Aquatic Environmental Effects Monitoring, June 2002):

10.1 Final Discharge Points

Bellekeno mine and mill operation will have two discharge sites into two different receiving waters (mine operation effluent discharges to Lightning Creek (KV-43); milling operation at the Keno District mill will discharge into Christal Creek and/or Christal Lake (KV-83).

The final monitoring location for KV-83 will require a year-round accessible site where an accurate flow measuring device, according to Environment Canada specifications, can be constructed (Guidance Documents for the Sampling and Analysis of Metal Mining Effluents, Environment Canada, April 2001). This will also serve as the location where effluent sampling and monitoring will occur.

10.2 Effluent Monitoring

Monitoring at the above sites for discharge and water quality is required on a weekly basis and will be triggered at each respective location when mine and or mill construction commenced. Acute lethal toxicity tests are required monthly. In addition to criteria specified in the Type A water license, effluent must meet the following criteria (MMER 2004, Metal Mining Effluent Regulations, subsections 34(2), 36(5) and 38(9) of the *Fisheries Act*):

The concentration of the deleterious substance in the effluent does not exceed authorized limits as shown in Table 3:

Table 3 MMER Standards

Deleterious Substance	Maximum Authorized Monthly Mean Concentration	Maximum Authorized Concentration in a Composite Sample	Maximum Authorized in a Grab Sample	Units
Arsenic	0.50	0.75	1.00	mg/l
Copper	0.30	0.45	0.60	mg/l
Cyanide	1.00	1.50	2.00	mg/l
Lead	0.20	0.30	0.40	mg/l
Nickel	0.50	0.75	1.00	mg/l
Zinc	0.50	0.75	1.00	mg/l
TSS	15.0	22.50	30.00	mg/l
Radium 226	0.37	0.74	1.11	Bq/l

*All concentrations are total values

The pH of the effluent is equal to or greater than 6.0 but is not greater than 9.5; and

The deleterious substance is not an acutely lethal effluent (trout and daphnia LT50)

10.3 Environmental Effects Monitoring (EEM) Program

An Environmental Effects Monitoring program is currently being developed with Environment Canada under the MMER for the Bellekeno operation. The sampling requirements under this program are as follows:

Part 1. Effluent and Water Quality Monitoring Studies

- a) Effluent Characterization: Quarterly sampling of extra parameters from final discharge point;
- b) Water Quality Monitoring: Quarterly sampling of sites within reference and exposure areas:
 - a. 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.
 - b. Exposure Area: All fish habitat and waters frequented by fish that are exposed to effluent; and
- c) 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 MMER.

Part 2: Biological Monitoring Studies

A number of study cycles that each include:

- A study design (first study design to be submitted within 12 months of triggering MMER and includes a site characterization);
- 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 exceed is equal to or greater than 0.1 ug/l or ppb – as determined by the effluent characterization program)
- c) Benthic Invertebrate Community: Studies conducted in exposure and reference areas.

The first study cycle (Cycle 1) is 30 months in duration, and was submitted in September, 2011. The Bellekeno Mine Cycle 1 Study Design is attached as Appendix F. The subsequent cycles are 24-72 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. In order to avoid redundancy in sampling sites and monitoring programs, final discharge points for MMER will be considered final discharge points under the proposed water licence for the Bellekeno mine/mill development and operations. All requirements and reports and data for the MMER EEM studies will be provided to the Yukon Water Board.

10.4 Christal Lake Characterization Study

To document local environmental conditions in Christal Lake an initial Characterization study will be conducted. This study will fulfill the requirement of Clause 48 of Water Licence QZ09-092, which states:

“The Licensee shall conduct sediment and benthic invertebrate characterization studies in Christal Lake during the first full open water season after the license is issued. The studies shall involve the collection of lake sediments, phytoplankton, zooplankton and water quality. The Licensee shall provide the results of the study and interpretation to the Board by March 31, 2012”

The purpose of this study will be to document limnological characteristics of Christal Lake and will be undertaken during the first year of construction /operation. The program will involve the collection of lake sediments, phytoplankton, zooplankton and water quality using

recognized guidance protocols. The program will be conducted three times during the open water season for phytoplankton only and one time sampling for other parameters. The results of this study will be considered as part of the MMER EEM program and the continuation of the Christal Lake Study will be integrated into the MMER EEM program as required.

11.0 SPILL CONTINGENCY PLAN

A Spill Contingency Plan was developed under the current Water Licence QZ07-078 for the purpose of advanced exploration and preliminary development activities at the Bellekeno Mine and has been modified for active operations. The Spill Contingency Plan outlines that:

“The Licencee shall immediately contact the 24-hour Yukon Spill Report Centre, (867) 667-7244, and implement the Spill Contingency Plan should a spill or an unauthorized discharge occur. A detailed written report on any such event including, but not limited to, dates, quantities, parameters, causes and other relevant details and explanations, shall be submitted to the board not later than 10 days after the occurrence”;

“All personnel shall be trained in procedures to be followed and the equipment to be used in the containment of a spill”; and

“The Spill Contingency Plan shall be posted on site for the term of the Licence”.

For more details, see the Spill Contingency Plan and the Emergency Response Plan submitted for QML--0009. All incident reports including the occurrence of a spill, should it occur, will be forwarded to FNNND.

12.0 ADAPTIVE MANAGEMENT PLAN (AMP)

In accordance with Clause 90 of Water Licence QZ09-092, an Adaptive Management Plan was developed specifically for the Bellekeno Undertaking. This licence was based on the framework established by the District Wide Adaptive Management Plan but was customized for the specific activities and developments of the Bellekeno Undertaking. The Bellekeno Adaptive Management Plan is attached as Appendix G, and a summary is presented below.

12.1 AMP Objectives

An adaptive management plan (AMP) is a management tool designed to guide responses to unforeseen or contingency events respecting for example, water quality and quantity and physical conditions of site workings and infrastructure. The adaptive management approach provides for assessment of mitigation measures and their effectiveness, and guides the orderly implementation of responses.

Because it is difficult to predict the specific environmental condition that may arise which requires a response from management, the AMP does not necessarily provide specific detailed descriptions of responses to a situation. Rather, the AMP provides a range of possible responses to use as a guide to respond to specific environmental conditions encountered.

The AMP framework encompassing active Company management includes:

- routine inspection and environmental monitoring, maintenance and reclamation;
- routine assessment of monitoring and performance data;
- performance thresholds for implementation of appropriate levels of responses for planned contingency measures; and
- reporting of monitoring results and actions.

Results of the current monitoring programs are assessed on an ongoing basis to determine if any negative trends in water quality, quantity or other parameters are occurring. If the results indicate that there are no negative environmental impacts, then the frequency and length of monitoring and maintenance continues as usual. Adaptive management will be implemented to respond to negative trends or impacts (known as “events”) observed through the monitoring programs.

Management uses the information collected by the monitoring programs together with the suggested range of responses within the AMP to determine a suitable response for dealing with a given event.

A number of events have been identified which represent potential environmental conditions that would require a management response, if they were to occur. They include the following:

1. Change in Water Quality or Quantity
2. Non-AML Waste Rock Disposal Area(s) Seepage Exhibits AML
 - a. Waste Rock Disposal Area(s) (including where used for road and general construction) runoff trending to AML conditions
3. Sludge Storage Area Effectiveness Compromised
 - a. Seepage Observed Near Sludge Storage Area
 - b. Sludge Storage Area Approaching Capacity
4. Physical Instabilities
 - a. Area of Significant Subsidence is Observed
 - b. Rock Fall or Landslide Occurs Within a Monitored Area
 - c. Structure Failure or Portal Collapse
5. Site Security Compromised
 - a. Gate, Fence or Sign Damaged
6. Development of high pore pressures underneath the DSTF
7. Development of significant erosion of exposed DSTF surfaces

8. Development of erosion at the Flame and Moth Site discharge area
9. Transport of sediment from the Flame and Moth discharge area into Christal Creek
10. Development of large differential settlements at the DSTF
11. Development of large differential settlements along the conveyance flume from the DSTF to the Flame and Moth Site collection and sediment pond
12. Exceedence of recommended water quality standards in the receiving environment occurring irrespective of compliance with effluent discharge standards
13. Identification of groundwater quality impacts at the Flame and Moth or Bellekeno mill sites; and
14. Identification of water quality impacts to Keno City water wells.

The AMPs for each of these events are described individually in the Bellekeno Adaptive Management Program attached as Appendix F, while Table 4 provides a summary of the approach to AMP events. This table describes a narrative trigger, indicators and response thresholds, monitoring locations and parameters.

12.2 AMP Approach

For each AMP event a methodical approach is provided:

1. Description of the event and possible environmental consequences - Addresses issues or information that trigger the AMP;
2. Location of possible event occurrence – Identifies specific working site locations if applicable to event;
3. Monitoring requirements – Identifies the parameters to be monitored, frequency and means for monitoring each parameter;
4. Specific indicators and thresholds - Defines the conditions when management actions should be taken. There may be a series of indicators and staged thresholds for an individual event; and
5. Approach to responses –Description of the approach to responses including a simplified flow chart to guide the implementation process if any specific thresholds have been crossed.

ALEXCO KENO HILL MINING CORP. BELLEKENO PROJECT
MONITORING AND SURVEILLANCE PLAN –QML-0009

Table 4 Overall AMP Summary

EVENT	NARRATIVE TRIGGER	INDICATORS	THRESHOLDS	MONITORING LOCATIONS	MONITORING PARAMETERS
1. CHANGE IN WATER QUALITY OR QUANTITY					
a. Significant change in water quality of treatment plant discharge	<u>Water Treatment Facilities</u> Decline in effluent pH noted or effluent quality trending towards possible exceedence of standards or exceeds licenced standards.	pH, Total zinc, ammonia, TSS	Treated effluent: TSS>20 mg/L for three consecutive days; OR Total Zinc > 0.40 mg/L and pH <6.5 for three consecutive days; OR Ammonia > 4.0 mg/L and pH > 9.0 for three consecutive days; OR Effluent quality standards exceeded.	Water Treatment Facilities	Routine in-situ, on-site total zinc, external multi-element ICP, hardness, pH, conductivity, TSS, ammonia, LT50
b. Significant change in water quality of adit discharge	Significant decline in pH or increase in conductivity from mine adit discharge to treatment plant	pH, conductivity	Adit discharge pH more than 1 pH standard unit lower or conductivity 2X higher than historic average	KV-42 Bellekeno adit discharge	Same as indicators
b. Adit discharge quantity significantly increases	Observed or measured flows display a sustained and statistically significant increase over historical flow conditions	Flow	Increase of flow to greater than 95% Upper Confidence Level when compared to the average for the previous 24 months or 90% Licence flow discharge criteria exceeded	KV-43 Bellekeno treatment plant; KV-XX Mill sediment pond discharge treatment plant	same as indicators
2. WASTE ROCK SEEPAGE EXHIBITS AML					
a. Waste rock seepage or runoff trending to AML conditions	Seepages from waste rock disposal areas or from works constructed or upgraded with non AML material show significant decline in pH and/or an increase in conductivity OR approaching licenced discharge standards	pH, conductivity	Significant decline in pH between measurements or pH <6.0 and/or conductivity showing a significant increasing trend or >2000 µS/cm; OR indicators approaching licenced discharge standards	Waste rock disposal areas and works or features constructed from non-AML material	pH, conductivity, Routine multi-element ICP

ALEXCO KENO HILL MINING CORP. BELLEKENO PROJECT
MONITORING AND SURVEILLANCE PLAN –QML-0009

EVENT	NARRATIVE TRIGGER	INDICATORS	THRESHOLDS	MONITORING LOCATIONS	MONITORING PARAMETERS
3. SLUDGE STORAGE AREA EFFECTIVENESS COMPROMISED					
a. Seepage observed near sludge storage areas	Routine inspection of sludge storage area shows seepage	Total zinc, pH	pH >8.5 and total zinc > 1.0 mg/L	Valley Tailings sludge storage cell	Same as indicator
c. Sludge storage area approaching capacity	Sludge storage area approaching minimum freeboard of 1.0 meter below the decant point	Visual observation of freeboard	Freeboard is at 1.5 meter below decant point	Valley Tailings sludge storage cell	Same as indicator
4. PHYSICAL INSTABILITIES					
a. Area of significant surface subsidence has occurred	An observed subsidence has exposed an opening to surface or resulting in slope failure	Visible slope failure, ground subsidence or opening on surface	Opening to underground workings or area of subsidence effects public safety or down gradient environment	Bellekeno Mine Production Unit Area	same as indicators
b. Rock fall or landslide is observed that affects road right-of-way or intrudes into stream	An observed rock fall or landslide effects a road right-of-way, infrastructure or intrudes into stream	Mine source material movement	Source material effects road or stream	Bellekeno Mine Production Unit Area	same as indicators
5. SITE SECURITY COMPROMISED					
a. Security gate, fence, sign damaged	Public health and wildlife safety measure damaged or removed	Sign, fence, gates, locks	Security feature damaged, removed, or compromised	Bellekeno Mine Production Unit Area	same as indicators
6. DEVELOPMENT OF HIGH PORE PRESSURES UNDERNEATH THE DSTF					
a. High porewater pressure within groundwater monitoring wells in the DSTF	Porewater pressure is observed in groundwater monitoring wells in the DSTF	Porewater pressure	Tip @1.0m or 1.7m depth – Porewater pressure parameter (Ru) exceeds 0.15	Groundwater monitoring wells in the DSTF	same as indicators
7.0 DEVELOPMENT OF SIGNIFICANT EROSION OF EXPOSED DSTF SURFACES					

ALEXCO KENO HILL MINING CORP. BELLEKENO PROJECT
MONITORING AND SURVEILLANCE PLAN –QML-0009

EVENT	NARRATIVE TRIGGER	INDICATORS	THRESHOLDS	MONITORING LOCATIONS	MONITORING PARAMETERS
a. Area of significant erosion on exposed DSTF surface	An observed movement of tailings caused by erosion on surface	Visual inspection of tailings surface	Geotechnical engineer or operator inspection identifies adverse operating condition	DSTF	Same as indicators
8. DEVELOPMENT OF EROSION AT THE FLAME AND MOTH SITE DISCHARGE AREA					
To be developed once discharge system is designed					
9. TRANSPORT OF SEDIMENT FROM THE FLAME AND MOTH DISCHARGE AREA INTO CHRISTAL CREEK					
To be developed once discharge system is designed					
10. DEVELOPMENT OF LARGE DIFFERENTIAL SETTLEMENTS AT THE DSTF					
a. Significant differential settlements are observed in the DSTF	An observation of significant differential settlements are observed at the DSTF	Displacement of survey monitors and slope indicators	Displacements greater than 25 mm in any direction	Survey monuments and slope inclinometers	Same as indicators
11. DEVELOPMENT OF LARGE DIFFERENTIAL SETTLEMENTS ALONG THE CONVEYANCE FLUME FROM THE DSTF TO THE FLAME AND MOTH SITE COLLECTION AND SEDIMENT POND					
a. Significant differential settlements are observed in along the conveyance flume	An observation of significant differential settlements are observed the conveyance flume	Displacement of survey monuments	Displacements greater than 25 mm in any direction	Survey monuments	Same as indicators
12. EXCEEDENCE OF RECOMMENDED WATER QUALITY STANDARDS IN THE RECEIVING ENVIRONMENT OCCURRING IRRESPECTIVE OF COMPLIANCE WITH EFFLUENT DISCHARGE STANDARDS					

ALEXCO KENO HILL MINING CORP. BELLEKENO PROJECT

MONITORING AND SURVEILLANCE PLAN –QML-0009

EVENT	NARRATIVE TRIGGER	INDICATORS	THRESHOLDS	MONITORING LOCATIONS	MONITORING PARAMETERS
a. Water quality standards are exceeded in the receiving environment even though authorized licenced discharges are within discharge limits	Receiving environment discharge standards exceed CCME and do not have a history of exceedence, and waste related to the Bellekeno undertaking are contributing greater than 10% of the mass load.	Licensed discharge parameters	Exceedence of CCME at a receiving environment monitoring station, no previous trend of exceedence, and Bellekeno undertaking contributes >10% of mass load	Receiving environment monitoring stations	Same as indicators
13. IDENTIFICATION OF GROUNDWATER QUALITY IMPACTS AT THE FLAME AND MOTH OR BELLEKENO MILL SITES					
a. A significant increasing trend is observed in groundwater near the Flame and Moth or Non-AML Waste Rock Disposal Area	Total zinc significantly exceeds baseline measurements for a given monitoring well, and exceeds licenced effluent discharge standards	Total Zn	Total zinc exceeds the highest baseline measurement by a factor of 2x, and exceeds licensed effluent discharge standards	Groundwater monitoring wells	Same as indicators
14. IDENTIFICATION OF WATER QUALITY IMPACTS TO KENO CITY WATER WELLS					
a. A significant increasing trend is observed in groundwater near the Flame and Moth or Non-AML Waste Rock Disposal Area	Total zinc significantly exceeds baseline measurements for a given monitoring well, and exceeds licenced effluent discharge standards	Total Zn	Total zinc exceeds the highest baseline measurement by a factor of 2x, and exceeds licensed effluent discharge standards	Groundwater monitoring wells	Same as indicators

13.0 RECLAMATION EFFECTIVENESS MONITORING PROGRAM

A reclamation effectiveness monitoring program will be designed to assess interim reclamation efforts at Bellekeno. Over time the assessment protocol of the monitoring program will evolve so post closure reclamation benchmarks are well defined, measurable and documented. A thorough effectiveness monitoring program will allow for quick recognition of restoration successes and needed improvements, so future reclamation planning and implementation can benefit from the monitoring results.

Progressive reclamation is limited to the dry stack tailings facility. Progressive reclamation will occur in a staged (possibly an annual) basis but has not yet commenced at the DSTF. After initiation of progressive reclamation, the reclamation effectiveness monitoring program will likewise occur in a staged fashion after reclamation at the DSTF has been initiated. Routine monitoring and surveying for a number of aspects of the DSTF including physical, chemical, geotechnical stability, effluent and seepage water quality are to be carried out under several monitoring and surveillance programs, including:

- QML-0009 Monitoring and Surveillance Plan (this plan)
- QML-0009 DSTF Construction and Operation Plan (especially DSTF Operations, Maintenance and Surveillance Manual)
- QZ09-092 Groundwater Monitoring Plan
- QZ09-092 Physical Inspections and Reporting Plan
- QZ09-092 Tailings Characterization Plan
- QZ09-092 Water Management Plan and Water Balance Report

Information collected during routine assessments under these monitoring plans will be used to help provide background information and aid in development of the effectiveness of progressive reclamation monitoring program. In addition, the following steps will be used to determine reclamation efficacy:

- 1) Initial targets and goals are outlined in the Progressive Reclamation section of the Decommissioning and Reclamation Plan and will be used in impact assessment in determining long-term impacts. These targets and goals will be refined based on development of objectives in the District-wide closure plan and will be well-defined, representative of success, unambiguous, and easily measured including percent vegetation cover, species composition, physical stability, cover integrity, dust control and water quality.
- 2) Refine objectives into metrics: As mentioned above, benchmark parameters should be easily measured. The sample size needed to adequately define condition will depend on the underlying variability in the parameter to be measured. Metrics for success, including water quality, have largely been

identified in water licence QZ09-092 but will be expanded with development of the District-wide closure plan.

- 3) Use Adaptive Management: During project construction and operations, adaptive management will be an element of reclamation success monitoring. If monitoring indicates a failure to meet benchmarks, reclamation procedures will be modified or new procedures adopted to compensate based on guidance from adaptive management principals. For example, monitoring may indicate that additional erosion or runoff control methods may be needed or that reseeding with a new mix of plant species required.

Success of implementation of final reclamation will be measured by the ability to achieve stated closure objectives in the Decommissioning and Reclamation Plan. As described above, objectives may in part be derived from development of site-wide closure in the Keno Hill District. Impacted watersheds for the Bellekeno project overlap with those of the District, and thus some of the metrics used to measure success will necessarily be the same as those for District-wide closure.

14.0 REPORTING

Reporting on water quality monitoring and management issues will be directed to the Yukon Water Board (YWB) and YG EMR in accordance with the requirements of the Water Licence and Quartz Mining Licence. Monthly and annual reporting will be carried out during Bellekeno mine development activities and through the implementation of site decommissioning until it can be demonstrated through the monitoring results that the final closure reclamation objectives have been achieved.

Alexco also continues to liaise with the regulatory agencies, FNNND, the Mayo RRC and the local community on environmental issues relating to the Bellekeno mine/mill development and operation program. For example all monthly and annual reports are provided to FNNND.

15.0 REFERENCES

- British Columbia. Ministry of Environment. 2009. *Air Quality Objectives and Standards*.
- British Columbia. Ministry of Environment. 1979. *Pollution Control Objectives for Mining, Smelting, and Related Industries of British Columbia*.
- Code of Federal Regulations. Title 40 –Protection of Environment, Chapter I – Environmental Protection Agency, Subchapter C – Air Programs, Part 51 – Requirements for Preparation, Adoption, and Submittal of Implementation Plans.
- Environmental Protection Agency, 1995a. *User's guide for the Industrial Source Complex (ISC3) Dispersion Models – Volume 1 – User Instructions*, Office of Air Quality Planning and Standards Emissions, Monitoring, and Analysis Division Research Triangle Park, North Carolina 27711.
- Environmental Protection Agency, 1995b. *User's guide for the Industrial Source Complex (ISC3) Dispersion Models – Volume 2 – Description of Model Algorithms*, Office of Air Quality Planning and Standards Emissions, Monitoring, and Analysis Division Research Triangle Park, North Carolina
- Pacwill Environmental. 2008. Original Dry Foam Frisbee-Type Deposit Dust Gauge.
- Reed, W.R. 2005. *Significant Dust Dispersion Models for Mining Operations*, Information Circular 9478, Department of Health and Human Services, Center for Disease Control and Prevention, National Institute for Occupational Safety and Health, USA.



ALEXCO KENO HILL MINING CORP.

QUARTZ MINING LICENCE

QML-0009

BELLEKENO MINE DEVELOPMENT

KENO HILL SILVER DISTRICT

YUKON

Appendix A



Alexco Keno Hill Mining Corp. Bellekeno Mine Operations

Groundwater Monitoring Plan

Water Use Licence QZ09-092

February 2011

Prepared by:



TABLE OF CONTENTS

1.0	INTRODUCTION.....	1
1.1	Purpose of Plan	1
2.0	MINE LOCATION AND DESCRIPTION	2
3.0	PREVIOUS GROUNDWATER STUDIES	4
4.0	REGIONAL GEOLOGY AND HYDROGEOLOGICAL IMPLICATIONS	5
5.0	FLAME AND MOTH SITE GROUNDWATER MONITORING	7
5.1	Shallow Subsurface Conditions in the Flame and Moth Area	9
5.2	Bedrock Geology and Structure in the Flame and Moth Area.....	10
6.0	BELLEKENO NON-AML WASTE ROCK DISPOSAL AREA GROUNDWATER MONITORING	13
7.0	KENO CITY GROUNDWATER MONITORING	17
8.0	REVIEW OF RESULTS	19
9.0	GROUNDWATER MONITORING SCHEDULE	19
10.0	REPORTING	20
11.0	REFERENCES	20

LIST OF FIGURES

Figure 1	Flame and Moth Groundwater Monitoring Plan Site Map.....	3
Figure 2	Conceptual WRDA Groundwater Monitoring Well Locations.....	16
Figure 3	Keno City Groundwater Monitoring Wells	18

LIST OF TABLES

Table 1	Flame and Moth Site Groundwater Monitoring Well Summary.....	8
Table 2	General Subsurface Conditions for Gravel Area	10
Table 3	Borehole Depths at Bellekeno Site	14
Table 4	Bellekeno WRDA Groundwater Monitoring Well Summary	15
Table 5	Groundwater Monitoring Schedule	19

APPENDICES

Appendix A	SRK Report 2010 Bellekeno Groundwater Program
Appendix B	2010 Flame and Moth Diamond Drill Logs
Appendix C	Flame and Moth Site Geotechnical Borehole Logs

1.0 INTRODUCTION

1.1 Purpose of Plan

This plan is submitted to fulfill the conditions set out in Part H, Clauses 85, 86, and 87 of Water Licence QZ09-092 (hereafter referred to as the Licence) issued to Alexco Keno Hill Mining Corp (Alexco) on August 19th 2010:

85. *Within six months of the effective date of this licence, the Licensee shall submit to the Board a Bellekeno Groundwater Monitoring Plan for both the Bellekeno Waste Rock Disposal Area and Flame and Moth Site and shall implement that plan.*
86. *The plan for the Waste Rock Disposal Area shall include the installation of at least four groundwater monitoring wells.*
87. *For the Flame and Moth Site, the plan shall be developed by considering existing knowledge of geological structures at the site and the consideration of groundwater table mapping based on sampling of KV -84, KV -85, KV -86, and KV -87. The developed plan shall include, but not necessarily be limited to the following:*
 - a) *Installing at least three multi-level groundwater monitoring wells down gradient of DSTF;*
 - b) *Where wells are installed into bedrock, the bedrock shall be cored'*
 - c) *Developing detailed geological logs for all new well installations including: identification of soil or rock types; soil condition or rock quality; and geological and hydrogeological features such as joints and fractures. The logs are also to include details of the well installations;*
 - c) *Based on baseline groundwater quality, development of trigger levels that would be used to enact the adaptive management strategy and provide early warning of the need for mitigative measures and/or changes in facility design/operations*

In addition, Part F Clauses 45 and 46 of the Licence provided additional guidance on the groundwater monitoring program:

45. *Monitoring results should be reviewed after each sampling event to identify groundwater changes, should they occur.*
46. *Groundwater wells determined to be subject to seasonal freezing shall have pressure transducers installed when cleared of seasonal ice.*

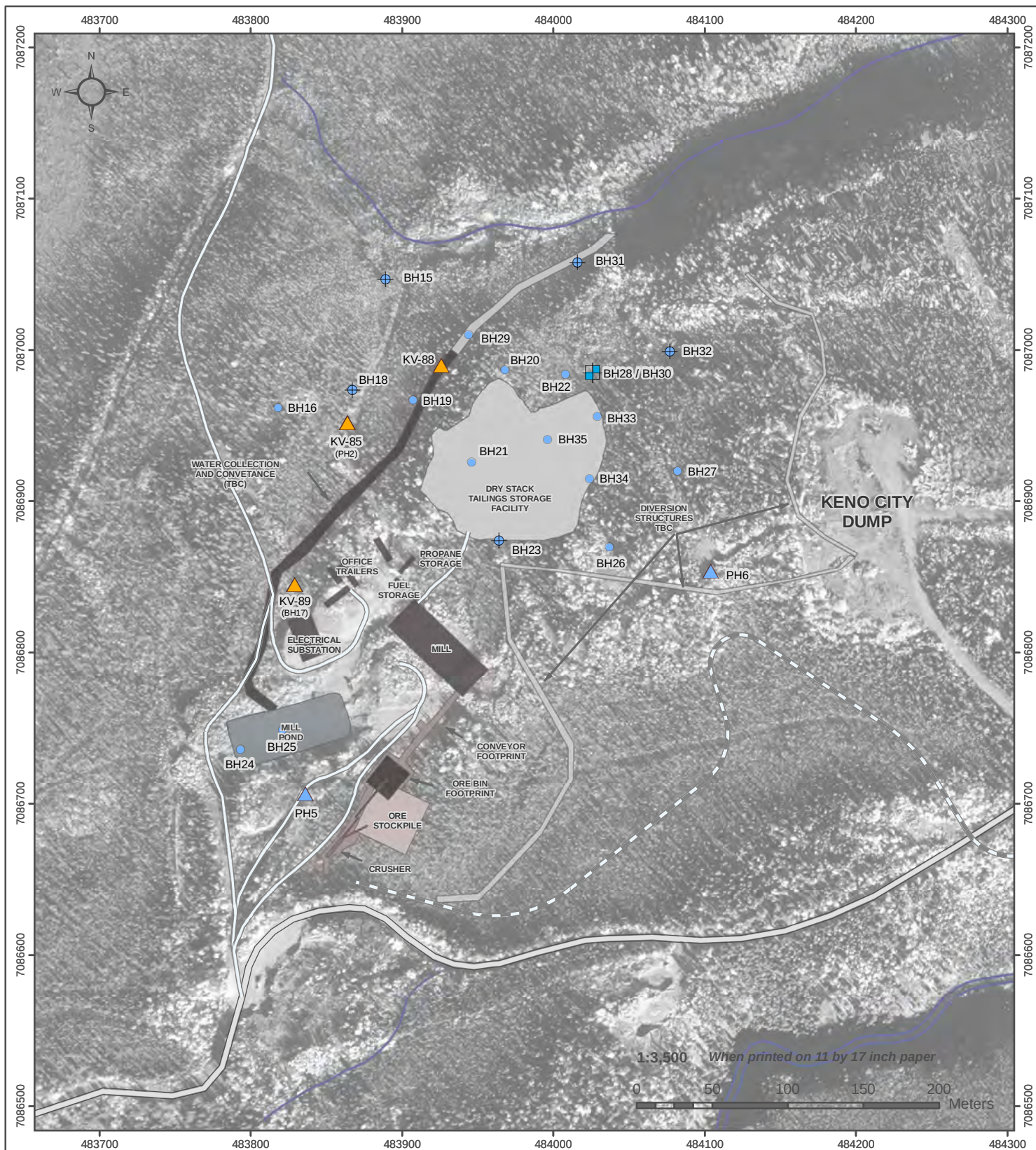
This plan outlines the groundwater monitoring strategy that will be used during mining operations at the Bellekeno Mine and Mill on Alexco's Keno Hill property.

2.0 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 mill site and Dry Stack Tailings Facility (hereinafter referred to as the "DSTF") are located approximately 1 km west of Keno City.

The portal at Bellekeno East is located on a steep slope above Thunder Gulch, a narrow tributary of Lightning Creek, and the haul road access to the mill site is provided by an approximately 3 km access road which crosses Lightning Creek approximately 2200 meters downstream from the confluence of Thunder Gulch and Lightning Creek. Please refer to see Figure 1 for the site map.

The proposed Waste Rock Disposal Area (hereafter referred to as the WRDA) will be constructed as a wrap around dump and located along the northeast flank of Sourdough Hill, as shown on Figure 3.



- ▲ Monitoring Well
- ▲ Monitoring Well and Ground Temperature
- ▲ Proposed Monitoring Well
- ⊕ Ground Temperature
- ⊕ Slope Indicator
- Bore Hole

- Mill Access Road
- Haul Road
- Duncan Creek Road
- Major Contour (5 meter interval)
- Minor Contour (1 meter interval)

QZ09-092 GROUNDWATER MONITORING PLAN

FIGURE 1 - MILL SITE AREA BOREHOLE AND GROUNDWATER MONITORING LOCATIONS



DRAWN BY MD FEB 2011 VERIFIED BY EA

Aerial photography flight date: July 13th 2006. Ortho-rectification produced by Challenger Geomatics Ltd. Site hydrography and contours derived from 2006 aerial imagery. Mill pond survey (Y.E.S. Sept 2010), mill structures, current DSTF footprint and roads survey (ACG, December 2011). Design data obtained from EBA.

I:\ALEX-05-01\Bellekeno\GIS\mxd\Permitting
GroundwaterMonitoringPlan\Fig1_MillSite_20110216.mxd

3.0 PREVIOUS GROUNDWATER STUDIES

SRK Consulting Canada Inc. (SRK) was retained by Alexco to investigate groundwater gradients in the vicinity of 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-85, KV-86 and KV-87, respectively. Key findings of the SRK groundwater investigation (SRK, 2010) include:

- The water table within the bedrock aquifer under the site and within a relatively thick overburden aquifer to the south is at considerable depth (>25 m);
- Water level data from monitoring wells at site and Keno City indicate that groundwater flows from east to west, or from Keno City towards the mill site and Christal Lake;
- These water level data also indicate a shallow gradient between Lightning Creek towards Christal Lake;
- Water quality analyses of samples taken immediately following monitoring well development indicate that in general, concentrations of dissolved anions and metal are low;
- The only notable exceptions are elevated levels concentrations of chloride and sodium in KV-87, which is located downgradient and could be indicative of seepage from the Keno City dump and; elevated concentrations of sulphate in KV-86 and KV-87, which are deemed to be indicative of natural mineralization in this area;
- The likelihood of effects to groundwater quality in general related to the mill and DSTF are considered very low, due to site water management plans for seepage and runoff interception, and collection and treatment if necessary;
- Because groundwater extraction is not planned at the mill site, there will be no effects on the amount of water available for extraction from wells in Keno City, and;
- The chance of water quality being affected in wells in Keno City is considered insignificant due to current understanding of the local groundwater gradient and the large distance between the mill site and Keno City water wells.

The SRK groundwater report, entitled “Bellekeno Groundwater Program” was issued in May 2010, and was submitted to the Board as supplemental information in support of the application for QZ09-092 (Exhibit 1.12 of the public registry). This report is included as Appendix A. Prior to issuance of their 2010 Bellekeno Groundwater report, SRK was also retained to complete initial (desktop) assessments of potential impacts of the proposed mill and DSTF site on groundwater quantity and quality (SRK, 2009a; SRK, 2009b).

4.0 REGIONAL GEOLOGY AND HYDROGEOLOGICAL IMPLICATIONS

Because of a long history of mine and exploration in the Keno Hill Silver District, regional geology is 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 (ACG, 2009).

The Keno Hill District 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 is host to most of the past producing ore bodies. Structurally juxtaposed below the quartzite is the Lower Schist which has been correlated with the Devonian-Mississippian Earn Group. The Lower Schist 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. The sills and boudins form bodies up to one kilometre long and thirty metres thick. Regional, greenschist facies metamorphism of all units is believed to have occurred in the Middle Cretaceous, about 105 million years ago.

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; reports of occurrences in the Central Quartzite are inconclusive and vague. The quartz-porphyry sills are believed to be of Cretaceous age.

Structurally, the property is characterized by four sets of faults; many of which have been filled by hydrothermal minerals, forming veins. The oldest fault set consists of south dipping structures that are generally parallel to foliation and are apparently associated with the Tombstone Thrust Fault since movement was contemporaneous or slightly later. 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. The latest movement along these faults is sinistral with offsets locally reaching more than 150 metres; however, more than one episode of movement commonly is indicated. 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 west with a dip of sixty degrees west to south west and offset vein or longitudinal faults by up to 2,000 metres. In the western part of the property, dextral movement is the most recent event along these structures, whereas in the eastern part of the property sinistral movement with less magnitude prevails."

SRK (2009a) further described summarized 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 (2009a) 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.

5.0 FLAME AND MOTH SITE GROUNDWATER MONITORING

As per Clause 87a of the Licence, three multi-level groundwater monitoring wells are to be installed down gradient of the DSTF. Clause 87 specifies that three multi-level groundwater monitoring wells (e.g. Westbay type) are to be installed down gradient of the DSTF. However, because to the known challenges in the ground conditions near the DSTF (the presence of permafrost and massive ice, in some cases), Alexco 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 is also based on discussions with professional hydrogeologists experienced in monitoring well installations.

Alexco believes that the intention of Clause 87a 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. Alexco proposes to comply with Clause 87a through use of the following groundwater monitoring network as described below in Table 1 and shown on

Figure 1. The selection of these wells was 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 1 Flame and Moth Site Groundwater Monitoring Well Summary

Station #	Hole #	Purpose	Total Depth (m)	Depth in Overburden (m)	Depth in Bedrock (m)	Northing ¹	Easting ¹
KV-85	PH2	Deep bedrock groundwater monitoring	27.01	11.5	15.51	7086952	483864
	TBD ²	Shallow or perched groundwater monitoring	5 [*]	5 [*]	-	TBD ²	TBD ²
KV-88	TBD ²	Deep bedrock groundwater monitoring	35 [*]	5 [*]	30 [*]	TBD ²	TBD ²
	TBD ²	Shallow or perched groundwater monitoring	5 [*]	5 [*]	-		
KV-89	TBD ²	Deep bedrock groundwater monitoring	35 [*]	14.5 [*]	20.5 [*]	7086845	483829
	BH17	Shallow or perched groundwater monitoring	14.5	14.5	-		

¹Coordinates are UTM Zone 8 NAD 1983

²TBD – “to be determined”, station not established at this time.

^{*}Estimated based on nearby wells or boreholes

PH2 and BH17 are monitoring wells already in place down gradient of the DSTF, and are proposed serve as one of the deep, and shallow groundwater monitoring locations.

In accordance with Clause 87c of the Licence, all new well installations will include collection of information on soil and rock types, soil condition or rock quality and geological and hydrogeological features such as joints or fractures where possible, and will include details of well installations.

Clause 46 of the Licence, states that all groundwater wells determined to be subject to seasonal freezing shall have pressure transducers installed. AHKM will install vibrating wire pressure transducers in groundwater wells deemed to be subject to seasonal freezing and these installations will be measured monthly for the first year (twelve monthly readings) as per Clause 44e and then quarterly for water level as per Schedule B Table 4.

Although Clause 87b, requires that where wells are installed into bedrock, the bedrock shall be cored, Alexco's preference is to complete these groundwater well installations (including bedrock holes) using more conventional drilling technology for the installation of monitoring wells (air-rotary, ODEX) for the following reasons:

- Air-rotary drilling is preferable to diamond drilling for monitoring well installation for a number of reasons including:
 1. More efficient drilling of both overburden and bedrock;
 2. Larger diameter borehole produced using an air-rotary drilling rig is preferable and reduces the chance of bridging during well completion;
- Alexco does not currently have a diamond drill program active at site, and;
- An air-rotary drilling rig will be on site in late February for other groundwater investigations related to District Closure, costs can be optimized if combined with this program.

The Reasons for Decision document for the Licence does not provide additional information regarding Clause 87b; however, Alexco believes that the intent of this Clause was to ensure that adequate data and information regarding the subsurface conditions (overburden and especially bedrock and structural geology) of the DSTF and mill site area were collected to better inform Alexco's mill site area construction plans and ensure that the monitoring strategy was appropriate. Alexco believes that information collected in both the shallow subsurface soils and the deeper bedrock is sufficient to inform the groundwater monitoring plan. These data are presented in Sections 5.1 and 5.2 below.

5.1 Shallow Subsurface Conditions in the Flame and Moth Area

A considerable amount of geotechnical information has been collected from the mill site and the area beneath the DSTF during geotechnical studies in support of preliminary and final design of the DSTF, mill building, mill site pond, ancillary facilities, and site water management infrastructure. This work was carried out by EBA Engineering Consultants Ltd. A summary of the subsurface conditions of the DSTF, from the Preliminary Design Report (EBA, 2010):

“Nine boreholes were drilled near the DSTF. Information gathered in these boreholes indicates two general soil profiles in the area:

- glaciofluvial GRAVEL underlain by bedrock and
- SILT and SAND till underlain by gravel and bedrock.”

“The gravel was encountered along the ridge that crosses the site. The gravel in the area of the DSTF was found in both frozen and unfrozen states. It is typically sandy with trace silt, compact, medium grained, well graded, and brown, and it is underlain by a thin layer of silt and sand till and then bedrock. Bedrock encountered in testholes is a competent quartzite. Subsurface conditions for the gravel area are summarized in Table 2.

Table 2 General Subsurface Conditions for Gravel Area

Soil Unit	Min thickness (m)	Max Thickness (m)	Average Thickness (m)
Gravel	1.3	3.7	2.5
Silt and Sand till	0.2	1.3	1.0
Bedrock (quartzite)	@2.1 mbgs*	@5.0 mbgs*	@3.4 mbgs*

*Meters below ground surface

All silt and sand till encountered in the area of the DSTF was frozen. The silt and sand till typically contains trace gravel and trace clay, is low to non-plastic, olive grey, is underlain by gravel seams within the till and then by quartzite bedrock. Two boreholes on the west side of the ridge, BH15 and BH17, were drilled through the silt and sand layer. The gravel seams were encountered below 16 m depth in BH15, and bedrock was encountered at 14.2 m depth in BH17. One borehole, BH23, was drilled through the till deposit on the east side of the ridge and gravel seams were encountered at 7.6 m depth. Two boreholes, BH24 and BH25, were drilled near a proposed water collection pond. The general soil conditions in this area are gravel fill over glaciofluvial gravel over silt and sand till over glaciofluvial gravel. The glaciofluvial gravel and silt and sand till are similar to the soils described above and are all unfrozen.”

Borehole Logs for drilled in the vicinity of the mill site and DSTF area are attached as Appendix C. Ongoing work and additional drilling provided further information on subsurface conditions over the mill site area. Borehole logs for these additional holes are also included in Appendix C. All of this data was taken into consideration for the placement of the groundwater monitoring wells.

5.2 Bedrock Geology and Structure in the Flame and Moth Area

Exploration drilling in the vicinity of the DSTF by Alexco during the 2010 season has provided additional data from the deeper subsurface in the form of information on rock quality and geological features. This drilling was designed to investigate the historically known mineralisation about the Flame and Moth underground mine workings and comprised 13 holes for a total of 3,974 metres that were completed from five locations.

Basic rock quality designation (RQD) information that is routinely logged for exploration diamond drill core was supplemented with additional data including Rock Strength, Total

Fracture Count, Total Vein Count, Vein Strength and % Vein for some of the Flame and Moth holes.

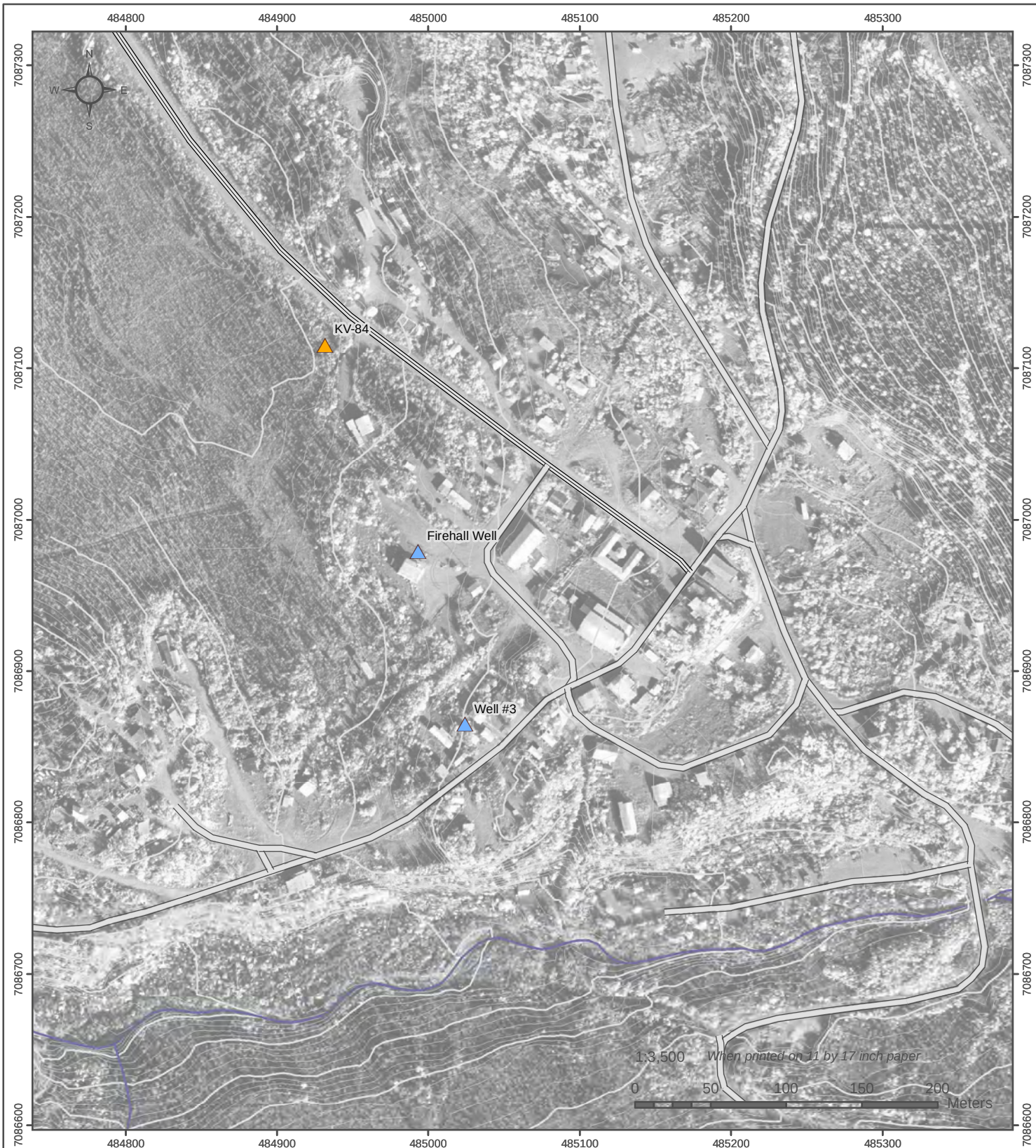
The details of location and orientation of the drill holes are shown in Table 3 while the RQD data, as well as the main rock types intercepted, is included in Appendix B.

Table 3 Details of Diamond Drill Hole at the Flame & Moth Prospect

Hole_ID	Total Depth (m)	UTM Easting (m)	UTM Northing (m)	Elevation (m)	Collar Azimuth	Collar Dip	Started	Completed	Core Size
K-10-0264	336.80	484131.84	7086649.76	927.98	306	-60	05/07/2010	20/07/2010	HQ
K-10-0271	347.47	484131.84	7086649.76	927.98	306	-70	21/07/2010	31/07/2010	HQ
K-10-0275	346.57	484131.54	7086649.51	927.98	328	-62	01/08/2010	24/08/2010	HQ
K-10-0285	324.31	484071.91	7086679.39	919.59	306	-50	25/08/2010	06/09/2010	HQ
K-10-0291	192.67	484101.25	7086870.75	936.78	285	-54	08/09/2010	13/09/2010	HQ
K-10-0295	313.94	484101.35	7086870.5	936.78	285	-80	13/09/2010	03/10/2010	HQ
K-10-0298	220.68	484101.5	7086870.4	936.78	250	-60	03/10/2010	11/10/2010	HQ
K-10-0299	306.32	484067.23	7086584.28	923.86	285	-68	05/10/2010	10/10/2010	HQ
K-10-0303	348.08	484067.96	7086584.23	923.85	285	-75	10/10/2010	19/10/2010	HQ
K-10-0304	252.07	484101.68	7086870.26	936.78	230	-75	11/10/2010	19/10/2010	HQ
K-10-0305	352.35	484076.44	7086582.7	924.14	340	-65	20/10/2010	30/10/2010	HQ
K-10-0312	388.93	484076.65	7086585.25	923.89	250	-55	30/10/2010	16/11/2010	HQ
K-10-0320	243.84	484076.45	7086586.09	923.99	290	-55	19/11/2010	26/11/2010	HQ

The interpreted surface geology of the Flame and Moth area is shown in Figure 2. The area is underlain by the Keno Hill Quartzite. Several distinctive east – west striking map units that dip moderately to the south are identified in this area:

- Upper Quartzite (Msq) - Comprising light to dark grey, platy quartzite with grey schist (phyllite) layers.
- Sericite Schist Marker (Mss) – Sericite +/-chlorite schist, schistose grit, minor light grey crystalline limestone.
- Graphitic Schist Marker (Msg) – Medium to dark grey schist (phyllite), locally calcareous.
- Basal Quartzite (Mkq) – Blocky buff, light to medium grey quartzite, locally calcareous. Thin graphitic schist bands are common.
- Greenstone (Trgn) – Chlorite-actinolite +/-calcite greenstone sills, locally with relict phaneritic texture.



- | | |
|--|--|
|  Monitoring Well |  Highway |
|  Proposed Monitoring Well |  Duncan Creek Road |
| |  Major Contour (5 meter interval) |
| |  Minor Contour (1 meter interval) |

QZ09-092 GROUNDWATER MONITORING PLAN

FIGURE 2 - KENO CITY AREA BOREHOLE AND GROUNDWATER MONITORING LOCATIONS



DRAWN BY MD

JAN 2011

VERIFIED BY EA

Aerial photography flight date: July 13th 2006. Ortho-rectification produced by Challenger Geomatics Ltd. Site hydrography and contours derived from 2006 aerial imagery obtained from Geodesy Remote Sensing Inc., Calgary Alberta.
Datum: NAD 83; Projection: UTM Zone 8N

I:\ALEX-05-01\Bellekeno\GIS\mxd\Permitting
GroundwaterMonitoringPlan\Fig2_KenoCity_20110125.mxd

As the amount of surface outcrop in the area is poor, the distribution of these rock units as shown on the map is somewhat interpretative. There is however evidence of possibly two significant north-east trending fault structures (Moth and Flame Faults) that offset the stratigraphy and that also host mineralised veins.

There is currently no surface geologic evidence for the presence of any later cross-cutting north-west trending faults.

Two diamond drill holes (K-10-0291, K-10-0295) were completed beneath the footprint of the DSTF from a site that was essentially on outcropping Basal Quartzite. These holes were however drilled at an oblique angle to the dominant stratigraphic structure, and this may affected the quality of the RQD information.

In K-10-0291, two zones displayed increased density of fracture development:

- In quartzite between 88.85 – 96.32 m,
- In a faulted quartzite zone associated with minor mineralisation between 129.84 – 157.28 m.

In K-10-0295, much wider zones in the Basal Quartzite display increased density of fracture development associated:

- Between 8.23 – 87.48 m,
- Between 166.73 – end of hole at 313.94 m.

Some of these fracture zones are associated with minor mineralisation, but may also reflect the thin bedded nature of some of the units.

6.0 BELLEKENO NON-AML WASTE ROCK DISPOSAL AREA GROUNDWATER MONITORING

Preliminary engineering design based on 5 boreholes for the Bellekeno Non-Acidic/Metal Leaching Waste Rock Disposal Area (WRDA) was undertaken by EBA Engineering Consultants Ltd. in late 2008 (EBA, 2008). Additional work in support of final design is expected prior to construction. Relevant findings on the subsurface conditions at the proposed WRDA site are excerpted below:

Subsurface Conditions

The subsurface conditions at the site were determined through interpretation of data from the five boreholes advanced by EBA on October 30, 2008. The subsurface conditions consist of sand that is gravely and silty. Bedrock was not encountered in any of the boreholes. The drill lost circulation in the boreholes and prevented the return of cuttings to the surface. A summary of the boreholes and their respective depths is shown in Table [3].

Table 4 Borehole Depths at Bellekeno Site

Borehole Number	Termination Depth (m)
W14101178-BH11(1)	9.0
W14101178-BH12	18.0
W14101178-BH13	12.0
W14101178-BH14	6.0
W14101178-BH15	10.0

(1) Ground Temperature Cable installed to 8.0 m

Groundwater

Groundwater was not encountered in any of the boreholes at the Bellekeno site.

Permafrost

The moisture content testing completed on the samples collected indicates elevated moisture contents attributed to either the presence of permafrost or increased silt contents of the soils. A ground temperature cable was installed in W14101178-BH11 to 8.0 m. Preliminary readings taken from the ground temperature cable indicate the presence of warm permafrost (-1 to -0.5°C).

Commencement of construction of the (WRDA) is scheduled for Q2 2012. Four groundwater monitoring wells below the Bellekeno WRDA (as per Clause 86 of the Licence) will be installed according to WRDA final design. Due to the known presence of permafrost and sloping topography in the area beneath the proposed WRDA, Alexco expects any seepage to be deflected by the frozen layer, causing it to run downslope within the active layer. Because of this, relatively shallow monitoring wells are considered appropriate and most likely to intersect and monitor for any seepage from the WRDA. Proposed monitoring wells in the vicinity of the WRDA are summarized in Table 5.

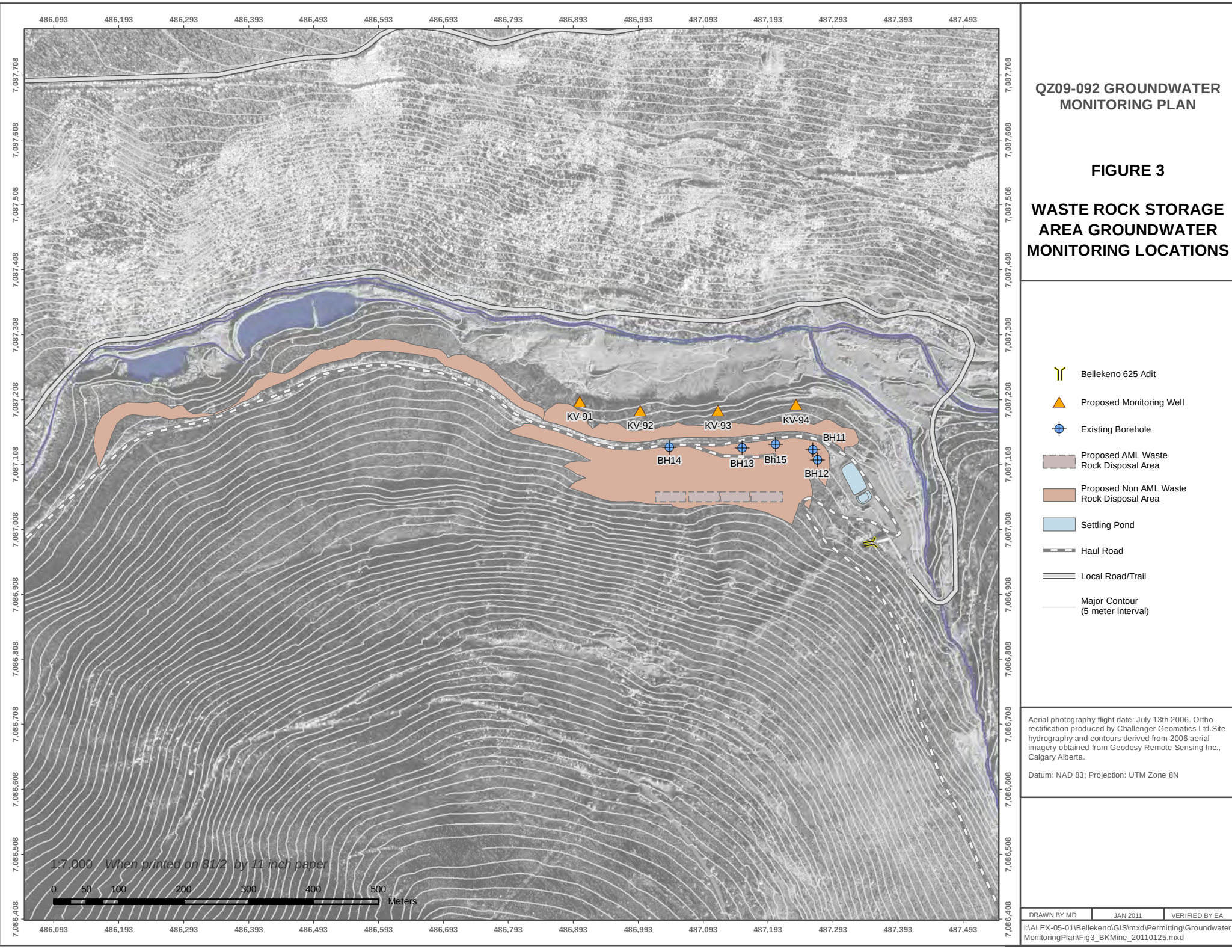
Table 5 Bellekeno WRDA Groundwater Monitoring Well Summary

Station Number	Purpose	Estimated Total Depth (m)	Estimated Overburden Depth (m)	Northing ¹	Easting ¹
KV-91	Seepage/shallow groundwater monitoring	10	10	TBD ²	TBD ²
KV-92	Seepage/shallow groundwater monitoring	10	10	TBD ²	TBD ²
KV-93	Seepage/shallow groundwater monitoring	10	10	TBD ²	TBD ²
KV-94	Seepage/shallow groundwater monitoring	10	10	TBD ²	TBD ²

¹Coordinates are UTM Zone 8 NAD 1983

²TBD – “to be determined”, station not established at this time.

Appropriate layout and borehole locations for the WRDA monitoring wells will be selected based on field conditions prior to construction and will depend on final WRDA and with the input from design engineers. Conceptual WRDA monitoring well locations are shown on Figure 3.

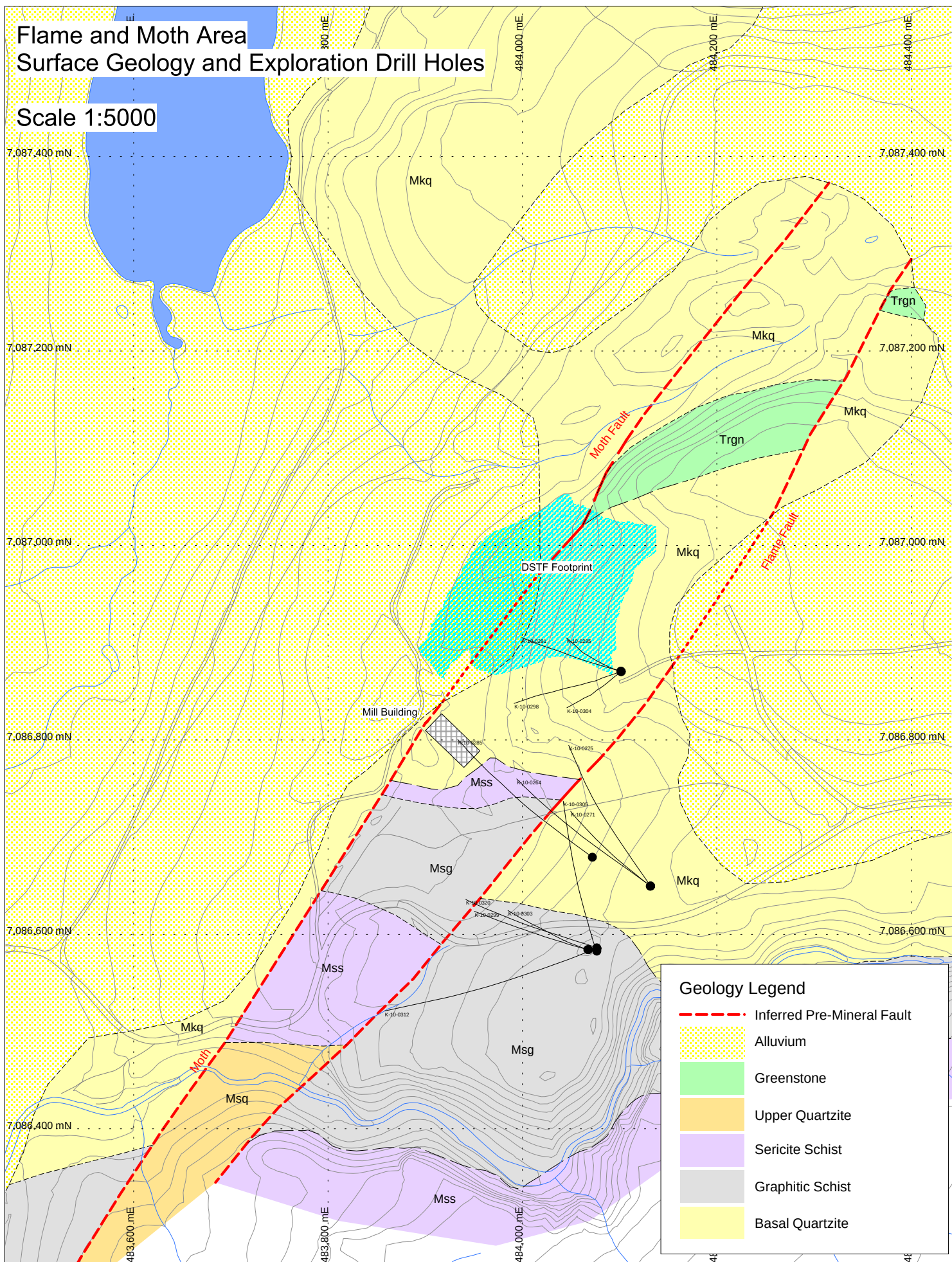


7.0 KENO CITY GROUNDWATER MONITORING

The licence requirement for monitoring of KV-84 requires that a Keno City Well be monitored on a quarterly basis. This monitoring is also subject to Clause 44, requiring that all wells be sampled monthly for the first twelve months that they contain water. Initial sampling as reported in the SRK Bellekeno Groundwater Study (SRK, 2010) used Keno City Well #3 which is owned by a private resident of Keno City. Well #3 and the Keno City Firehall well have been sampled since issuance of the Licence in order to fulfill monitoring requirements for KV-84, but because of difficulties coordinating sampling, this is not viewed as a satisfactory solution for the duration of the Licence. Alexco, through part of the District Closure Planning, is currently planning installation of several wells around Keno City for a hydrogeology study as part of a hydrogeologic study of the Keno City area. It is anticipated that this work will be carried out during February 2011, and that once installed, one of these wells will be selected for reporting for KV-84. A notification will be submitted to the YWB and Water Resources in order to provide notification to regulators of the final sampling location of the Keno City well. The locations of the existing Keno City area wells including an approximate location for KV-84 are also shown on Figure 4

Flame and Moth Area Surface Geology and Exploration Drill Holes

Scale 1:5000



8.0 REVIEW OF RESULTS

Results of all groundwater monitoring activities will be subject to periodic review and interpretation by Alexco. This review and interpretation is key in identifying any potential changes in baseline conditions, and if necessary, trigger mitigation and/or adaptive management measures. The results of these reviews and analyses will be reported with the Annual Report.

9.0 GROUNDWATER MONITORING SCHEDULE

Groundwater monitoring will follow the schedule as described in Schedule B, Table 4 of the Licence, which is summarized below as Table 6.

Table 6 Groundwater Monitoring Schedule

Monitoring Station	Field Parameters			
	pH	Temp.	Cond.	Level
KV-84	Q*	Q*	Q*	Q*
KV-85	Q*	Q*	Q*	Q*
KV-86	Q*	Q*	Q*	Q*
KV-87	Q*	Q*	Q*	Q*
KV-88	Q*	Q*	Q*	Q*
KV-89	Q*	Q*	Q*	Q*
KV-90	Q*	Q*	Q*	Q*
KV-91	Q*	Q*	Q*	Q*
KV-92	Q*	Q*	Q*	Q*
KV-93	Q*	Q*	Q*	Q*
KV-94	Q*	Q*	Q*	Q*

*Represents monthly sampling for the first twelve months that they contain water based on Clause 44 of the Licence

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).

10.0 REPORTING

As per Clause 54 of Water Licence QZ09-092:

Unless otherwise specified in this licence, all monitoring data, reports, plans, studies, study results, designs or manual shall be submitted to the Board in the following format:

- a) All reports required to be submitted to the Board will be unbound and reproducible by standard photocopier, accompanied by one electronic copy on a CD/DVD.*
- b) The Licensee shall provide to the Board 5 additional copies of all reports. The additional copies may be either 5 bound paper copies or 5 electronic copies on individual CDs/DVDs.*
- c) Electronic copies shall be IBM compatible in one of the following formats: Word 97-2003, Excel 97-2003 workbooks, or Adobe .pdf format. Water quality results must be presented in Excel 97-2003 .xls format.*

The results of the weekly physical inspections will be summarized from the weekly inspection checklists and incorporated into the annual reports (as per section 55 of the licence). Requirements of the annual reports are outlined in sections 55 and 56 of the Licence.

11.0 REFERENCES

Access Consulting Group, 2009. Keno Hill Silver District Environmental Conditions Report Version 1. Report prepared for Alexco Resource Corp.

EBA Engineering Consultants Ltd. 2010. Preliminary Engineering Design and Management Plan, Dry-Stacked Tailings Facility, Bellekeno Mine Mill Site, Yukon. Report prepared for Alexco Keno Hill Mining Corp.

EBA Engineering Consultants Ltd. 2008. Geotechnical Evaluation – Potential Mill Sites Bellekeno Project near Keno City, Yukon. Letter to Alexco Resource Canada Corp.

SRK Consulting (Canada) Inc (2010) 2010 Bellekeno Groundwater Program. Report Prepared for Alexco Keno Hill Mining Corp. SRK Project # 1CA009.003.

SRK Consulting (Canada) Inc (2009a) Desktop review: Effects of Water Extraction at Christal Lake on Water Levels in the Keno City Community Well. Memorandum to Alexco Keno Hill Mining Corp. SRK Project # 1CE012.003.

SRK Consulting (Canada) Inc (2009b) Assessment of Potential Groundwater Impacts from the Bellekeno Mill Site and Dry Stack Tailings Facility. Letter to Alexco Resource Corp. SRK Project # 1CE012.003.



ALEXCO KENO HILL MINING CORP.

QUARTZ MINING LICENCE

QML-0009

BELLEKENO MINE DEVELOPMENT

KENO HILL SILVER DISTRICT

YUKON

Appendix B



Alexco Keno Hill Mining Corp. Bellekeno Mine Operations

Physical Inspection and Reporting Plan

Water Use Licence QZ09-092

October 2010

Prepared by:



TABLE OF CONTENTS

1.0	INTRODUCTION.....	1
1.1	Purpose of Plan	1
2.0	MINE LOCATION AND DESCRIPTION	1
3.0	PHYSICAL INSPECTION LOCATIONS	3
4.0	PHYSICAL INSPECTION SCHEDULE	3
5.0	PHYSICAL INSPECTION METHOD.....	4
5.1	Photo Documentation	4
5.2	Inspection Checklists	5
5.3	DSTF Surveillance, Inspection and Monitoring.....	6
6.0	REPORTING	7

LIST OF FIGURES

Figure 1	Physical Inspection and Reporting Plan Site Map	2
----------	---	---

LIST OF TABLES

Table 1	Physical Inspection Schedule	3
Table 2	Approximate Photo Hub Descriptions	4

APPENDICES

Appendix A	Physical Inspection Weekly Checklist
Appendix B	Physical Inspection Monthly Checklist
Appendix C	DSTF OMS Manual Section 9 -- Surveillance

1.0 INTRODUCTION

1.1 *Purpose of Plan*

This plan is submitted to fulfill the conditions set out in Part H, Clauses 92, 93 of Water Licence QZ09-092 issued to Alexco Keno Hill Mining Corp on August 19th 2010:

92. Within 60 days of the effective date of this licence, the licensee shall submit to the Board a plan titled "Physical Inspection and Reporting Plan for all water retaining structures, water conveying structures, and mine Waste structures and shall implement that plan.

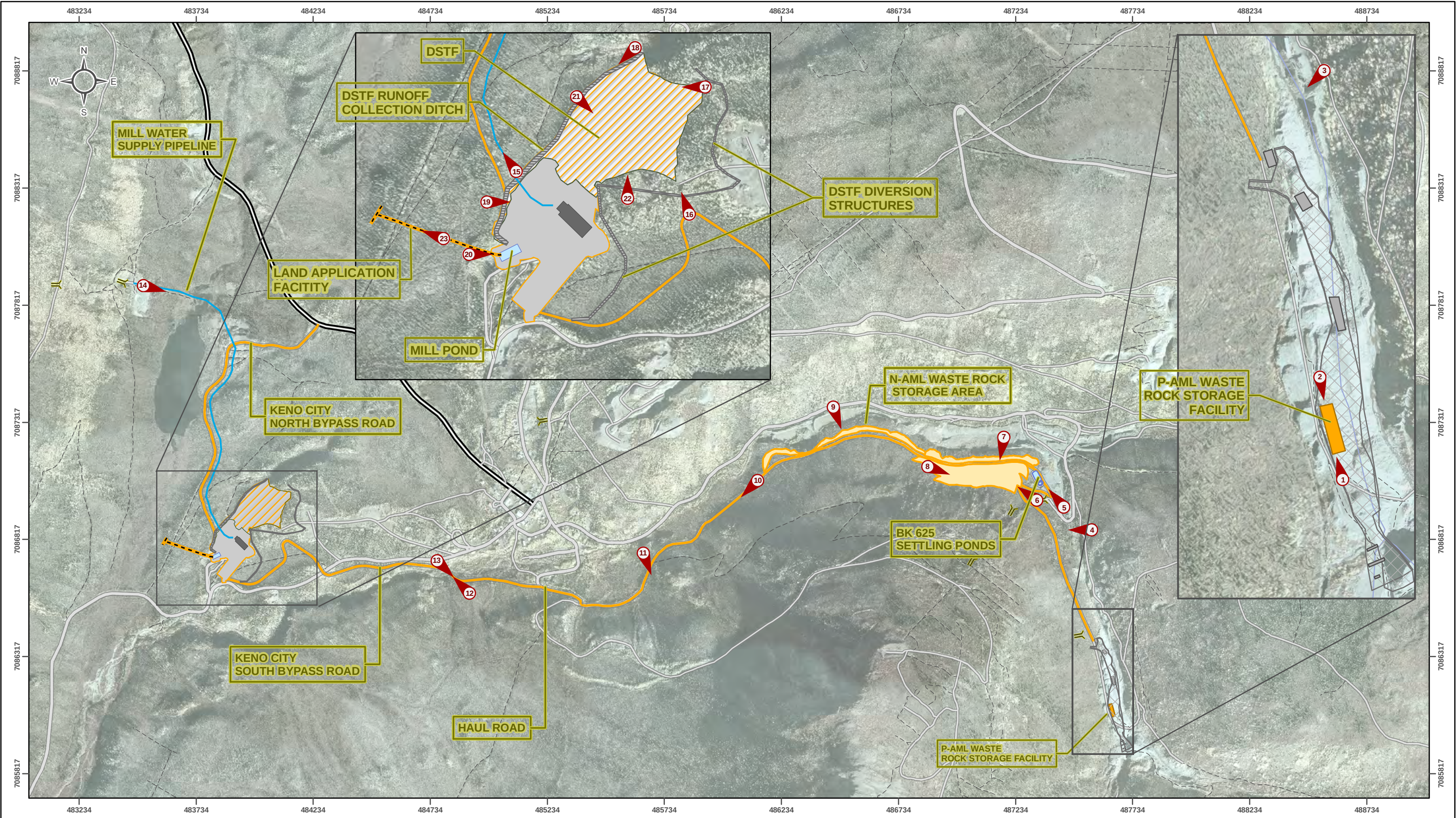
93. Inspections will be conducted on at least a weekly basis for all structures identified in the Bellekeno Physical Inspections and Reporting Plan.

This plan outlines the Physical Inspection and Reporting methodology that will be used during mining operations at the Bellekeno Mine and Mill on Alexco's Keno Hill property.

2.0 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 mill site and Dry Stack Tailings Facility (hereinafter referred to as the "DSTF") are located approximately 1 km west of Keno City.

The portal at Bellekeno East is located on a steep slope above Thunder Gulch, a narrow tributary of Lightning Creek, and the haul road access to the mill site is provided by an approximately 3 km access road which crosses Lightning Creek approximately 2200 meters downstream from the confluence of Thunder Gulch and Lightning Creek. Please refer to see Figure 1 for the site map.



National topographic Data Base (NTDB) compiled by Natural Resources Canada at a scale of 1:50,000. Reproduced under license from Her Majesty the Queen, as represented by the Minister of Natural Resources Canada. All rights reserved. NTS sheets 105M13, 105M14, 106D3 and 106D04. Aerial photography flight date: July 13th 2009. Ortho-rectification produced by Challenger Geomatics Ltd. The location of the photo hubs are approximate and subject to change. Some mine and mill feature footprints are subject to change.

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

1:15,000 (when printed on 11 x17 inch paper)



Point Features

- Adit
- Photo Hub Location (Photo direction as shown by point)

Road Types

- Haul Road
- Highway
- Local
- Track
- Trail

Mill Site Features

- Mill Water Supply, Conceptual
- Mill Pond Discharge

Mill Site Features

- Mill
- Mill Pond
- Diversion Structure/Flume
- DSTF Footprint
- Mill Site Area

Mine Site Features

- BK East Portal Area
- Non AML Waste Rock Disposal Area
- Temporary Potential - AML Waste Rock Storage Facility
- Settling Pond
- Mine Feature Footprint



BELLEKENO MINE

WUL- QZ09-92

PHYSICAL INSPECTION AND REPORTING PLAN

FIGURE 1 - SITE MAP

Drawn By: MD

OCTOBER 2010

Verified by: RM/EA

D:\Project\AllProjects\ALEX-05-01\Bellekeno\GIS\mxd\Physical_Inspection_Reporting_Plan\October_2010.mxd

3.0 PHYSICAL INSPECTION LOCATIONS

As per Part H, Clause 94 of Water Licence QZ09-092, the areas to be inspected include:

- Bellekeno 625 settling ponds;
- Non-AML Waste Rock Disposal Area;
- Potential-AML Waste Rock Storage Facility;
- Access and haul roads;
- Mill site & DSTF collection and sedimentation pond; and
- Dry stack tailings facility.

Additional water retaining or conveying structures associated with the project which will be included in the physical inspection schedule by Alexco include:

- Mill water supply pipeline between Galkeno 900 and mill site;
- Mill site & DSTF collection and sedimentation pond land application system
- Mill site water diversion structures; and
- Mill site and DSTF water collection structures.

4.0 PHYSICAL INSPECTION SCHEDULE

The physical inspection schedule is shown in Table 1 below.

Table 1 Physical Inspection Schedule

Physical Inspection Location	Inspection Schedule		Monthly Photo Documentation
	Weekly	Monthly	
Bellekeno 625 settling ponds	x		x
Mill site & DSTF collection and sedimentation pond	x		x
Potential-AML waste rock storage facility	x		x
Non-AML waste rock disposal area		x	x
Access and haul roads		x	x
Dry stack tailings facility*			x
Water supply pipeline between Galkeno 900 and mill		x	x
Mill site water diversion structures	x**	x	x
Mill site and DSTF water collection structures	x**	x	x
Mill site & DSTF collection and sedimentation pond land application system		x	x

*See Appendix C for DSTF inspection schedule

**Weekly during freshet and other periods of high rainfall/runoff

The physical inspection for the all water retaining structures above structures will be conducted on a weekly basis. These include the Bellekeno 625 settling ponds, the Potentially-AML Waste Rock Storage Facility at Bellekeno East, and the Mill site & DSTF collection and sedimentation pond.

All remaining water conveying and mine waste features will be subject to physical inspection on a monthly basis with photo documentation occurring monthly for all sites.

5.0 PHYSICAL INSPECTION METHOD

The purpose of the physical inspection is to observe and record sufficient information to allow for the identification of areas or issues that could potentially require modification, repair or rehabilitation as required.

Physical inspections will consist of visual inspections conducted by competent and trained field operators. The operators will document the condition of the various infrastructure at each location and record any non-standard observations (e.g. excessive icing, rilling of soils, sloughing). 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 1), and a detailed list and description of these photo hubs is included in Table 2 below.

Table 2 Approximate Photo Hub Descriptions

Photo Hub #	Photo Hub Description
1	P-AML waste rock storage facility 1
2	P-AML waste rock storage facility 2
3	Bellekeno mine haul road (Non-AML Waste Rock) from opposite Thunder Gulch
4	Bellekeno East portal pad (Non-AML Waste Rock) from opposite Thunder Gulch

5	Bellekeno 625 settling pond 1
6	Non-AML Waste Rock Disposal Area 1
7	Non-AML Waste Rock Disposal Area from opposite Lightning Creek 1
8	Non-AML Waste Rock Disposal Area 2
9	Non-AML Waste Rock Disposal Area from opposite Lightning Creek 2
10	Powerline Road (Non-AML Waste Rock)
11	Powerline Road (Non-AML Waste Rock) from opposite Lightning Creek
12	Keno City South Bypass Road (Non-AML Waste Rock) 1
13	Keno City South Bypass Road (Non-AML Waste Rock) 2
14	Mill water supply pipeline 1
15	Mill water supply pipeline 2
16	Mill site water diversion structures 1
17	Mill site water diversion structures 2
18	Mill site and DSTF water collection structures 1
19	Mill site and DSTF water collection structures 2
20	Mill site & DSTF collection and sedimentation pond 1
21	Dry Stack Tailings Facility 1
22	Dry Stack Tailings Facility 2
23	Mill site & DSTF collection and sedimentation pond land application system

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 circulated to appropriate internal technical staff, in case notable changes are identified.

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. The site manager will then be responsible to immediately re-asertain whether or not the system or element is safe for use for the next 24 hours.

If issues are identified during the weekly inspections of structures, works and installations (e.g. waste rock storage area, overburden stockpiles, embankments, diversion ditches, sediment ponds, and pipelines) 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 also need to be implemented as required. If fair or poor conditions are noted during an inspection, NND will be notified of the details and of any planned mitigative action.

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 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 C.

6.0 REPORTING

As per clause 54 of Water Licence QZ09-092:

Unless otherwise specified in this licence, all monitoring data, reports, plans, studies, study results, designs or manual shall be submitted to the Board in the following format:

- a) All reports required to be submitted to the Board will be unbound and reproducible by standard photocopier, accompanied by one electronic copy on a CD/DVD.*
- b) The Licensee shall provide to the Board 5 additional copies of all reports. The additional copies may be either 5 bound paper copies or 5 electronic copies on individual CDs/DVDs.*
- c) Electronic copies shall be IBM compatible in one of the following formats: Word 97-2003, Excel 97-2003 workbooks, or Adobe .pdf format. Water quality results must be presented in Excel 97-2003 .xls format.*

The results of the weekly physical inspections will be summarized from the weekly inspection checklists and incorporated into the annual reports (as per section 55 of the licence). Requirements of the annual reports are outlined in sections 55 and 56 of the Water Licence.

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.

Alexco Keno Hill Mining Corp.

Physical Inspection and Reporting Plan

Water Use Licence QZ09-092

Appendix A

Weekly Checklist for Water Retaining Structures

Physical Monitoring Program Water Retaining Structures Weekly Inspection Checklist

Date:

Check ☒ if correct or ☐ if not (record details in spaces below) Rating Scale: Excellent, Good, Fair or Poor

	Bellekeno 625 Settling Ponds	Mill Site & DSTF Collection/Sedimentation Pond	Bellekeno P-AML Waste Rock Storage Facility
--	------------------------------	--	---

General

Check visually			
Photo(s) taken?			
Checked after storm event?			
Materials being disposed of in assigned areas?			

Soil/Rock Structures

Check for movement?			
Crest checked?			
Tension Cracks?			
Toe checked?			
Seepage?			
Sinkholes?			
Depressions?			
Bulging?			
No creep?			
No failure?			
Safe for use next 24 hrs?*			

Water Structures

No loose material or exposed liner?			
Spillway clear?			
Checked for seepage?			
Good runoff management?			
Diversion clear?			
No failure?			
Safe for use next 24 hrs?*			
Limits adhered to?			

Piping

Leaks?			
Signs of wear?			

Inspector's Initials

* Site Manager must countersign "safe for use next 24 hours" in any case where any "poor" rating is given

Comments (recommendations / corrective actions required)

Alexco Keno Hill Mining Corp.

Physical Inspection and Reporting Plan

Water Use Licence QZ09-092

Appendix B

Monthly Checklist

Physical Monitoring Program Monthly Inspection Checklist

Date:

Check ☒ if correct or ☐ if not (record details in spaces below) Rating Scale: Excellent, Good, Fair or Poor								
	Non-AML Waste Rock Storage Facility	Mill Water Supply Pipeline	Mill Site Water Diversion Structures	Mill Site Water Collection Structures	Access and Haul Roads			
					Upper Road	Powerline Road	Keno City Bypass South	Keno City Bypass North
General								
Check visually								
Photo(s) taken?								
Checked after storm event?								
Materials being disposed of in assigned areas?								
Soil/Rock Structures								
Check for movement?								
Crest checked?								
Tension Cracks?								
Toe checked?								
Seepage?								
Sinkholes?								
Depressions?								
Bulging?								
No creep?								
No failure?								
Safe for use next 24 hrs?*								
Water Conveyance Structures								
No loose material or exposed liner?								
Spillway clear?								
Checked for seepage?								
Good runoff management?								
Diversion clear?								
No failure?								
Safe for use next 24 hrs?*								
Limits adhered to?								
Piping								
Leaks?								
Signs of wear?								
Inspector's Initials								
* Site Manager must countersign "safe for use next 24 hours" in any case where any "poor" rating is given								
Comments (recommendations / corrective actions required)								



ALEXCO KENO HILL MINING CORP.

QUARTZ MINING LICENCE

QML-0009

BELLEKENO MINE DEVELOPMENT

KENO HILL SILVER DISTRICT

YUKON

Appendix C

2.0 PHYSICAL ENVIRONMENT

Chapter 2 of this Environmental Conditions Report summarizes the physical environment for the Keno Hill Silver District including climate (evaporation, precipitation), terrestrial resources (geology, physiography, soils), and water quality and hydrology for watercourses and discharging adits.

2.1 CLIMATE

2.1.1 General

An automated meteorological station (Calumet Weather Station) was installed on Galena Hill above Hector adit in June 2007. The location is shown on Figure 2-4 – Water Quality Sample Stations below in Section 2.3 (Water Quality and Hydrology). The station measures air temperature, relative humidity, barometric pressure, rainfall, wind speed and direction, solar radiation, and soil temperature. A Yukon Government monitored snow course station also exists in the area.

The following sections present the 1996 characterization of climate, which was in turn used to derive site hydrological conditions at the time. Based on comparisons with the latest site data, the original techniques and hydrological inputs were deemed appropriate in deriving site hydrological condition (Clearwater Consultants Ltd, 2008; Refer to Appendix A). The following information is therefore considered valid and accurate.

2.1.2 Available Data

The climate records from a total of eleven climate stations were assembled in 1996 to assist in characterizing the climate of the Keno Hill Silver District. Details of these stations are presented in Table 2-1. The table also identifies the type of climatic information each station provided for the study.

The region around the Keno Hill Silver District has been served by a network of climate monitoring stations. At least three climate stations have been operated within the boundaries of the silver district. Two of these stations were maintained by the Atmospheric Environment Service (AES) and were located at the Elsa townsite and on the southern flank of Keno Hill. The third station was operated on a seasonal basis by

DIAND at a site in the Flat Creek catchment near the Elsa townsite. In addition to these stations, the AES operate a principal climatological station at the Mayo Airport, located some 40 km southwest of Elsa. The data from the Mayo Airport can be combined with that of two discontinued stations in the near vicinity of the airport (i.e. Mayo Landing and Mayo) to construct a long-term climate record.

Table 2-1 Details of Regional Climate Stations

Station Name ³	Latitude		Longitude		Elevation (m.a.s.l.)	Period of Record	Mean Annual Precipitation (mm)	Information Applicable To This Study
	Deg.	Min.	Deg.	Min.				
AES¹								
Boundary/ Mile 34 Boundary Rd	64	14	140	21	1036	1967 - 1978	576	Precipitation
Clinton Creek	64	28	140	44	576	1964 - 1978	370	Precipitation
Dawson	64	3	139	26	320	1897 - 1979	306	Precipitation/ Humidity/ Temperature
Dawson Airport	64	3	139	8	369	1976 - 1995	340	Precipitation/ Humidity/ Temperature
Elsa	63	55	135	29	814	1948 - 1965, 1974 - 1989	413	Precipitation
Pelly Ranch/ Fort Selkirk	62	49	137	22	454	1954 - 1995	286	Precipitation/ Bright Sunshine
Keno Hill	63	56	135	12	1472	1974 - 1982	590	Precipitation
Klondike/ Dempster	64	27	138	13	960	1966 - 1995	469	Precipitation
Mayo Airport/ Mayo/ Mayo Landing	63	37	135	52	504	1924 - 1995	306	Precipitation/ Humidity/ Temperature
Snag Airport	62	22	140	24	587	1943 - 1966	339	Humidity/ Temperature
DIAND²								
Flat Creek	63	55	135	30	730 (approx.)	1992 - 1994 (summers only)	Not available	Humidity/ Temperature

Notes: 1. Environment Canada, Atmospheric Environment Service

2. Department of Indian Affairs and Northern Development, Fire Management Program

3. For some stations, more than one name is presented. Where this happens, the first name given is the current official designation of the station. Other names represent past designations of the station. Name changes appear to have most often been triggered by the slight relocation of the station.

2.1.3 Precipitation

Mean annual precipitation (MAP) within a mountainous region typically increases with increasing elevation. The region around the Keno Hill Silver District is no exception to this rule as illustrated by the graph of MAP versus elevation shown on Figure 2-1. The data points on this graph were obtained from the information assembled in Table 2-1 for the regional AES climate stations.

The Keno Hill Silver District is in an area of significant relief. Accordingly, MAP can be expected to vary considerably within the boundaries of the district. In order to quantify this variation, an empirical relationship was derived between MAP and elevation using the data from the two AES stations which were operated on the property, namely the Elsa and Keno Hill stations. These are suitable stations for deriving the relationship since their elevations are widely separated (i.e. 814 m versus 1472 m). Assuming a linear relationship between MAP and elevation, a line was fitted to the data of these two

stations (see Figure 2-1). The slope of this line indicates that MAP increases by an average of 27 mm for every 100 m of ascent, a value not too dissimilar from that observed in other regions of the Yukon interior.

The curve fitted exclusively to the Elsa and Keno Hill data seems to also explain much of the variation in MAP observed at the other regional AES climate stations. The scatter about the line drawn on Figure 2-1 can largely be attributed to a mild drying trend as one moves from the northwest to the southeast across the region. This drying trend is made apparent by noting where the individual climate stations are located in relation to the property. All stations plotting above the line are located north and west of the property. In contrast, the two stations plotting below the line are found south of the property.

The adopted empirical relationship shown on Figure 2-1 should be viewed as providing only approximate estimates of MAP for ungauged points within the district. Although elevation is the principal control, precipitation also varies according to other variables such as slope and aspect which are not explicitly accounted for in the empirical relationship.

Figure 2-2 was prepared to illustrate the seasonal distribution of precipitation at the property. As with MAP, the seasonal distribution is influenced by elevation. To demonstrate this influence, the seasonal distributions for Mayo Airport (504 m), Elsa (814 m), and Keno Hill (1472 m) have been plotted on Figure 2-2. The following observations can be drawn from examining these distributions:

- precipitation is common throughout the year;
- the wettest period is normally the summer months of July and August;
- the driest month of the year is typically April;
- the proportion of total precipitation which falls as rain decreases as elevation increases (60% of total precipitation at Mayo Airport, 53% at Elsa, and 41% at Keno Hill); and,
- the precipitation gradient during winter is steeper than that during summer (which suggests orographic effects are more pronounced during snowfall than during rainfall).

Figure 2-1 Mean Annual Precipitation as a Function of Elevation

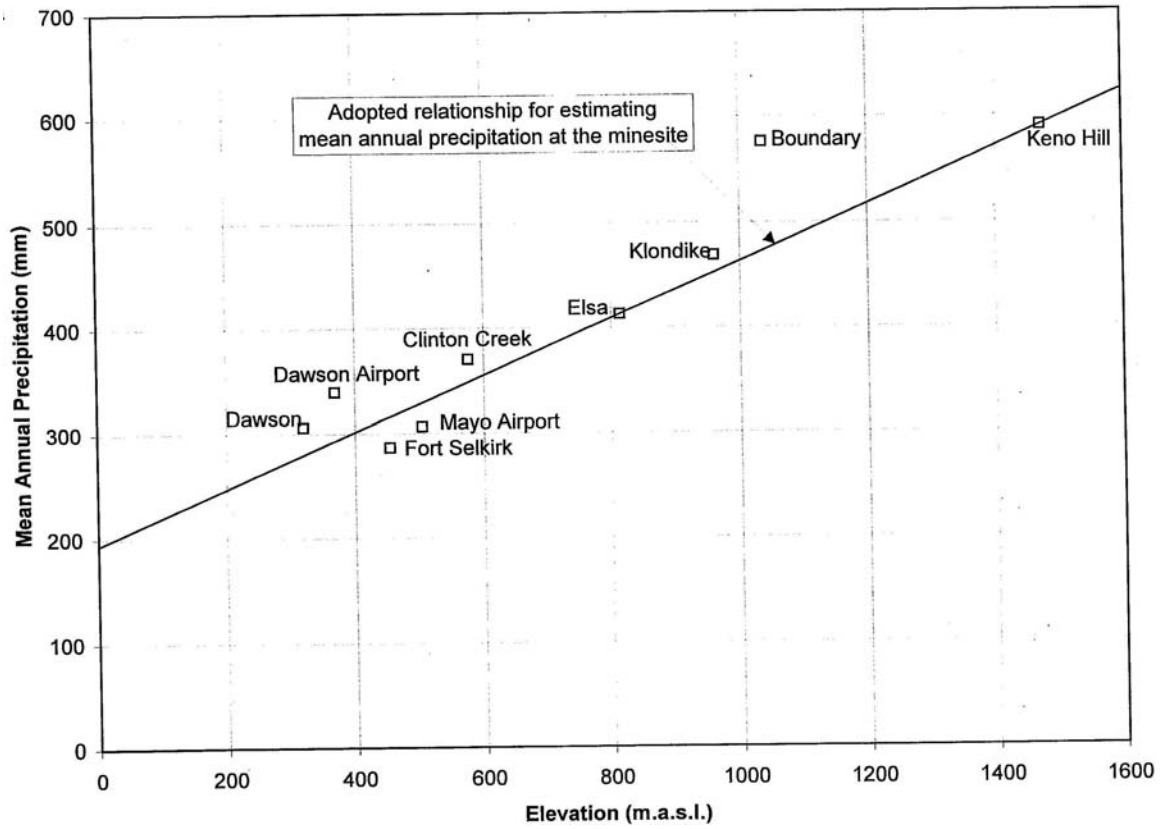
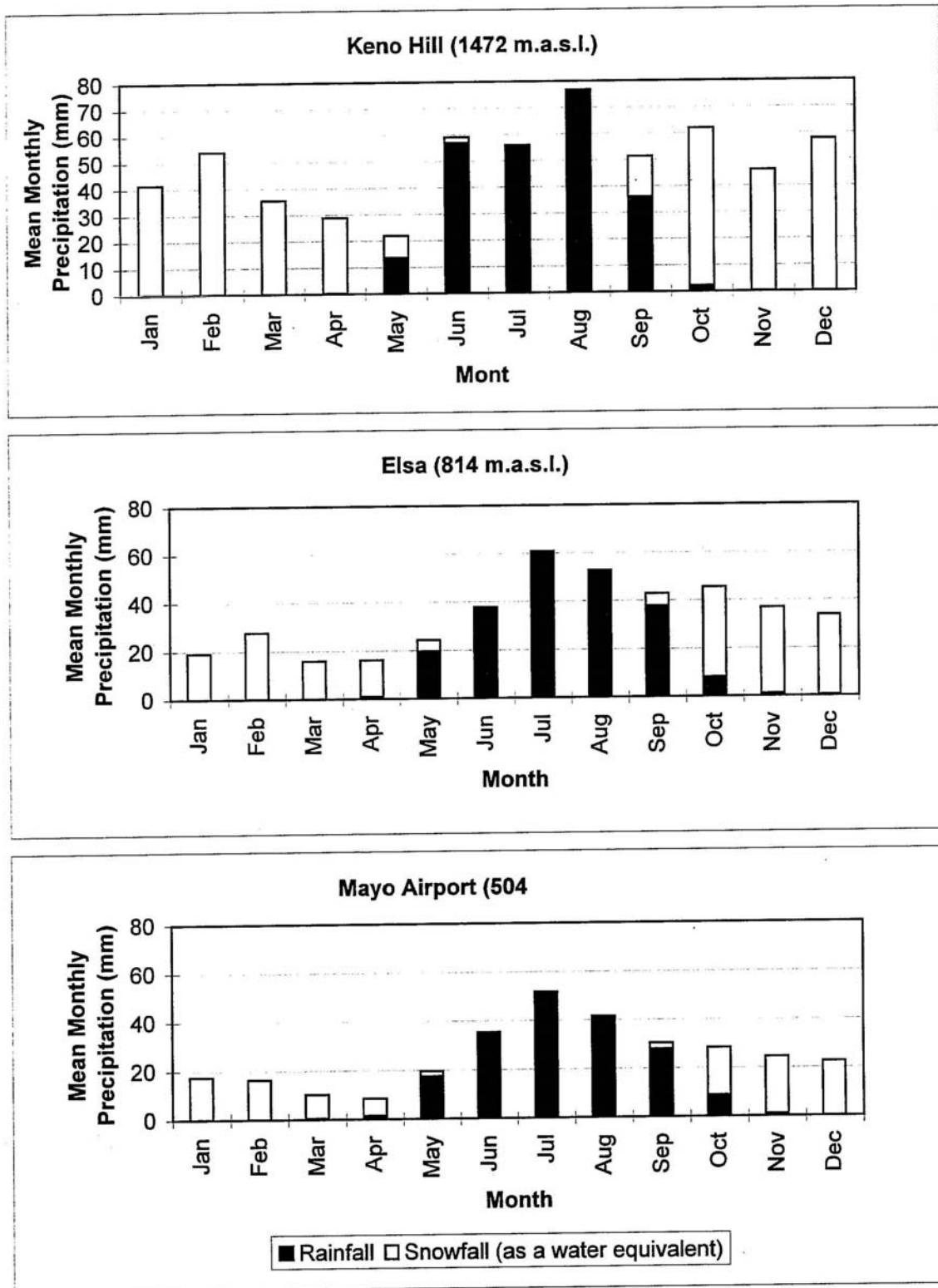


Figure 2-2 Mean Monthly Precipitation



2.1.4 Evaporation

Two rates of evaporation are of interest: lake evaporation and evapotranspiration. The former refers to evaporation from a free-water surface while the latter refers to evaporation from a land surface including transpiration from plants. Both rates were estimated from meteorological data using a computer program known as WREVAP which was developed by Environment Canada's National Hydrology Research Institute.

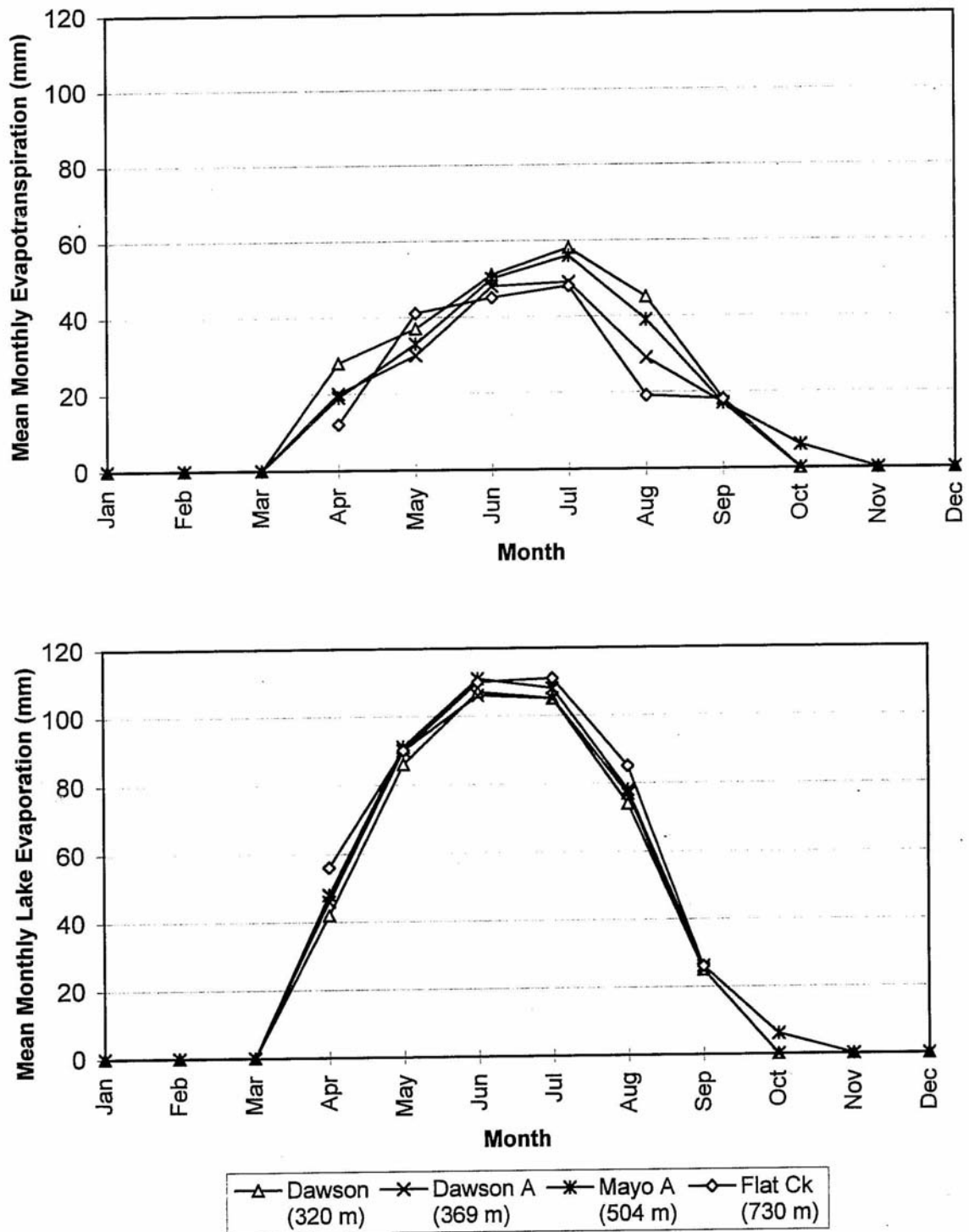
The meteorological inputs to the WREVAP model comprise humidity, temperature, and sunshine duration. In order to obtain valid estimates of evaporation, the model must be provided with accurate measurements of the first two climatic variables. Model results are less sensitive to the accuracy of the third input requirement (sunshine duration). Thus, the use of sunshine duration records from another nearby climate station provides adequate accuracy. With this in mind, a search was made for climate stations which met the following two criteria:

- the station experiences a comparable climate to the Keno Hill Silver District; and,
- as a minimum, the station monitors both humidity and air temperature.

Using these criteria, a total of four climate stations were selected for the evaporation modelling, one located on the property itself (Flat Creek) and three located in the general region (Dawson, Dawson Airport, and Mayo Airport). However sunshine duration has not been maintained at any of these locations. To obtain this additional information, reference was made to the closest climate station equipped to measure sunshine duration that being Pelly Ranch or, as it was formerly known, Fort Selkirk.

Figure 2-3 displays the results of applying the WREVAP model to the meteorological conditions at each of the four climate stations. The top graph shows estimates of mean monthly evapotranspiration while the bottom graph shows the monthly distribution of lake evaporation. As can be observed, all four stations experience similar rates of both lake evaporation and actual evapotranspiration. Based on this similarity, the average of the evaporation rates at the four stations was selected to represent the conditions at the property. The average annual lake evaporation is about 460 mm while the estimated actual evapotranspiration is about 200 mm per annum, or 43% of lake evaporation.

Figure 2-3 Mean Monthly Evaporation Data





ALEXCO KENO HILL MINING CORP.

QUARTZ MINING LICENCE

QML-0009

BELLEKENO MINE DEVELOPMENT

KENO HILL SILVER DISTRICT

YUKON

Appendix D

Memorandum

Date: June 20, 2011
To: Vanessa Benwood, Alexco Keno Hill Mining Corp (AKHM)
C: Jim Harrington, Alexco Resource Corp.
From: Ethan Allen, Access Consulting Group
Subject: Keno District Mill Preliminary Dustfall Monitoring Results



1. INTRODUCTION

In accordance with Clause 69 of the Decision Document for the assessment for the Bellekeno Mine Project (YESAB File Number 2009-0030), dustfall monitoring was installed at two locations near the Keno District mill site. Samples have been collected on an approximately monthly basis at two locations near the mill site continuously since March 6, 2011. The dust monitoring program is described in the Monitoring and Surveillance Plan Revision 1 (June, 2011).

1.1 Purpose

At the request of Yukon Government, Alexco and Access Consulting Group met with representatives of Yukon Government on May 17, 2011 to discuss the implementation of the dust monitoring program for the Bellekeno Project. A commitment to provide results of initial sampling to Yukon Government was made by Alexco at this meeting.

This memorandum summarizes the results of initial dustfall monitoring undertaken by AKHM for the period between March 6, 2011 and May 10, 2011.

2. METHODS

Mill site layout and infrastructure and locations of Bergerhoff dust monitoring gauges currently in place at two locations at the edge of the mill site are shown on Figure 1.



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 under license 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

Main Map: 1:2,500 Inset Map: 1:60,000
(when printed on 11 x17 inch paper)

▲ Dust Monitor Station

— Mill Access Road

— Haul Road

— Local Road



MONITORING AND SURVEILLANCE PLAN QML - 0009

FIGURE 1
PRELIMINARY DUST MONITORING RESULTS

DRAWN BY MD	JUNE 2011	VERIFIED BY EA
-------------	-----------	----------------

I:\ALEX-05-01\Bellekeno\GIS\mxd\Permitting\Monitoring_and_Surveillance_Plan_QML_0009\Prelim_Dust_Monitoring_Srms_20110603.mxd
(Last edited by: mducharme.03/06/2011/14:32 PM)

2.1 Site sampling procedure

Two samples were collected for the period between March 6, 2011, and May 10, 2011 at each sampling location on approximately monthly intervals. Because of the prevailing winter/spring conditions during collection of these two initial samples, no special procedure was undertaken with respect to ensuring maintenance of water in the collection bottle. All samples contained a significant amount of water (or snow) at the time of collection. Samples were emptied and rinsed with deionized water into secondary sample bottles and sent to Maxxam Analytical Laboratories of Burnaby, BC for analysis.

2.2 Laboratory Analytical Procedure

The following samples were subjected to the following procedure upon receipt by Maxxam:

- Samples were split into two portions of 60 mL.
- One aliquot was run for Total Suspended Solids.
- The second aliquot for Total Solids, fixed and volatile.

Total Suspended Solids (TSS) Aliquot

- Extraneous material was removed prior to filtering.
- Samples were filtered using a Whatman 934AH 12.5 cm 1.5µm filter to determine TSS.

Total Solids Aliquot

- Samples were dried overnight at 105 degrees C.

Loss on Ignition (LOI)

- LOI was conducted on both aliquots at 600 degrees C on the filtrate from the total and suspended solids aliquots in order to determine total weight of the fixed and volatile portions. The volatile fraction, which was burned off during LOI was assumed to be organic material.

Moving forward, Maxxam has been instructed to run the sample for only TSS. Also, Maxxam has been instructed to keep the solids from the Total Solids and if enough sample is available (at least 1 gram) to proceed with a ICP metals analysis.

3. RESULTS

The results of preliminary dust monitoring for DM1 and DM2 are summarized in Table 1 below. A summary table and calculated deposition rate for each sample and for the two sample periods is included in Table 2. Analytical certificates for these samples are included as Attachment 1.

Table 1 Summary of Results

Station #	Units	Total Solids Aliquot			Total Suspended Solids Aliquot		
		Total	Fixed	Volatile	Total	Fixed	Volatile
DM1	mg/sample ¹	18	<10	18	<10	<1	<1
DM2	mg/sample ¹	22	<10	18	<10	7	<1
DM1	mg/sample ¹	19	<10	19	<10	2	<1
DM2	mg/sample ¹	13	<10	12	<10	2	<1
RDL²		10	10	10	10 ³	1	1

Notes: ¹All measurements calculated to represent the entire sample (both aliquots)

²RDL = Reportable Detection Limit

³The RDL was raised to from 1 to 10 due to insufficient sample volume

Table 2 Dust Deposition Summary Table

Station #	Collection Period	Days	Surface Area of Sample Bottle (dm ²)	Deposition Based on TSS Fixed (mg/(dm ² *d))
DM1	March 6 - April 3	29	1.46	0.012*
DM2	March 6 - April 3	29	1.46	0.165
DM1	April 3 - May 10	38	1.46	0.036
DM2	April 3 - May 10	38	1.46	0.036

*Assuming below detection result was 0.5x RDL

Dust deposition was calculated based on the TSS fixed. RDL for the Total Solids was too high, resulting in all of the measurements being below detection. The TSS fixed value was divided by the surface area of the sample bottle mouth and the number of days over each sample was collected. The resultant dust deposition values are reported in mg/(dm²*d), which is comparable to the Ambient Air Control Objectives in the *Pollution Control Objectives for the Mining, Smelting and Related Industries of BC* (1979), which

provides an acceptable range of between 1.7 to 2.9 mg/(dm²*d). The use of only the fixed solids measurements is deemed the most appropriate representation of dust which may originate from the site, and is expected to consist wholly of minerals, which would not be significantly volatilized by LOI.

4. DISCUSSION AND RECCOMENDATIONS

A number of observations and interpretations are made from these data:

- RDL for the TSS measurement is an order of magnitude lower than the Total Solids measurement (1 mg compared with 10 mg) which enabled a measurable result for all but one sample.
- The highest calculated dust deposition rate was over an order of magnitude below the lowest value of 1.7 mg/(dm²*d) listed under the *Ambient Air Control Objectives*, which is the trigger for Phase 2 (TSP) sampling.
- The highest observed deposition (0.165 mg/(dm²*d) was recorded at DM1 for the period between March 6 – April 3, but still over an order of magnitude lower than the Phase 2 trigger. This dust may be attributable to dust emanating from the crushers during periods of cold weather. This interpretation is supported by the observation that the crushers are located directly upwind according to the modeled and observed predominant winds at the site and that some cold weather was experienced in March.
- The majority of the Total Solids fraction (between 82% and 100%) was volatile (organic) and lost during ignition.

Potential dust sources at the mill site have been identified as the Dry Stack Tailings Facility (DSTF), the tailings and concentrate loadout areas, the fine ore stockpile, the primary and secondary crushers, and fugitive dust from mill site area roads. Based on the dust modeling conducted and submitted as part of the DSTF Construction and Operation Plan and preliminary data collected to date, these potential dust sources are expected to be more likely to produce dust at different times of the year. Dust from crushing activity is most likely during periods of cold weather during the winter months, when natural water in ore is too frozen to provide natural dust suppression. Dust from

other sources (DSTF, loadout areas, stockpiles, and roads) is considered more likely to be produced during the summer months during periods of dry weather.

Based on the preliminary monitoring period summarized in this memo, the following recommendations are made relating to future dust monitoring activities as described

- These preliminary results justify continuation of the Phase 1 (dustfall) monitoring program as there were no exceedences of the trigger of $1.7 \text{ mg}/(\text{dm}^2\cdot\text{d})$ for the second phase (TSP) monitoring.
- Two additional monitoring Bergerhoff dust monitoring stations are recommended along the northwest and southeast margins of the mill site. These additional stations will provide additional confidence that windblown dust resulting from any predominant wind direction is adequately sampled.
- Only TSS should be measured for future dust samples by the laboratory, because of its more sensitive RDL.
- A sampling period length of approximately 1 month is recommended during the spring and summer months as other potential dust sources are exposed.
- A longer sampling period (e.g. 60 days) during winter/spring months may be warranted in order to attempt to collect a greater (measurable) sample weight which will provide a greater margin above RDLs.
- Implementation of more sophisticated field sampling procedures (including the periodic addition of deionized water to sampling jars) as described in the Monitoring and Surveillance Plan Revision 1 is warranted during the summer months in order to prevent potentially drying out of the sample jars, which could cause loss of sample.

Continuation of pre-emptive and reactive dust control procedures as outlined in the DSTF Construction and Operation Plan, Traffic Management Plan, and Monitoring and Surveillance Plan is recommended to help ensure that fugitive dusting does not become an issue.

5. CLOSURE

Should you have any questions, please contact the undersigned at (867)-668-6463.



E. Allen, M.Sc.
Environmental Geoscientist

Attachments:

1. Dust Monitoring Analytical Certificates from Maxxam Analytical



ALEXCO KENO HILL MINING CORP.

QUARTZ MINING LICENCE

QML-0009

BELLEKENO MINE DEVELOPMENT

KENO HILL SILVER DISTRICT

YUKON

Appendix E

VEREIN
DEUTSCHER
INGENIEURE

Messung partikelförmiger Niederschläge
Bestimmung des Staubbiederschlags
mit Auffanggefäßen aus Glas
(Bergerhoff-Verfahren) oder Kunststoff
Measurement of Particulate Precipitations
Determination of Dust Precipitation
with Collecting Pots Made of Glass
(Bergerhoff Method) or Plastic

VDI 2119

Blatt 2 / Part 2

Ausg. deutsch/englisch
Issue German/English

Der Entwurf der Richtlinie wurde mit Ankündigung im Bundesanzeiger einem öffentlichen Einspruchsverfahren unterworfen.

Die deutsche Version dieser Richtlinie ist verbindlich.

The draft of this Guideline has been subject to public scrutiny after announcement in the Bundesanzeiger (Federal Gazette).

No guarantee can be given with respect to the English translation. The German version of this Guideline shall be taken as authoritative.



Inhalt	Seite	Contents	Page
Vorbemerkung	2	Preliminary Note	2
1 Grundlage des Verfahrens	2	1 Principle of Method	2
2 Geräte und Betriebsmittel	2	2 Apparatus and Materials	2
2.1 Auffanggefäß aus Glas (Bergerhoff-Verfahren)	3	2.1 Glass Collecting Pot (Bergerhoff Method)	3
2.2 Auffanggefäße aus Kunststoff	3	2.2 Plastic Collecting Pots	3
2.2.1 PE-Gefäß (weich)	4	2.2.1 PE Pot (Soft)	4
2.2.2 PE-Gefäß (hart)	4	2.2.2 PE Pot (Hard)	4
2.2.3 PVDF-Gefäß	4	2.2.3 PVDF Pot	4
3 Einrichten der Meßstelle	5	3 Installation of Measurement Point	5
4 Durchführen der Messung	6	4 Measurement Procedure	6
4.1 Vorbereiten der Probenahme	6	4.1 Preparation for Sampling	6
4.2 Probenahme	6	4.2 Sampling	6
4.3 Aufbewahren der Staubbiederschlags- proben	6	4.3 Storage of Dust Precipitation Samples	6
4.4 Bestimmen des gesamten Staubbiederschlags	7	4.4 Determination of Total Dust Precipitation	7
5 Berechnen der Ergebnisse	8	5 Calculation of Results	8
6 Verfahrenskenngrößen	9	6 Performance Characteristics of Method	9
7 Einsatzmöglichkeiten und Wartung	12	7 Possible Applications and Maintenance	12
Schrifttum.	12	References	12

Kommission Reinhaltung der Luft im VDI und DIN

Arbeitsgruppe Messen von Partikeln in der Außenluft
im Ausschuß Immissionsmeßverfahren

VDI/DIN-Handbuch Reinhaltung der Luft, Band 4

Vorbemerkung

Das in dieser Richtlinie beschriebene Meßverfahren dient der Bestimmung des Staubniederschlages in der Außenluft. Staubniederschlag im Sinne dieser Richtlinie ist der Trockenrückstand des während der Expositionsdauer in einem Auffanggefäß gesammelten atmosphärischen Stoffeintrages. Bei dem hier beschriebenen Verfahren bestehen die Auffanggefäße aus Glas oder Kunststoff. Die Auffanggefäße aus Glas entsprechen denen des Bergerhoff-Gerätes [1; 2]. Das Gerät kann aber auch mit Auffanggefäßen aus Kunststoff betrieben werden. Mit dem Einsatz von Kunststoffgefäßen werden Meßwertausfälle durch Frostbruch vermieden, die bei der Verwendung des Glasgefäßes nach *Bergerhoff* auftreten können.

Verschiedene Auffanggefäße aus Kunststoff wurden in mehrjährigen Meßreihen mit dem Glasgefäß nach *Bergerhoff* verglichen [3]. Der Vergleich der Ergebnisse beim Staubniederschlag zeigte keine signifikanten Unterschiede zwischen den verschiedenen Gefäßen.

Die vorliegende Richtlinie ersetzt die frühere Ausgabe des Blattes 2 vom Juni 1972. Ein wesentlicher Aspekt für die Neufassung der Richtlinie ist der Betrieb des Bergerhoff-Gerätes mit Auffanggefäßen aus Kunststoff.

1 Grundlage des Verfahrens

Der atmosphärische Stoffeintrag wird durch Exposition der Auffanggefäße über die vorgesehene Meßdauer, in der Regel ein Monat, erfaßt. Anschließend wird die Probe eingedampft und der Trockenrückstand gravimetrisch bestimmt. Das Ergebnis wird in den Einheiten $\text{g}/(\text{m}^2\text{d})$ oder $\text{mg}/(\text{m}^2\text{d})$ angegeben.

2 Geräte und Betriebsmittel

<i>Auffanggefäß</i>	Haushaltskonservenglas (DIN 5071) oder Kunststoffgefäß
<i>Ständer mit Schutzkorb¹⁾</i>	zur Aufnahme des Auffanggefäßes (Bild 1); Schutzkorb aus mit Kunststoff ummanteltem Draht
<i>Abdampfschale</i>	z.B. 200 ml (DIN 12336) oder Becherglas 200 ml
<i>Pinzette</i>	
<i>Destilliertes Wasser</i>	das eingesetzte destillierte Wasser ist in regelmäßigen Abständen auf die Masse seines Abdampfdruckstandes zu überprüfen

¹⁾ Hersteller: R. Kühnemund KG, Hamm/Rheinhausen

Preliminary Note

The method of measurement described in this Guideline serves to determine the dust precipitation in ambient air. For the purpose of this Guideline, dust precipitation is the dry residue of the input of atmospheric matter collected in a collecting pot during the period of exposure. In the method described here the collecting pots are made of glass or plastic. The glass collecting pots are those used in the Bergerhoff apparatus [1; 2], but this apparatus can also be operated with plastic collecting pots. The use of plastic pots avoids measurements being lost due to frost breakage, which may occur if the *Bergerhoff* glass pot is used.

Various plastic collecting pots have been compared with *Bergerhoff* glass pots in series of measurements lasting several years [3], but the comparison of the dust precipitation results revealed no significant differences between the different pots.

This Guideline replaces the previous edition of Part 2, which was dated June 1972. An important aspect of the new version of the Guideline is the use of the Bergerhoff apparatus with collecting pots made of plastic.

1 Principle of Method

The input of atmospheric matter is determined over the planned period of measurement, as a rule one month, by exposing the collection pots. The sample is then evaporated down and the dry residue is determined gravimetrically, the result being reported in $\text{g}/(\text{m}^2\text{d})$ or $\text{mg}/(\text{m}^2\text{d})$.

2 Apparatus and Materials

<i>Collecting pot</i>	domestic preserve jar (DIN 5071) or plastic pot
<i>Post with protective basket¹⁾</i>	for accommodating the collecting pot (Figure 1); protective basket made of wire sheathed with plastic
<i>Evaporating dish</i>	for example, 200 ml (DIN 12336) or 200 ml beaker
<i>Tweezers</i>	
<i>Distilled water</i>	the distilled water used shall be checked at regular intervals to determine the mass of its evaporation residue

¹⁾ Manufacturer: R. Kühnemund KG, Hamm/Rheinhausen (Germany)

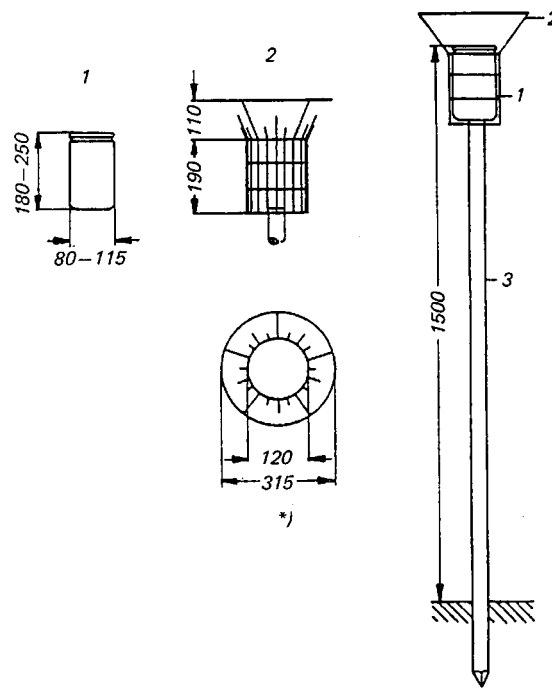


Bild 1. Probenahmegerät (alle Maße in mm)

1 Auffanggefäß

2 Schutzkorb

*) Der Außenring ($d = 315$ mm) kann entfallen

3 Ständer

Fig. 1. Sampling apparatus (all dimensions in mm)

1 Collecting pot

2 Protective basket

*) The outer ring ($d = 315$ mm) can be omitted

3 Post

Wischer aus inertem Material, z.B. PTFE*Sieb* Maschenweite 1,12 mm (DIN 4189)*Waage* Genauigkeit 0,1 mg*Trockenschrank**Wiper* made of inert material, for example PTFE*Screen* mesh size 1.12 mm (DIN 4189)*Balance* accuracy 0.1 mg*Drying cabinet***2.1 Auffanggefäß aus Glas (Bergerhoff-Verfahren)**

Als Auffanggefäß dient ein Haushaltskonservenglas (DIN 5071) mit einem Nenndurchmesser von 9,5 cm und einem Volumen von 1,5 l. Bei einer lichten Weite der Glasöffnung von 8,9 cm beträgt die Auffangfläche 62,2 cm². Das Glas ist mit Deckeldichtring, Deckel und Klammer dicht verschließbar.

2.2 Auffanggefäße aus Kunststoff

Für die Kunststoffsammlgefäße sind Werkstoffe geeignet, die witterungsbeständig sind und keine Veränderungen an der Probe hervorrufen. Grundsätzlich ist es erforderlich, die Eignung der Kunststoffgefäße für den vorgesehenen Einsatz durch Ermittlung von Blindwerten zu überprüfen.

Erfahrungsgemäß eignen sich Kunststoffe bzw. fertige Gefäße, die den Empfehlungen des Bundesgesundheitsamtes für „Kunststoffe im Lebensmittelverkehr“ [4] entsprechen bzw. die das „Gütezeichen für Haushaltswaren“ nach DIN 7725 [5] besitzen. Auf Grund der Abmessungen des Schutzkorbes liegen die

2.1 Glass Collecting Pot (Bergerhoff Method)

The collecting pot used is a domestic preserve jar (DIN 5071) having a nominal diameter of 9.5 cm and a capacity of 1.5 l. If the inside diameter of the glass opening is 8.9 cm, the collecting area is 62.2 cm². The jar shall be capable of being closed with a sealing ring, lid and clamp.

2.2 Plastic Collecting Pots

The materials used for the plastic pots shall be weather-resistant and not produce any changes in the sample. The suitability of the plastic pots for the planned use shall always be checked by determining blank values.

Experience has shown that plastics or pots are suitable which comply with the recommendations of the Federal German Health Board for "plastics for use in the food trade" [4] or have the "quality symbol for domestic products" in accordance with DIN 7725 [5]. Because of the dimensions of the protective basket,

Maße der Auffanggefäße aus Kunststoff in folgendem Bereich:

Außendurchmesser	
d_a am Boden	$8 \text{ cm} \leq d_a \leq 11,5 \text{ cm}$
lichte Weite	
d_i der Öffnung	$8 \text{ cm} \leq d_i \leq 12 \text{ cm}$
Höhe h	$1,5 d_i \leq h \leq 2 d_i$ (höchstens 25 cm)
Volumen V	$1 \text{ l} \leq V \leq 2,5 \text{ l}$

Eine leicht konische Form mit einem größeren Durchmesser an der Öffnung als am Boden ist wegen der Ausdehnung der Probe beim eventuellen Gefrieren vorteilhaft.

Die Innenflächen des Kunststoffgefäßes müssen glatt und frei von Ecken und Vorsprüngen sein, um eine vollständige Überführung der Probe in die Abdampfschale zu ermöglichen. Die Gefäße sollen einen dicht schließenden Deckel haben.

Im folgenden werden geeignete Auffanggefäße aus Kunststoff aufgeführt, mit denen die im Abschnitt 6 angegebenen Verfahrenskenngrößen ermittelt wurden.

2.2.1 PE-Gefäß (weich)

Dieses Auffanggefäß aus weichem Polyethylen wurde aus einer Laborflasche (Volumen 2000 ml, Enghals) durch Abschneiden des sich verjüngenden Halsteiles in einer Höhe von 18 cm hergestellt [6]. Das Gefäß hatte die Maße:

Höhe	$h = 18 \text{ cm}$
lichte Weite der Öffnung	$d_i = 11,5 \text{ cm}$
Auffangfläche	$A = 103,9 \text{ cm}^2$
Außendurchmesser am Boden	$d_a = 11,0 \text{ cm}$
Volumen	$V = 1,7 \text{ l}$

2.2.2 PE-Gefäß (hart)

Diese Auffanggefäße aus härterem Polyethylen werden von einigen Herstellern²⁾ von Kunststoffbehältern als Lebensmittelbehälter für den Haushalt hergestellt. Sie haben einen dicht schließenden Deckel, der einen sicheren Transport der Proben ermöglicht. Die Maße sind wie folgt:

Höhe	$h = 21 \text{ cm}$
lichte Weite der Öffnung	$d_i = 10,3 \text{ cm}$
Auffangfläche	$A = 83,2 \text{ cm}^2$
Außendurchmesser am Boden	$d_a = 9,0 \text{ cm}$
Volumen	$V = 1,4 \text{ l}$

2.2.3 PVDF-Gefäß

Das PVDF-Gefäß wurde aus dem Kunststoff Polyvinylidenfluorid (PVDF) hergestellt. Es kann entweder aus Halbzeug oder durch Spritzguß gefertigt wer-

the dimensions of the plastic collecting pots must fall within the following limits:

External diameter	
d_a at base	$8 \text{ cm} \leq d_a \leq 11.5 \text{ cm}$
Inside diameter	
d_i of opening	$8 \text{ cm} \leq d_i \leq 12 \text{ cm}$
Height h	$1.5 d_i \leq h \leq 2 d_i$ (not more than 25 cm)
Capacity V	$1 \text{ l} \leq V \leq 2.5 \text{ l}$

A slightly conical shape with a larger diameter at the opening than at the base is an advantage because of the expansion of the sample if it freezes.

The internal surfaces of the plastic pot shall be smooth and free from corners or projections to enable the sample to be transferred completely to the evaporating dish. The pots shall have a tightly closing lid.

Suitable plastic collecting pots are listed below which were used to determine the performance characteristics of the method reported in section 6.

2.2.1 PE Pot (Soft)

This collecting pot is composed of soft polyethylene and was made from a laboratory bottle (capacity 2000 ml, narrow-neck) by cutting off the tapering neck part at a height of 18 cm [6]. The pot had the following dimensions:

Height	$h = 18 \text{ cm}$
Inside diameter of opening	$d_i = 11.5 \text{ cm}$
Collecting area	$A = 103.9 \text{ cm}^2$
External diameter at base	$d_a = 11.0 \text{ cm}$
Capacity	$V = 1.7 \text{ l}$

2.2.2 PE Pot (Hard)

These collecting pots are made of harder polyethylene and are manufactured as domestic foodstuff containers by several plastic container manufacturers²⁾. They have a tightly sealing lid which makes it possible to transport the samples safely. The dimensions are as follows:

Height	$h = 21 \text{ cm}$
Inside diameter of opening	$d_i = 10.3 \text{ cm}$
Collecting area	$A = 83.2 \text{ cm}^2$
External diameter at base	$d_a = 9.0 \text{ cm}$
Capacity	$V = 1.4 \text{ l}$

2.2.3 PVDF Pot

The PVDF pot was made of polyvinylidene fluoride (PVDF) and can be manufactured either from a half-finished product or by injection molding. Compared

²⁾ z.B. Tupperware, Frankfurt

²⁾ e.g. Tupperware, Frankfurt/Germany

den. Polyvinylidenfluorid ist ein thermoplastisches Fluoropolymer und hat im Vergleich zu anderen Kunststoffen u.a. eine höhere Korrosions- und Lösungsmittelbeständigkeit sowie eine höhere Witterungs- und Alterungsbeständigkeit, auch gegen UV-Strahlung. Letzteres ist für den hier gegebenen Einsatzfall von großem Vorteil.

Die folgenden Maße ergaben sich auf Grund der Herstellung aus Halbzeug (Rohrabschnitt mit angeschweißter Bodenplatte)³⁾. Sie können bei Herstellung durch Spritzguß verändert werden.

Höhe	$h = 25 \text{ cm}$
lichte Weite der Öffnung	$d_i = 10,2 \text{ cm}$
Auffangfläche	$A = 83,6 \text{ cm}^2$
Außendurchmesser am Boden	$d_a = 11,0 \text{ cm}$
Volumen	$V = 2,0 \text{ l}$

Anmerkung

- Auffanggefäße aus Glas können als Standardgefäße betrachtet werden, da sie seit Jahrzehnten für Staubbiederschlagsmessungen eingesetzt wurden und hierfür weiterhin Verwendung finden.
- In den Fällen, bei denen wegen erhöhter Frostbruchgefahr Auffanggefäße aus Glas nicht eingesetzt werden können, ist die Verwendung von Auffanggefäßen aus Kunststoff anzuraten.
- Die aufgeführten Auffanggefäße aus Kunststoff stellen eine Auswahl dar, die sich zur Zeit der genannten Vergleichsmessungen [3] anbot. Sie waren in dieser Zeit, parallel zu den Vergleichsmessungen, an verschiedenen Stellen im praktischen Einsatz und wurden deshalb zu Vergleichszwecken mit herangezogen. Änderungen in den Bezugsmöglichkeiten können aber in Zukunft nicht ausgeschlossen werden.
- Bei den Vergleichsmessungen zeigten sich folgende Ausfallraten:

Auffanggefäß	Einsatzzeit (Monate insges.)	Ausfälle (Anzahl)	Ausfälle (%)
Glas	406	33	8
PE-Gefäß (weich)	368	1	0,3
PE-Gefäß (hart)	349	7	2
PVDF	84	2	2

Die Ausfälle bei den Auffanggefäßen aus Glas waren ausschließlich auf Frosteinwirkung zurückzuführen. Bei den Auffanggefäßen aus PE (hart) zeigten sich hauptsächlich Schäden, die durch Versprödung des Kunststoffes infolge UV-Strahlung hervorgerufen wurden. Insgesamt zeigten aber die prozentualen Ausfallraten, daß die Auffanggefäße aus Kunststoff für die Meßaufgabe geeignet sind.

- Für die Auswahl von Auffanggefäßen aus Kunststoff werden keine Bedingungen festgelegt außer denen der Abmessung, wie sie in Abschnitt 2.2 angegeben sind. Unter diesen Bedingungen zeigten sich bei den Vergleichsmessungen keine signifikanten Unterschiede bei den Meßergebnissen, die mit den verschiedenen Sammelgefäßen erzielt wurden.

3 Einrichten der Meßstelle

Der Ständer mit Schutzkorb wird so aufgestellt, daß die Öffnung des Auffanggefäßes (Auffangfläche) horizontal ausgerichtet ist. Dabei muß eine freie Anströmung des Gerätes gewährleistet sein. Es ist darauf zu achten, daß der Aufstellungsort nicht durch

with other plastics, the properties of polyvinylidene fluoride, which is a thermoplastic fluoropolymer, include a higher resistance to corrosion and solvents and a higher resistance to weathering and ageing, even with respect to UV radiation, the latter being very advantageous for the application given here.

The following dimensions resulted from production from a half-finished product (tube section with base plate welded on)³⁾, but they may be different for production by injection molding.

Height	$h = 25 \text{ cm}$
Inside diameter of opening	$d_i = 10.2 \text{ cm}$
Collecting area	$A = 83.6 \text{ cm}^2$
External diameter at base	$d_a = 11.0 \text{ cm}$
Capacity	$V = 2.0 \text{ l}$

Note

- Glass collecting pots may be regarded as standard pots since they have been used for decades to measure dust precipitation and continue to be used for that purpose.
- In cases where glass collecting pots cannot be used because of a higher than usual risk of frost breakage, it is advisable to use plastic collecting pots.
- The plastic collecting pots listed are a selection which was available at the time of the comparison measurements [3] mentioned. At that time they were being used in practice at various sites in parallel with the comparison measurements and were therefore used for comparison purposes. However, changes in availability cannot be excluded in future.
- The following failure rates were found in the comparison measurements:

Collecting pot	Time used (months, total)	Failures (number)	Failures (%)
Glass	406	33	8
PE pot (soft)	368	1	0.3
PE pot (hard)	349	7	2
PVDF	84	2	2

The failures in the case of the glass collecting pots were attributable solely to the effect of frost. In the case of PE (hard) collecting pots, the damage which occurred was mainly due to embrittlement of the plastic as a result of UV radiation. However, the total failure rates show that the plastic collecting pots are suitable for the measurement task.

- No conditions are laid down for the selection of plastic collecting pots apart from those of the dimensions stated in section 2.2. Under these conditions, the comparison measurements revealed no significant differences in the measurement results obtained with the various collecting pots.

3 Installation of Measurement Point

The post and protective basket shall be set up so that the opening of the collecting pot (collecting area) is horizontal, steps being taken to ensure free inflow to the apparatus. Care shall be taken that the site is not affected by emissions from immediately adjacent

³⁾ Hersteller z.B. Georg Fischer AG, Albershausen

³⁾ Manufactured, e.g. by Georg Fischer AG, Albershausen/Germany

Emissionen unmittelbar benachbarter Quellen (z.B. Bäume, Baustellen) beeinflusst ist, die die von der Meßaufgabe geforderte Repräsentativität einschränken könnten. Ferner ist bei der Standortauswahl Vorsorge gegen mutwillige Beeinflussung der Probenahme zu treffen. Wo in Städten, Siedlungen oder Wäldern die geforderte freie Anströmung nicht gewährleistet ist, kann die Aufstellung z.B. in Höfen, Gärten oder Lichtungen erfolgen.

4 Durchführen der Messung

4.1 Vorbereiten der Probenahme

Vor der Messung des Staubniederschlages werden die Auffanggefäße und Deckel (beim Glasgefäß auch der Gummiring) gründlich gereinigt. Bei dieser Vorreinigung können Spülmittel verwendet werden, die die Oberfläche des Auffanggefäßes nicht beschädigen. Nach jeder Vorreinigung müssen die Auffanggefäße mit destilliertem bzw. vollentsalztem Wasser nachgespült werden. Nach sorgfältiger Reinigung sind die Auffanggefäße mit dem Deckel dicht zu verschließen (beim Glasgefäß einschließlich Gummiring und Klammer). Die Auffanggefäße sind dauerhaft so zu kennzeichnen, daß eine eindeutige Zuordnung zum Meßort gewährleistet werden kann.

4.2 Probenahme

Die zur Probenahme bestimmten Auffanggefäße werden grundsätzlich dicht verschlossen transportiert. Erst an der Meßstelle wird der Deckel entfernt. Das Aufstelldatum wird in ein Protokollbuch eingetragen und das Auffanggefäß senkrecht in den Schutzkorb des nach Vorschrift aufgestellten Gerätes eingesetzt. Flüssigkeiten oder Chemikalien, die z.B. Algenbildung oder Frostsäden verhindern sollen, dürfen nicht in das Gefäß gegeben werden. Nach Beendigung der vorgeschriebenen Expositionsdauer, die bei Pegelmessungen 30 ± 2 Tage, üblicherweise ein Kalendermonat, beträgt (12 Messungen pro Jahr), werden die Auffanggefäße aus den Schutzkörben genommen, sofort dicht verschlossen und in Transportkisten, die einen ausreichenden Schutz gegen Bruch geben müssen, verpackt.

4.3 Aufbewahren der Staubniederschlagsproben

Die Auffanggefäße mit den Staubniederschlagsproben und der aus Regenniederschlägen stammenden Flüssigkeit dürfen nicht länger als 14 Tage bis zur Probenaufbereitung gelagert werden. Während dieser Lagerzeit müssen die Auffanggefäße dicht verschlossen und kühl sowie möglichst lichtgeschützt aufbewahrt werden, um das Wachstum von Mikroorganismen (z.B. Pilzen und Algen) weitgehend einzuschränken.

sources (for example, trees, building sites) which could limit the representative nature of the measurements required by the measurement task. Furthermore, in selecting the site, precautions shall be taken to prevent mischievous interference of the sampling. In places where free inflow is not guaranteed in towns, housing schemes or woods, courtyards, gardens or clearings, for example, may be chosen as sites.

4 Measurement Procedure

4.1 Preparation for Sampling

Before measuring the dust precipitation, clean the collecting pots and lids (also the rubber ring in the case of glass pot) thoroughly. Rinsing agents may be used for this preliminary cleaning which do not damage the surface of the collecting pot. Every time a preliminary cleaning has been carried out, rinse the collecting pots with distilled or fully demineralized water. When they have been carefully cleaned, tightly seal the collecting pots with the lid (including rubber ring and clamp in the case of a glass pot). Permanently mark the collecting pots to enable clear correlation with the measurement point.

4.2 Sampling

Always transport the collecting pots to be used for sampling in the tightly sealed state and only remove the lid at the measurement point. Enter the date of installation in the record book and insert a collecting pot perpendicularly into the protective basket of the apparatus which has been set up as specified. Do not introduce any liquids or chemicals into the pot which are intended to prevent, for example, algae formation or frost damage. At the end of the specified period of exposure, which, for level measurements, is 30 ± 2 days, normally one calendar month (twelve measurements per year), remove the collecting pots from the protective baskets, immediately seal them tightly and pack them in transport boxes which ensure adequate protection against breakage.

4.3 Storage of Dust Precipitation Samples

The collecting pots containing the dust precipitation samples and the liquid from rain precipitations shall not be stored for more than fourteen days prior to sample treatment. During this period, the collecting pots shall be tightly sealed, refrigerated and, if possible, protected from light, thereby substantially limiting the growth of microorganisms (for example, fungi and algae).

4.4 Bestimmen des gesamten Staubbiederschlages

Der Staubbiederschlag wird durch Wägen des gesamten Trockenrückstandes bestimmt. Zum Eindampfen der nach der Probenahme vorhandenen Flüssigkeit verwendet man Abdampfschalen aus Jenaer Glas mit flachem Boden und Ausguß nach DIN 12336 (Außendurchmesser 95 mm, Höhe 55 mm) oder Bechergläser (Inhalt 200 ml, niedrige Form). Die im folgenden gemachten Angaben für die Behandlung der Abdampfschalen gelten auch für die Bechergläser. Die Abdampfschalen werden den Proben entsprechend gekennzeichnet. Um das Taragewicht der Schalen zu ermitteln, werden diese eine Stunde lang bei 105 °C im Trockenschrank getrocknet, anschließend mindestens 30 min lang im Wägebraum (konstante Temperatur und rel. Feuchte) abgekühlt und nach der Abkühlung auf einer Analysenwaage gewogen. Hierbei muß der Nullpunkt der Waage bei jeder Meßserie vor der Wägung und nach jeder 50. Bestimmung kontrolliert werden. Das so ermittelte Taragewicht ist in ein Laborprotokoll einzutragen.

Nach dieser Vorbereitung werden die Auffanggefäße geöffnet. Das an dem Deckel haftende Probematerial (Staub und Flüssigkeit) wird mit destilliertem bzw. vollentsalztem Wasser in das zugehörige Auffanggefäß gespült. Mit Hilfe einer Pinzette entfernt man dann die groben Verunreinigungen (z.B. Blätter, Insekten usw.) und spült diese über dem Auffanggefäß sorgfältig mit destilliertem Wasser ab. Beträgt die Gesamtoberfläche der Laubblätter in einem Auffanggefäß 200 cm² und mehr (das entspricht etwa der Oberfläche von drei durchschnittlich großen Eichen- oder Rotbuchenblättern), so muß die Staubbiederschlagsprobe als verunreinigt verworfen werden.

Im allgemeinen enthalten die Auffanggefäße je nach Jahreszeit größere Mengen an Flüssigkeit. Wenn die Flüssigkeitsmenge in den Auffanggefäßen das Fassungsvermögen der Abdampfschalen übersteigt, empfiehlt es sich, den Inhalt der Auffanggefäße durch Erwärmen bis auf etwa 150 ml einzuengen. Ist jedoch die Flüssigkeitsmenge geringer als 150 ml, dann wird sie durch Zusatz von destilliertem Wasser um den fehlenden Betrag ergänzt.

Beim Einengen ist darauf zu achten, daß die Flüssigkeit in den Auffanggefäßen nicht über 80 °C beim Glasgefäß bzw. nicht über 60 °C bei den Kunststoffgefäßen erwärmt wird. Der Trockenschrank muß geeignet sein, die entstehenden Wasserdampfmen gen abzuführen. Hierbei darf kein Fremdstaub in das Auffanggefäß gelangen.

Die restliche Flüssigkeit wird quantitativ folgendermaßen in die vorgewogenen Abdampfschalen über-

4.4 Determination of Total Dust Precipitation

Determine the dust precipitation by weighing the total dry residue. To evaporate down the liquid present after sampling, use DIN 12336 evaporating dishes made of Jenaer glass having a flat-bottom and a spout (diameter 95 mm, height 55 mm) or shallow beakers (capacity 200 ml). The instructions for handling the evaporating dishes given below also apply to the beakers. Mark the evaporating dishes to indicate the samples they contain. In order to determine the weight of the dishes when empty, dry them for one hour at 105 °C in a drying cabinet and then cool them for at least thirty minutes in the balance room (constant temperature and relative humidity) and weigh them on an analytical balance after cooling. Check the zeroing of the balance for every series of measurement before weighing and after every fiftieth determination. Enter the weight when empty determined in this way in a laboratory record.

After carrying out this preparatory work, open the collecting pots. Rinse the sample material (dust and liquid) adhering to the lid into the appropriate collecting pot with distilled or fully demineralized water. Then use tweezers to remove the coarse impurities (for example, leaves, insects etc.) and rinse off the latter carefully with distilled water over the collecting pot. If the total area of the fallen leaves in a collecting pot is 200 cm² or over (approximately equivalent to the surface of three leaves from oak trees or European beeches of average size), discard the dust precipitation sample on grounds of contamination.

Depending on the season, the collecting pots generally contain fairly large amounts of liquid. If the amount of liquid in the collecting pots exceeds the capacity of the evaporating dishes, it is advisable to evaporate the contents of the collecting pots down to about 150 ml by heating. However, if the amount of liquid is less than 150 ml, make up the missing amount by adding distilled water.

When evaporating down, ensure that the liquid in the collecting pots is not heated above 80 °C in the case of a glass pot or above 60 °C in the case of plastic pots. The drying cabinet must be suitable to carry off the emerging water vapour quantities, ensuring that no foreign dust gets into the collecting pot.

Transfer the remaining liquid quantitatively to the already weighed evaporating dishes in the following

führt. Die an der Gefäßwandung des Auffanggefäßes haftenden Feststoffe werden mit einem Teflon-Wischer sorgfältig an allen Stellen abgelöst und aufgerührt. Danach wird der Gefäßinhalt durch ein Sieb DIN 4189 mit einer Maschenweite von 1,12 mm in die Abdampfschale gegossen. Die Innenwand des Auffanggefäßes wird mit destilliertem Wasser abgespült und das Spülwasser ebenfalls durch das Sieb in die Abdampfschale gegeben. Der auf dem Sieb befindliche Rückstand wird verworfen. Nach jeder Benutzung ist das Sieb gründlich mit Leitungswasser zu reinigen und anschließend mit destilliertem Wasser abzuspülen.

Die Gesamtflüssigkeitsmenge (Flüssigkeit der Staubprobe und Spülwasser) darf in der Abdampfschale nicht mehr als 200 ml betragen. Die gefüllten Abdampfschalen werden in einem Trockenschrank bei 105 °C eingedampft. Nach dem Eindampfen bleiben die Abdampfschalen mindestens noch eine Stunde bei derselben Temperatur im Trockenschrank. Anschließend läßt man sie wieder mindestens 30 min auf Raumtemperatur abkühlen und bestimmt das Bruttogewicht (Nullpunktkontrolle siehe oben).

Die ausgewogenen Abdampfschalen sind sorgfältig zu reinigen, mit destilliertem Wasser abzuspülen, zu trocknen und an einem staubfreien Ort aufzubewahren.

Das zur Spülung der Auffanggefäße verwendete destillierte Wasser ist in regelmäßigen Abständen auf die Masse seines Eindampfrückstandes zu überprüfen.

5 Berechnen der Ergebnisse

Der als Staubbiederschlag auszuwertende Inhalt des Auffanggefäßes ergibt sich aus der Differenz G zwischen Brutto- und Taragewicht in g pro Abdampfschale. Für die Berechnung des Staubbiederschlages ist die tatsächliche Auffangfläche A für jedes einzelne Gefäß zu ermitteln. Der an jeder Meßstelle ermittelte Staubbiederschlag wird wie folgt in die allgemeine Bezugsgröße umgerechnet:

$$x = \frac{G \cdot f}{A \cdot \tau}$$

mit

- x Staubbiederschlag in g/(m²d) oder mg/(m²d)
- A Auffangfläche in cm²
- f 10 000 cm²/m² (Umrechnungsfaktor)
- G Masse der Staubbiederschlagsprobe in g oder mg
- τ Probenahmedauer (Sammelzeit) in d (Tagen)

way. Carefully detach at every point the solids adhering to the wall of the collecting pot, using a Teflon wiper, and stir them. Then pour the contents of the pot through a DIN 4189 screen having a mesh size of 1.12 mm into the evaporating dish. Rinse the internal wall of the collecting pot with distilled water and also pour the rinsing water through the screen into the evaporating dish. Discard the residue on the screen. Every time the screen has been used, thoroughly clean it with tap water and then with distilled water.

The total amount of liquid (liquid from the dust sample and rinsing water) in the evaporating dish shall not exceed 200 ml. Evaporate the contents of the evaporating dishes in a drying cabinet at 105 °C. After evaporation, keep the evaporating dishes in the drying cabinet for at least one more hour at the same temperature. Then allow them to cool again to room temperature for at least 30 min and determine the weight of the dish and its contents (checking the zeroing see above).

Clean the weighed evaporating dishes carefully, rinse them with distilled water, dry them and store them in a dust-free place.

Check the distilled water used for rinsing the collecting pots at regular intervals to determine the mass of its evaporation residue.

5 Calculation of Results

The collecting pot contents to be evaluated as dust precipitation are given by the difference G between the weight of the dish and contents after evaporation and weight when empty in g for each evaporating dish. For calculating the dust precipitation determine the actual collecting area A for every single pot and convert the dust precipitation at every measurement point into the standard units generally used in the following way:

$$x = \frac{G \cdot f}{A \cdot \tau}$$

with

- x dust precipitation in g/(m²d) or mg/(m²d)
- A collecting area in cm²
- f 10 000 cm²/m² (conversion factor)
- G mass of the dust precipitation sample in g or mg
- τ period of sampling (collecting time) in d (days)

6 Verfahrenskenngrößen

Die Nachweisgrenzen wurden bei dem Glasgefäß nach *Bergerhoff* und den in Abschnitt 2.2 genannten Auffanggefäßen aus Kunststoff wie folgt bestimmt: Die Auffanggefäße wurden mit 200 ml bidestilliertem Wasser ausgespült. Das Wasser wurde in vorgewogenen Abdampfschalen zur Trockne eingedampft. Das Gewicht der Schalen wurde erneut bestimmt. Es ergab sich jeweils für die verschiedenen Auffanggefäße eine mittlere Massenzunahme von

$$M = (0,9 \pm 0,2) \text{ mg/Auffanggefäß.}$$

Daraus errechnet sich eine Nachweisgrenze von 1,5 mg.

Bezogen auf eine Probenahmedauer von 30 ± 2 Tagen liegt je nach Größe der Auffangfläche des Gefäßes die relative Nachweisgrenze in einem Bereich von 5 bis 8 mg/(m²d).

Die Standardabweichung s_D aus Doppelbestimmungen wurde an drei Meßstellen ermittelt, die in bezug auf ihre Immissionssituation als hoch, mittel und niedrig belastet eingestuft werden können:

Wetzlar:	Stadtzentrum, Industriegebiet, hoch belastet
Berlin-Marienfelde:	Stadtrand, Gewerbegebiet, mittel belastet
Schauinsland:	Schwarzwald, Höhenlage, niedrig belastet

Der Meßbereich lag zwischen 6 und 530 mg/(m²d). Die Probenahmedauer betrug 30 ± 2 Tage. In Tabelle 1 sind die Standardabweichungen s_D für die verschiedenen Auffanggefäße nach Meßorten getrennt angegeben.

Die Ergebnisse der Vergleichsmessungen [3] (Probenahmedauer 30 ± 2 Tage) zwischen dem Glasgefäß nach *Bergerhoff* und den verschiedenen Auffanggefäßen aus Kunststoff sind für die schon genannten Meßorte in Tabelle 2 aufgeführt. Außerdem sind die zusammengefaßten Ergebnisse von allen Meßorten (zusätzlich Westerland, Langenbrügge, Hannover und München) angegeben.

Die Regressionskoeffizienten a und b und die Korrelationskoeffizienten r zeigen zum Teil größere Abweichungen von ihren Idealwerten. In diesem Zusammenhang ist auf die prinzipiellen Streuungen bei Depositionsmessungen (siehe Tabelle 1) hinzuweisen. Diese Streuungen sind in Bild 2 zu erkennen. Es zeigt die Ergebnisse der Vergleichsmessungen zwischen dem Glasgefäß und den verschiedenen Kunststoffgefäßen (jeweils alle Meßorte zusammengefaßt) und die jeweiligen Regressionsgeraden (Koeffizienten siehe Tabelle 2). Unter Berücksichtigung der Prüfgröße t des paarweisen Differenzen- t -Testes,

6 Performance Characteristics of Method

The limits of detection were determined for the *Bergerhoff* glass pot and the plastic collecting pots mentioned in section 2.2 by rinsing out the collecting pots with 200 ml of doubly distilled water and evaporating the water to dryness in evaporating dishes which had already been weighed. The weight of the dishes was determined again and in each case there was a mean increase in mass for the various collecting pots of

$$M = (0.9 \pm 0.2) \text{ mg/collecting pot.}$$

The limit of detection found from this by calculation is 1.5 mg.

For a period of sampling of 30 ± 2 days, the relative limit of detection ranges from 5 to 8 mg/(m²d) depending on the size of the collecting area of the pot.

The standard deviation s_D was found from duplicate determinations at three measurement points in Germany whose pollution situation may be classified as high, moderate and low:

Wetzlar:	City center, industrial region, highly polluted
Berlin-Marienfelde:	City outskirts, industrial region, moderately polluted
Schauinsland:	Black Forest, elevated position, low polluted

The measurement range was between 6 and 530 mg/(m²d) and the period of sampling was 30 ± 2 days. Table 1 shows the standard deviations s_D for the various collecting pots at the different sites.

The results of the measurements [3] (period of sampling time 30 ± 2 days) aided at comparing the *Bergerhoff* glass pot with the various plastic collecting pots are listed in Table 2 for the measurement sites already mentioned. In addition, the combined results of all the measurement sites (additionally, Westerland, Langenbrügge, Hanover and Munich) are reported.

In some cases, the regression coefficients a and b and the correlation coefficients r exhibit fairly large deviations from their ideal values. In this connection attention is called to the variations of deposition measurements on principle (see Table 1). These variations can be seen in Figure 2, which shows the results of the measurements aided at comparing the glass pot and the various plastic pots (with all the measurement sites combined in each case) and the associated regression lines (see Table 2 for coefficients). Taking account of the test variable t of the pairwise difference t -test which is in all cases less than the associ-

Tabelle 1. Standardabweichungen s_D aus Doppelbestimmungen in $\text{mg}/(\text{m}^2\text{d})$ für verschieden belastete Meßorte (n Anzahl der Wertepaare)

Ort	Bergerhoff-Glasgefäß		PE-Gefäß (weich)		PE-Gefäß (hart)		PVDF	
	n	s_D	n	s_D	n	s_D	n	s_D
Wetzlar	33	33	32	29	30	22	5	28
Berlin	31	23	31	16	31	23	16	19
Schauinsland	17	17	30	14	27	23	–	–

Table 1. Standard deviations s_D of duplicate determinations in $\text{mg}/(\text{m}^2\text{d})$ for various polluted measurement sites (n number of pairs of values)

Site	Bergerhoff glass pot		PE pot (soft)		PE pot (hard)		PVDF	
	n	s_D	n	s_D	n	s_D	n	s_D
Wetzlar	33	33	32	29	30	22	5	28
Berlin	31	23	31	16	31	23	16	19
Schauinsland	17	17	30	14	27	23	–	–

Tabelle 2. Ergebnisse der Vergleichsmessungen [3] zwischen Glasgefäßen nach *Bergerhoff* (x) und Auffanggefäßen aus Kunststoff (y) – Mittelwerte (x_m bzw. y_m) in $\text{mg}/(\text{m}^2\text{d})$; Ordinatenabschnitt a in $\text{mg}/(\text{m}^2\text{d})$ und Steigung b der Regressionsgeraden $y = a + bx$, Korrelationskoeffizient r , Anzahl der Wertepaare n und Prüfgröße t des paarweisen Differenzen- t -Testes [7]

Ort		PE-Gefäß (weich)	PE-Gefäß (hart)	PVDF
Wetzlar	x_m	211	205	–
	y_m	198	195	–
	a	–32	5	–
	b	1,09	0,92	–
	r	0,91	0,84	–
	n	32	31	–
	t	1,60	1,08	–
Berlin	x_m	81	75	80
	y_m	73	82	72
	a	–17	–15	1
	b	1,10	1,28	0,90
	r	0,78	0,79	0,70
	n	32	29	17
	t	1,46	1,05	0,71
Schauinsland	x_m	40	44	48
	y_m	40	48	46
	a	3	–5	–16
	b	0,92	1,22	1,28
	r	0,64	0,53	0,80
	n	19	19	16
	t	0,06	0,62	0,39
alle Orte	x_m	107	103	65
	y_m	104	101	59
	a	–8	9	0
	b	1,03	0,89	0,92
	r	0,87	0,76	0,74
	n	235	227	33
	t	1,18	0,60	0,82

Table 2. Results of measurements [3] made to compare *Bergerhoff* (x) glass pots and plastic pots (y) – means (x_m or y_m) in $\text{mg}/(\text{m}^2\text{d})$; vertical axis intercept a in $\text{mg}/(\text{m}^2\text{d})$ and slope b of regression line $y = a + bx$, correlation coefficient r , number of pairs of values n and test quantity t of the pairwise difference t -test [7]

Site		PE pot (soft)	PE pot (hard)	PVDF
Wetzlar	x_m	211	205	–
	y_m	198	195	–
	a	–32	5	–
	b	1.09	0.92	–
	r	0.91	0.84	–
	n	32	31	–
	t	1.60	1.08	–
Berlin	x_m	81	75	80
	y_m	73	82	72
	a	–17	–15	1
	b	1.10	1.28	0.90
	r	0.78	0.79	0.70
	n	32	29	17
	t	1.46	1.05	0.71
Schauinsland	x_m	40	44	48
	y_m	40	48	46
	a	3	–5	–16
	b	0.92	1.22	1.28
	r	0.64	0.53	0.80
	n	19	19	16
	t	0.06	0.62	0.39
all sites	x_m	107	103	65
	y_m	104	101	59
	a	–8	9	0
	b	1.03	0.89	0.92
	r	0.87	0.76	0.74
	n	235	227	33
	t	1.18	0.60	0.82

die in allen Fällen kleiner ist als der dazugehörige Wert der t -Verteilung, kann dennoch gefolgert werden, daß keine signifikanten Unterschiede zwischen den verschiedenen Auffanggefäßen auftreten.

ated value of the t -distribution, it can be concluded, however, that there are no significant differences between the various collecting pots.

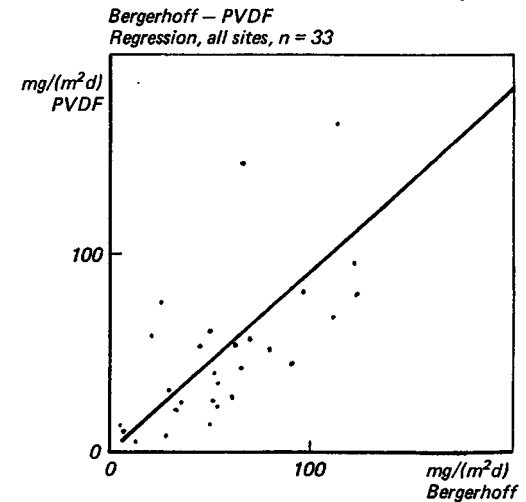
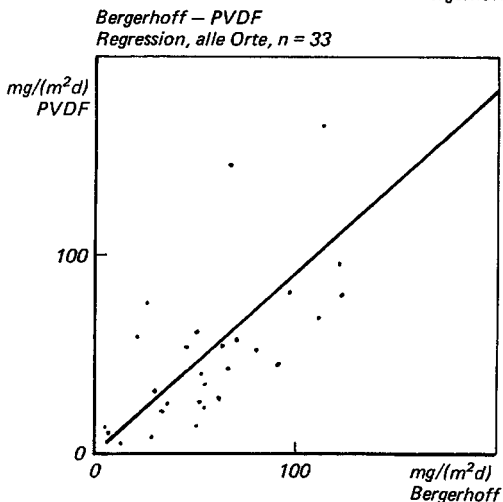
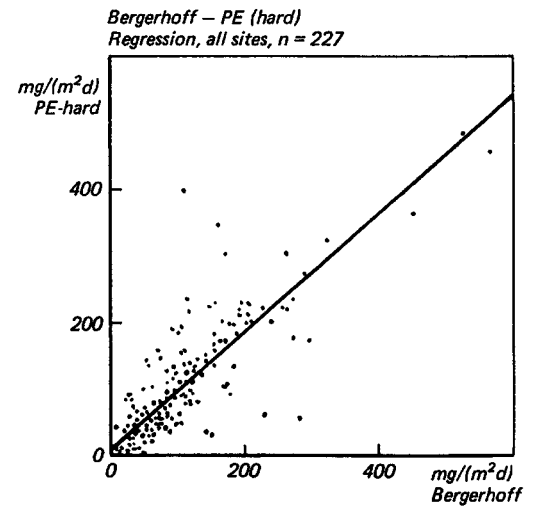
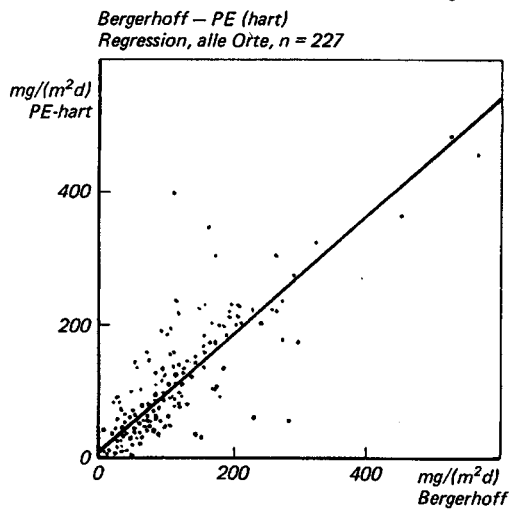
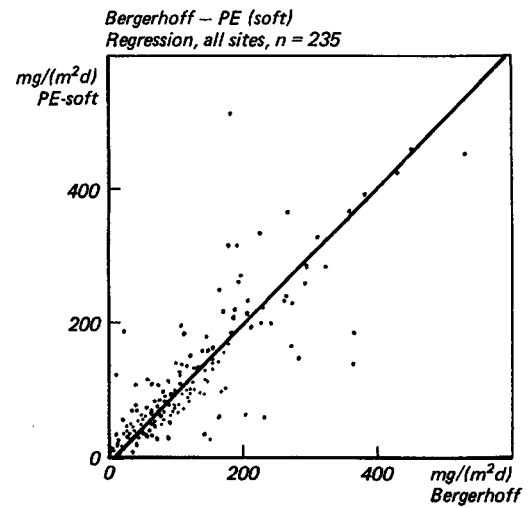
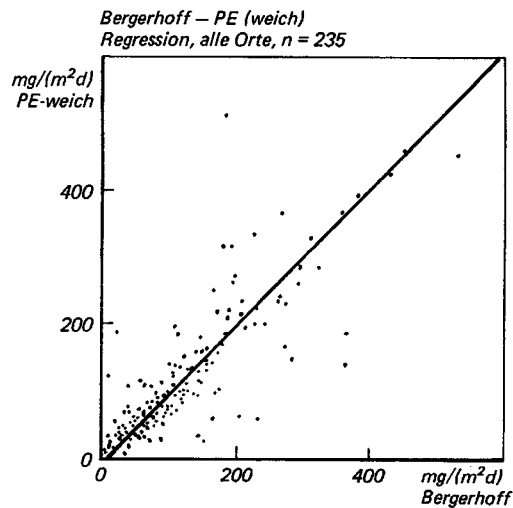


Bild 2. Graphische Darstellung der bei Vergleichsmessungen mit Glasgefäßen nach *Bergerhoff* und mit verschiedenen Kunststoffgefäßen erzielten Ergebnisse

Fig. 2. Graphs showing the results obtained in the measurements aimed at comparing *Bergerhoff* glass pots and the various plastic pots

7 Einsatzmöglichkeiten und Wartung

Die beschriebene Methode ist ein Konventionsverfahren gemäß Richtlinie VDI 2449 Blatt 2 [8], das hinsichtlich der Erfassung des tatsächlichen Staubbiederschlags nicht kalibriert werden kann.

Das Meßgerät ist im Gelände leicht aufzubauen, da keine Hilfsenergie benötigt wird. Das Auswechseln der Auffanggefäße kann auch von angelernten Mitarbeitern ausgeführt werden; alle Arbeiten, die fachliche Sorgfalt erfordern, werden im Labor durchgeführt. Die handliche Größe der Auffanggefäße erleichtert wesentlich den Transport. Die relativ geringe Abdampfmenge gewährleistet eine schnelle Bearbeitung. Die Meßstelle braucht nur einmal je Probenahmezeit aufgesucht zu werden. Die Höhe der Auffanggefäße ist ausreichend, so daß das Regenwasser bei einer Probenahmedauer von einem Monat im allgemeinen nicht überläuft.

In vielen Fällen ist es erforderlich, neben der Gesamtmasse auch einzelne Inhaltsstoffe des Staubbiederschlags zu bestimmen. In diesen Fällen wird auf die Blätter der Richtlinie VDI 2267 [9] verwiesen.

Da der Preis des Meßgerätes niedrig ist, können bei Pegelmessungen mit geringem finanziellen Aufwand ausreichend viele Meßstationen eingerichtet werden.

Zu den genannten PE-Gefäßen ist folgendes zu bemerken:

Das weiche PE-Gefäß kann sich bei gefrorenem Inhalt so verformen, daß es nicht mehr mit dem Deckel zu verschließen ist. Eine Abdeckung mit einer Folie (Kunststoff oder Aluminium) ist dann bei vorsichtigem Transport der Probe möglich.

Bei einzelnen der harten PE-Gefäße traten bei längerem Einsatz Risse auf, die auf eine Versprödung des Materials durch UV-Strahlen zurückgeführt werden können. Um einen Verlust der Probe zu verhindern, ist es ratsam, diese PE-Gefäße regelmäßig zu begutachten und gegebenenfalls gegen neue Gefäße auszutauschen.

Schrifttum / References

- [1] *Bergerhoff, H.*: Staubpegelmessungen nach Sedimentationsmessungen der Landesanstalt für Bodennutzungsschutz des Landes NW. Bochum: 1956 (Eigenverlag)
- [2] *Herpertz, E.*: Kenngrößen des Bergerhoffverfahrens zur Bestimmung des Staubbiederschlags. Schriftenreihe der Landesanstalt für Immissions- und Bodennutzungsschutz des Landes NW in Essen, H. 17, S. 66/72. Essen: W. Girardet 1969
- [3] *Bake, D., L. Laskus u. E. Lahmann*: Einfluß der Probenahmebedingungen auf die Ergebnisse von Depositionsmessungen. Abschlußbericht zum Forschungsvorhaben Nr. 104 02 444, gefördert vom Umweltbundesamt. Berlin: 1989

7 Possible Applications and Maintenance

The procedure described in this Guideline is a reference method according to Guideline VDI 2449 Part 2 [8] which cannot be calibrated with reference to the determination of the actual dust precipitation.

Since no power supply is required, the measuring equipment can readily be set up in the open, and as all the operations requiring expert care are carried out in the laboratory, the collecting pots can even be changed by semi-skilled employees. The manageable size of the pots makes it much easier to transport them, while the relatively small volume which has to be evaporated speeds up processing. The measurement point has to be visited only once each time a sample is collected and the collecting pot will normally be deep enough to prevent the rainwater from overflowing if the sampling time is one month.

In many cases it is necessary to determine not only the total mass, but also individual constituents of the dust precipitation. In such cases, reference shall be made to the Parts of Guideline VDI 2267 [9].

Since the cost of the measuring equipment is low, a large number of measuring stations can be set up with a low financial outlay if level measurements are required.

The following points should be noted about the PE pots:

If the contents freeze, the soft PE pot may be deformed to such an extent that it can no longer be closed with the lid. In such cases, it may be covered with plastic film or aluminium foil provided care is taken in transporting the sample.

After prolonged use, cracks occurred in some of the hard PE pots and these were ascribed to embrittlement of the material by UV radiation. To prevent loss of sample, it is advisable to inspect such PE pots regularly and, if necessary, replace them with new ones.

- [4] *Kunststoffe im Lebensmittelverkehr. Empfehlungen der Kunststoff-Kommission des Bundesgesundheitsamtes Berlin (R. Franck Hrsg.)*. Köln: C. Heymanns Verlag
- [5] DIN 7725 Gütezeichen für Haushaltswaren
- [6] *Bröndler, M.*: persönliche Mitteilung aus dem Staatlichen Institut für Hygiene und Infektionskrankheiten, Saarbrücken
- [7] *Sachs, L.*: Angewandte Statistik. 6. Aufl. Berlin, Heidelberg, New York, Tokio: Springer-Verlag 1984
- [8] VDI 2449 Bl. 2 Grundlage zur Kennzeichnung vollständiger Meßverfahren; Begriffsbestimmungen
- [9] VDI 2267 Stoffbestimmung an Partikeln in der Außenluft



ALEXCO KENO HILL MINING CORP.

QUARTZ MINING LICENCE

QML-0009

BELLEKENO MINE DEVELOPMENT

KENO HILL SILVER DISTRICT

YUKON

Appendix F



BELLEKENO MINE CYCLE 1

ENVIRONMENTAL EFFECTS MONITORING

STUDY DESIGN



September 2011

Prepared by





Bellekeno Mine Project

Environmental Effects Monitoring Program

Cycle 1 Study Design

September 2011

Report Prepared for:

Alexco Keno Hill Mining Corporation
Suite 1150, 200 Granville Street
Vancouver, B.C
V6C 1S4

Report Prepared by:

Access Consulting Group
3 Calcite Business Centre
151 Industrial Road
Whitehorse, YK
Y1A 2V8

and

Minnow Environmental Inc.
2 Lamb Street
Georgetown, Ontario
L7G 3M9



Bellekeno Mine Cycle 1 Environmental Effects Monitoring Study Design

September 2011

Report Prepared for:

Alexco Keno Hill Mining Corporation
Suite 1150, 200 Granville Street
Vancouver, B.C
V6C 1S4

Report Prepared by:

Access Consulting Group
3 Calcite Business Centre
151 Industrial Road
Whitehorse, YK
Y1A 2V8

and

Minnow Environmental Inc.
2 Lamb Street
Georgetown, Ontario
L7G 3M9

TABLE OF CONTENTS

1.0	Introduction	1-1
1.1	BACKGROUND	1-1
1.2	OBJECTIVE	1-5
1.3	REPORT ORGANIZATION.....	1-5
1.4	CONTACTS	1-6
2.0	Site Characterization	2-1
2.1	BELLEKENO MINE HISTORY	2-1
2.2	BELLEKENO MINE OPERATIONS	2-2
2.3	CURRENT BELLEKENO MINE WATER USE	2-4
2.4	BELLEKENO MINE WATER TREATMENT SYSTEM	2-5
2.5	MILL OPERATIONS	2-7
2.6	TAILINGS HANDLING	2-8
2.7	DRY STACK TAILINGS DISPOSAL PROCEDURE	2-8
2.8	CURRENT MILL WATER USE.....	2-9
2.9	CURRENT MILL WATER USE.....	2-9
2.10	EFFLUENT DISCHARGE POINT	2-10
2.11	APPLICABLE REGULATIONS.....	2-11
2.12	EFFLUENT CHEMISTRY	2-12
2.12.1	Effluent Mixing and Discharge	2-12
2.12.2	Effluent Sublethal Toxicity Testing.....	2-18
2.12.3	Toxicity Testing	2-18
2.13	OTHER AREA CHARACTERISTICS.....	2-19
2.13.1	Climate and Weather Monitoring	2-19
2.13.2	Historical Data Collection	2-19
2.13.3	Geological Setting	2-21

3.0	Receiving Environment.....	3-1
3.1	PHYSICAL CHARACTERISTICS.....	3-1
3.2	HISTORICAL WATER QUALITY.....	3-3
3.3	EFFLUENT EXPOSED AREA	3-9
3.4	REFERENCE AREA	3-9
3.5	BENTHIC INVERTEBRATE COMMUNITY SURVEY.....	3-12
3.6	FISH SURVEYS ON LIGHTNING CREEK	3-13
3.6.1	Results of Previous Investigations.....	3-14
4.0	EEM Study Design – Cycle one.....	4-1
4.1	BENTHIC INVERTEBRATE COMMUNITY SURVEY.....	4-1
4.1.1	Sample Collection	4-1
4.1.2	Sample Processing	4-3
4.1.3	Data Analysis	4-3
4.2	FISH POPULATION SURVEY	4-4
4.2.1	Sample Collection	4-5
4.2.2	Fish Processing	4-6
4.2.3	Laboratory Processing	4-6
4.2.4	Data Analysis	4-6
4.3	FISH TISSUE SURVEY	4-7
4.3.1	Field Collection.....	4-7
4.3.2	Fish Processing	4-7
4.3.3	Laboratory Analysis	4-10
4.3.4	Data Analysis	4-10
4.4	SUPPORTING ENVIRONMENTAL VARIABLES.....	4-10
4.5	EFFLUENT AND WATER QUALITY MONITORING.....	4-11
5.0	SCHEDULE	5-1
6.0	REFERENCES	6-1



LIST OF TABLES

Table 2.1 Compliance Monitoring frequency and limits applicable to the Bellekeno Mine	2-14
Table 2.2 Summary of Bellekeno Mine Effluent Quality (Station KV-43) ^a	2-16
Table 2.3 Minimum expected dilution of effluent in Lightning Creek based on minimum winter flows recorded to date	2-17
Table 2.4 First Sub-lethal Toxicity Test Results (Sample taken December 2010).....	2-18
Table 2.5 Precipitation and Evapotranspiration at Select Keno Hill District Locations	2-20
Table 3.1 Stream length and catchment for specific areas within Lightning Creek	3-1
Table 3.2 Lightning Creek Catchment Water Quality Monitoring Sites.....	3-3
Table 3.3 Lightning Creek Catchment 2004 to 2010 Water Quality Summary Statistics.....	3-4
Table 3.4 Lightning Creek Catchment 2010 Water Quality Summary Statistics.....	3-5
Table 3.5 Change in Zinc, Cadmium and TSS Concentrations along Lightning Creek	3-8
Table 3.6 Lightning Creek Exposure Station KV-41 Summary of Water Quality	3-10
Table 3.7 Lightning Creek Reference Station KV-37 Summary of Water Quality.....	3-11
Table 3.8 Taxonomic Richness Index of Benthic Invertebrates	3-12
Table 3.9 Taxa community occurrence	3-13
Table 3.10 Previous fish sampling effort and results on Lightning Creek	3-15
Table 4.1 Endpoints to be examined as part of the Bellekeno Mine Cycle 1 EEM fish population survey	4-8



LIST OF FIGURES

Figure 1.1 Project Location.....	1-2
Figure 1.2 Keno Hill Property Overview	1-3
Figure 1.3 Bellekeno Project Overview	1-4
Figure 2.1 Bellekeno Mine Site Layout.....	2-3
Figure 2.2 Bellekeno 625 Water Treatment System	2-6
Figure 2.3 Bellekeno Mill Water Feed Process	2-10
Figure 2.4 Lightning Creek catchments and environmental monitoring stations	2-13
Figure 2.5 Effluent discharge rate at KV-43 vs flow at KV-41(Lightning Creek) 2003 through 2011	2-15
Figure 2.6 Mean Annual Precipitation as a Function of Elevation.....	2-20
Figure 3.1 Lightning Creek Gradient Profile	3-2
Figure 3.2 Lightning Creek Monthly Average Discharge 2004-2007 at KV41	3-2
Figure 3.3 Lightning Creek Catchment, Total As	3-6
Figure 3.4 Lightning Creek Catchment, Total Se	3-7
Figure 4.1 Benthic Invertebrate Fisheries Sampling Areas.....	4-2



LIST OF APPENDICES

Appendix A	Letter from Environment Canada on Bellekeno Subject to MMER
Appendix B	KV-43 Water Quality Data
Appendix C	KV-41 Water Quality Data
Appendix D	KV-37-Water Quality Data



1.0 INTRODUCTION

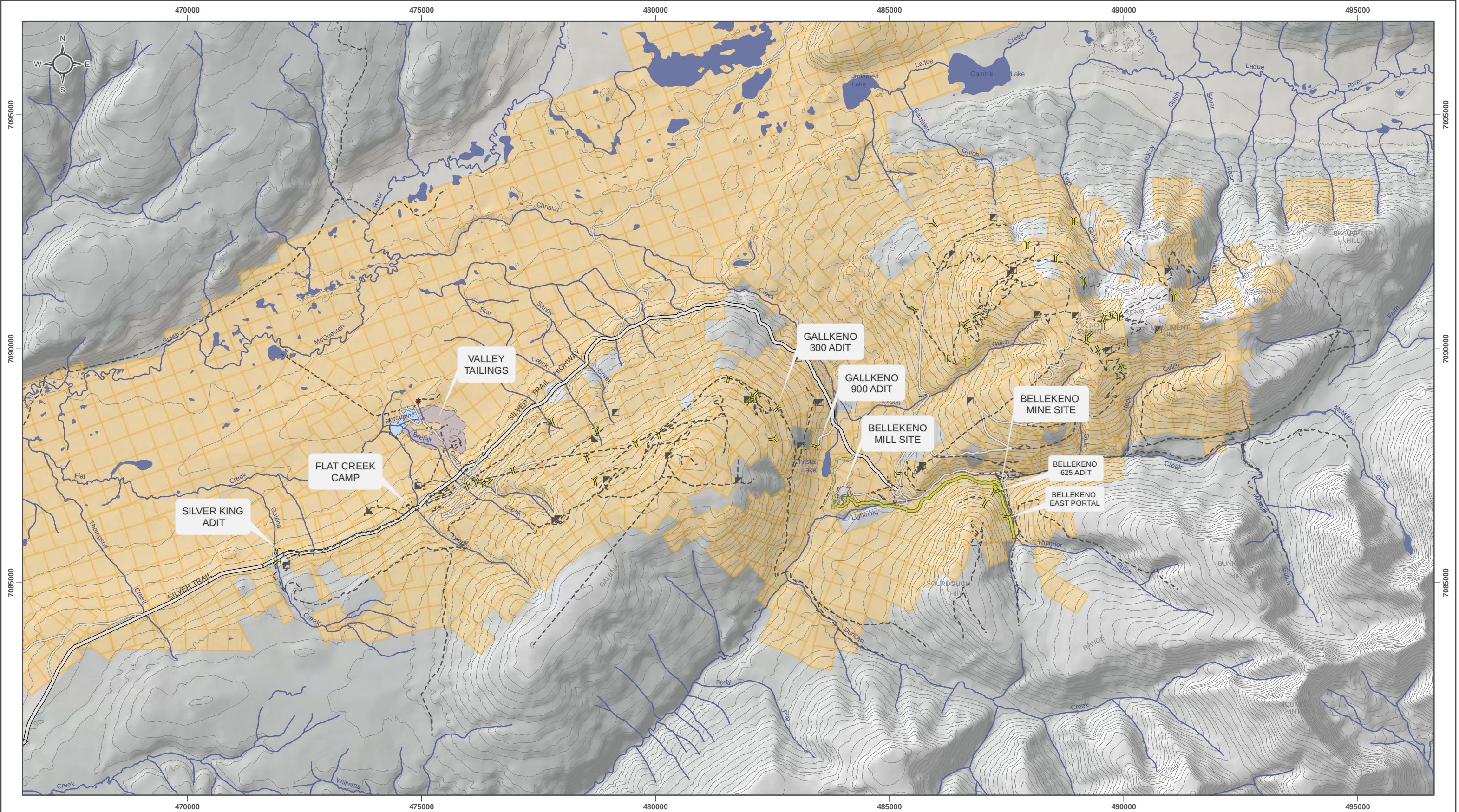
Alexco Resources Corp. and its wholly owned subsidiary Alexco Keno Hill Mining Corporation (AKHMC), own 1,563 claims and leases that span an area of approximately 24, 262 ha within the Keno Hill Silver District (KHSD), including the Bellekeno Mine. This area is located directly 354 km north of Whitehorse, Yukon, 45 km northeast of Mayo, and 3 km east of Keno City (Figure 1.1). The KHSD is located within the traditional territory of the Nacho Nyak Dun First Nation (NNDNFN) and is centrally located at 63°55'N, 135°29'W within the McQuesten River Valley. Access to the property is via a paved, two-lane highway from Whitehorse to Mayo (407 km.) and an all weather gravel road northeast from Mayo to Elsa (45 km).

Bellekeno is a silver, lead, zinc mining operation consisting of an underground mine and supporting infrastructure (waste rock dumps, maintenance facility, water treatment and office), Mill (Flame and Moth Mill) and tailings facility, and main camp known as the Flat Creek Camp (Figure 1.2). The Bellekeno mine site is located near the confluence of Thunder Gulch and Lightning Creek (Figure 1.3). Lightning Creek flows into Duncan Creek, which then drains into the Mayo River. The Mill is located approximately 500 m south and upstream of Christal Lake and 1.0 km east of Keno City. Christal Lake drains into Christal Creek, which is fed by Erikson Gulch and eventually drains into the South McQuesten River

The total life of the Bellekeno project is expected to be 15 years, including 6 years of construction and mine operation, and 7-15 years for decommissioning and reclamation, closure, and post closure. There is, however, potential to extend the Bellekeno Mine life as well as potential for development at additional mines within the Keno Hill Silver District. Based on current Preliminary Economic Assessment, estimated annual production includes 3,300,000 oz. Silver, 30,000,000 lbs. Lead, and 24, 500, 000 lbs. Zinc. Estimated ore production rate is 250 tonnes/ day for years 1-2 and 400 tonnes/ day for years 3-5, leaving 500,000 tonnes of waste rock produced from underground development. There is expected to be ore mining for 360 days/ year; mill operation 360 days/ year; with 100, 000 tonnes of waste material placed on the surface each year.

1.1 BACKGROUND

Federal effluent regulations for the metal mining industry (Metal Mining Effluent Regulations; MMER) were updated in the Canada Gazette in June 2002 and in February 2009 (Government of Canada 2002; 2010). These regulations, administered under the federal *Fisheries Act*, apply to mining and milling operations that discharge effluent(s) at a rate greater than 50m³/day and therefore apply to the Bellekeno Mine project. The MMER outline requirements for routine effluent monitoring, acute lethality testing, and Environmental Effects Monitoring (EEM). The objective of EEM is to determine whether mining activity is causing an effect on fish, benthic invertebrate communities and/or the use of fisheries resources (based on mercury accumulation in fish tissues). On the 20th of August 2010, a Type A Water License QZ09-092 was issued to Alexco



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 under license from Her Majesty the Queen in Right of Canada, Department of Natural Resources Canada. All rights reserved. Quartz claim boundaries and ownership current as of February 24th, 2011. Data source: <http://geomatics.yukon.ca>.

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

1:75,000 (when printed on 11 x17 inch paper)

0 0.5 1 2 3 Kilometers

- | | | | |
|---|---|---|--|
|  Adit |  Haul Road |  Highway |  Contour (100 ft) |
|  Shaft |  Mill Access |  Local |  Watercourse |
|  Alexco Quartz Claims | |  Trail |  Waterbody |

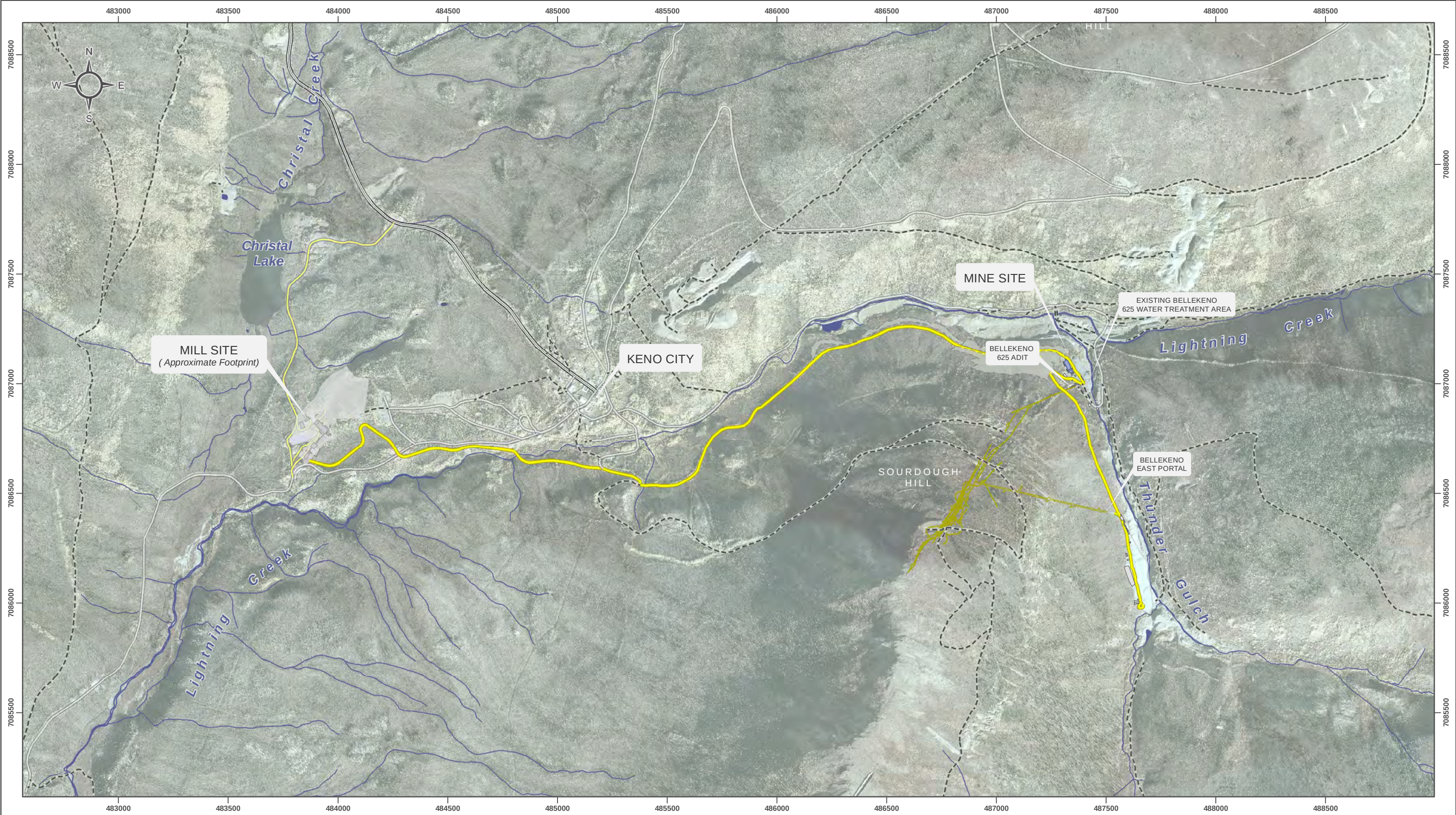


BELLEKENO MINE PROJECT - ENVIRONMENTAL
EFFECTS MONITORING PROGRAM - CYCLE I STUDY DESIGN

FIGURE 1.2
KENO HILL PROPERTY OVERVIEW

DRAWN BY MD	SEPTEMBER 2011	VERIFIED BY SD
-------------	----------------	----------------

I:\ALEX-05-01\Bellekeno\GIS\mxd\Development\Construction_Site_Plan\Fig1.2_KenoHillProperty_20110907.mxd
(Last edited by: mducharme, 07/09/2011 14:35 PM)



Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13 and 14 2006. Site hydrography and contours provided by Aero Geometrics LTD, derived from aerial photograph.

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

1:16,000 (when printed on 11 x17 inch paper)



==== Silver Trail Highway

==== Haul Road

==== Mill Access

==== Local

==== Track

==== Underground workings



BELLEKNO MINE PROJECT - ENVIRONMENTAL
EFFECTS MONITORING PROGRAM - CYCLE I STUDY DESIGN

FIGURE 1.3
BELLEKNO PROJECT OVERVIEW

DRAWN BY MD

SEPTEMBER 2011

VERIFIED BY VB

I:\ALEX-05-01\Bellekeno\GIS\mxd\Development\Construction_Site_Plan\Fig1.3_Bellekeno_Overview_20110907.mxd
(Last edited by: mducharme, 07/09/2011 14:35 PM)

Keno Hill Mining Corp. (AKHM) for operation of the Bellekeno Mine and Mill complexes. The Bellekeno Mine and Mill Development and Operations Program triggered the MMER on September 7th, 2010 (see Appendix A). This cycle 1 EEM Study Design Report has been prepared collaboratively by Access Consulting Group and Minnow Environmental Inc., with Access taking primary responsibility for Site Characterization and Minnow taking responsibility for Study Design (Section 4.0).

The Bellekeno mining and milling operation are located at two different sites and on two distinct watersheds:

- Lightning Creek – Mining operations
- Christal Creek – Milling Operations

However since no water has been discharged from the Mill site to date and the plan is to discharge very little to no water during future operations at the mill, AKHMC has elected to conduct the EEM program on the Lightning Creek watershed where the likelihood of operational impact on the aquatic environment is greatest. Much of the background data presented in this document is in support of the program on Lightning Creek however; certain mill activities are also described herein.

1.2 OBJECTIVE

The objective of this Cycle 1 EEM Study Design is to provide a comprehensive overview of the characteristics of the mine and its local environment (site characterization) based on information collected to date, and to describe how chemical and biological monitoring will be conducted to meet the objectives of the EEM program in accordance with the MMER. In accordance with technical guidance (Environment Canada 2011), the Phase 1 EEM Study Design will be formulated to take into account all relevant site characterization information, previous biological monitoring data, and comments and/or recommendations stemming from previous monitoring efforts in the area.

1.3 REPORT ORGANIZATION

The content of this report reflects the requirements outlined under the EEM portion of the MMER (Government of Canada 2002; 2010) and in the Technical Guidance Document for Metal Mining EEM (Environment Canada, 2011). A detailed site characterization and history is provided in Section 2.0. Section 3.0 provides a summary of information relevant to the receiving environment. A detailed EEM study design including a benthic invertebrate community survey, a fish survey, a fish tissue survey, supporting environmental measures, sub-lethal effluent toxicity testing, effluent characterization, and receiving water quality monitoring is presented in Section 4.0. Section 5.0 describes the schedule of activities and expected effort involved in future monitoring. References cited throughout the document are provided in Section 6.0.



1.4 CONTACTS

Please contact the Bellekeno Mine and Mill Operation *Site Environmental Coordinator*, Ms. Vanessa Benwood if there are any questions or comments regarding this report.

Ms. V. Benwood, Site Environmental Coordinator

Bellekeno Mine site, YK

Tel: (867) 996 2330, ext. 5909

Fax: (867) 995 2600

E-mail: vbenwood@alexcoresource.com

In the event that Alexco Keno Hill Mining Corporation personnel should be unavailable to address technical questions or comments, Mr. Paul LePage of Minnow Environmental Inc. or Mr. David Petkovich of Access Consulting Group may also be contacted as follows:

Mr. Paul LePage, Aquatic Scientist

Minnow Environmental Inc.

2 Lamb Street

Georgetown, Ontario

L7G 3M9

Email: plepage@minnow-environmental.com

Mr. D. Petkovich, Senior Environmental Manager

Access Consulting Group

#3 Calcite Business Centre

151 Industrial Road

Whitehorse, Yukon Y1A 2V3

Telephone: (867) 668-6463

Fax: (867) 667-6680

Email: david@accessconsulting.ca

2.0 SITE CHARACTERIZATION

United Keno Hill Mines Limited and UKH Minerals Ltd. were the previous owners of the properties located on and around Galena Hill, Keno Hill and Sourdough Hill, collectively known as the Keno Hill Mining Property. For the purposes of this report these mining areas are referred to as the Keno Hill District. The Keno Hill District is located in north-central Yukon Territory (Figure 1.1) and is comprised of approximately 1,563 mineral claims that cover an area of approximately 15,000 ha (about 29 km long and 8 km wide). With the exception of the Bellekeno Mine on Sourdough Hill, the mine has not operated since 1989, and abandoned adits, buildings/structures, and waste material associated with the site represent sources of contaminants to the downstream watersheds. The most significant of these sources include the lime-treated discharge from the Elsa Tailings pond system, Galkeno 900 Adit, Galkeno 300 Adit, Bellekeno 600 Adit, Silver King Adit and Valley Tailings (Figure 1.2). The influence from these sources is largely limited to the tributaries that drain the properties (Christal, Flat and Lightning Creeks), although some influence on water and sediment quality can be measured further downstream in the South McQuesten River. In addition to the historical mining activities, the area is currently host to a number of placer mining operations which cause extensive alteration of the watercourses and impacts to habitat and water quality downstream.

In June 2005, Alexco Resources Corp. was selected as the preferred purchaser of the UKHM assets. As required in the purchase agreement, Alexco formed a company – Elsa Reclamation and Development Company Ltd. (ERDC), to own and manage the site. In order to support activities relating to care and maintenance of the historic mine workings prior to mine closure, the Yukon Water Board granted a “Type B” Water Licence to ERDC pursuant to the *Waters Act* (licence number QZ06-074). The scope of monitoring (sample types, substances, sampling frequency and locations) as well as reporting requirements (e.g., annual reports) are also outlined in the licence.

In 2006, Alexco Resources Corp. formed Alexco Keno Hill Mining Corp. (AKHM) to mine the Bellekeno deposit on the Keno Hill District property. AKHM obtained a Quartz Mining Licence pursuant to the *Quartz Mining Act* (QML-0009) and a Type A Water Licence (licence number QZ09-092). The mine operates under the provisions of these licences and those prescribed by the Metal Mining Effluent Regulations (MMER).

2.1 BELLEKENO MINE HISTORY

Various mineralized zones within the Bellekeno ore deposit have seen commercial production from different operators over the years. Access to early production was from adits at the 100 and 200 levels, and later from the 625 adit. Operators have included Bellekeno Mines Ltd., Mayo Mines Ltd., and United Keno Hill Mines Ltd. Much of the ore from early mining was shipped out to smelters as direct-shipping ore, and in 1953 Mackeno Mines Ltd. constructed a flotation mill at Christal Lake to further concentrate the ore prior to shipping to smelters, including over 10,000 tons of ore produced from the Bellekeno Mine between 1953-1954.

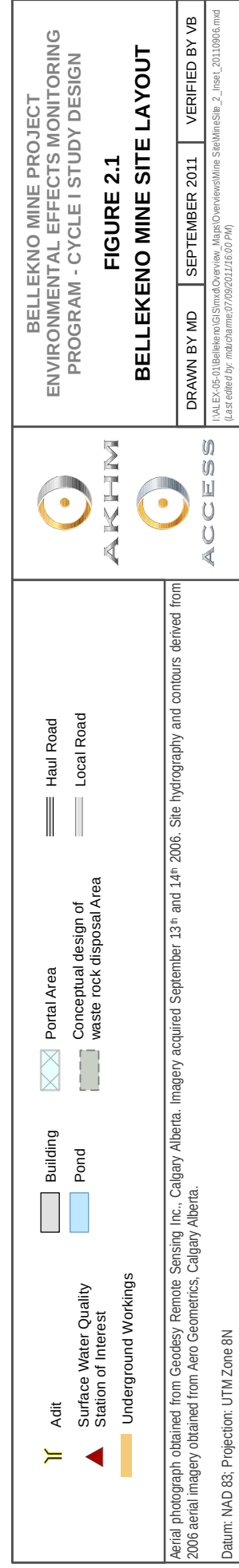
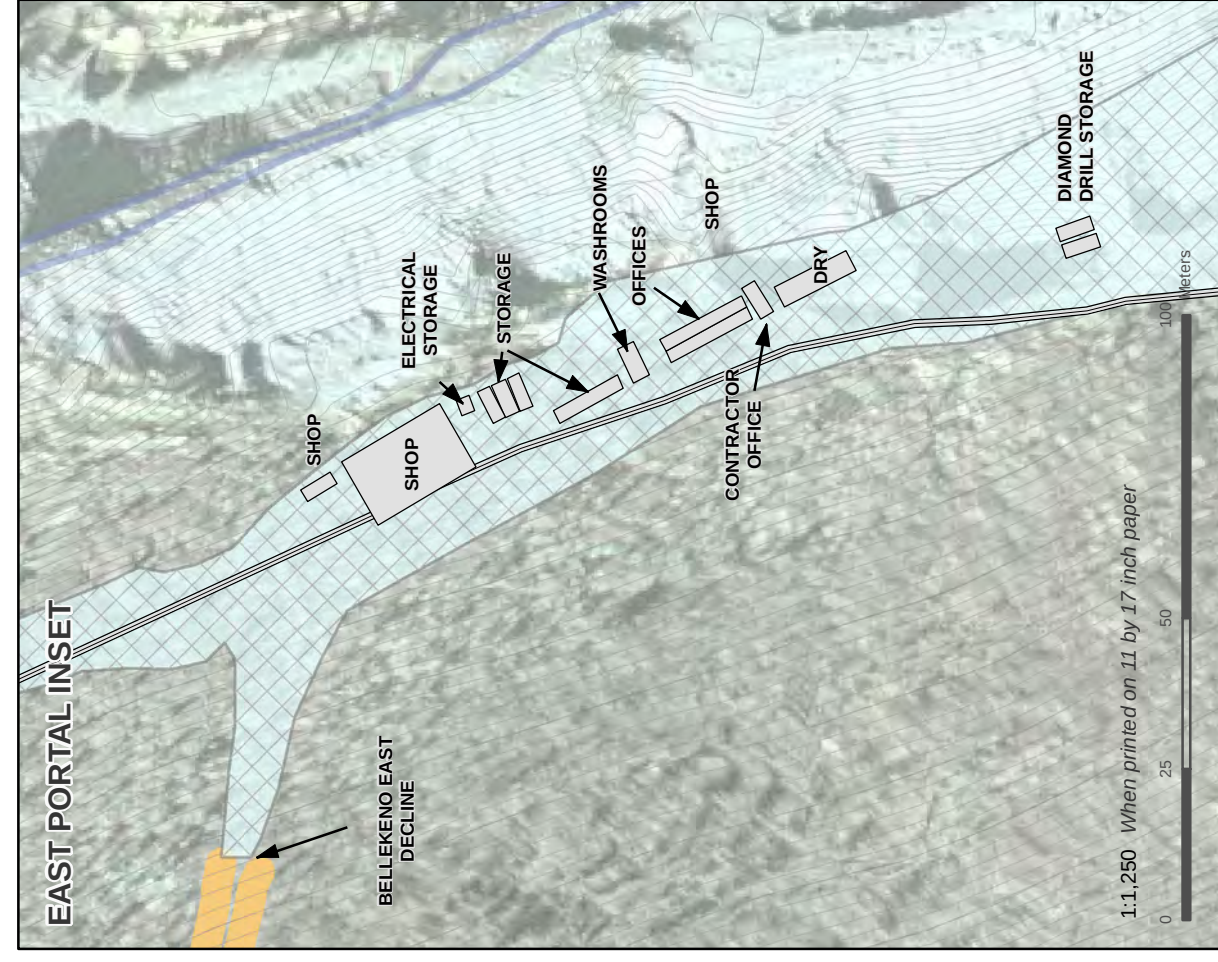
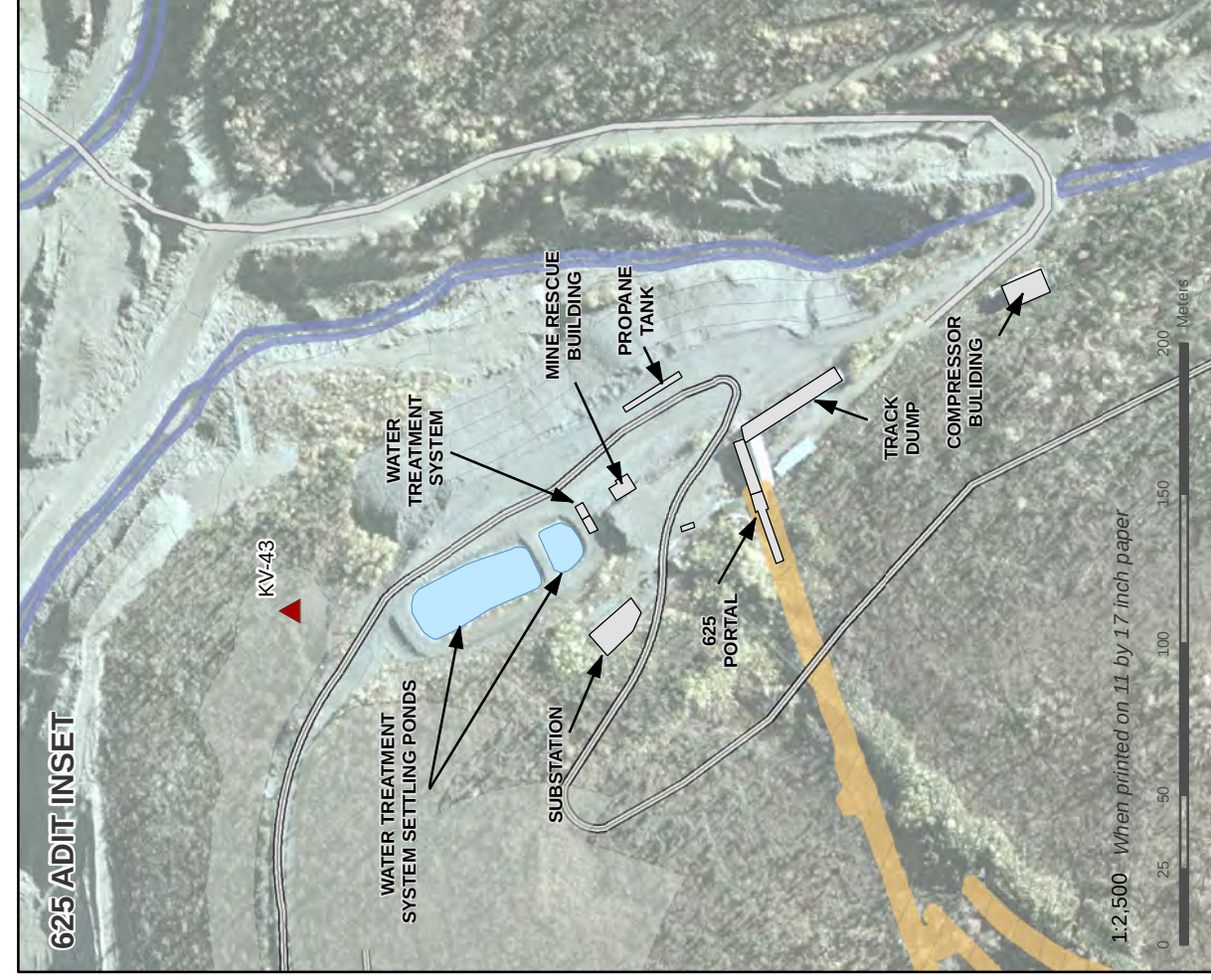
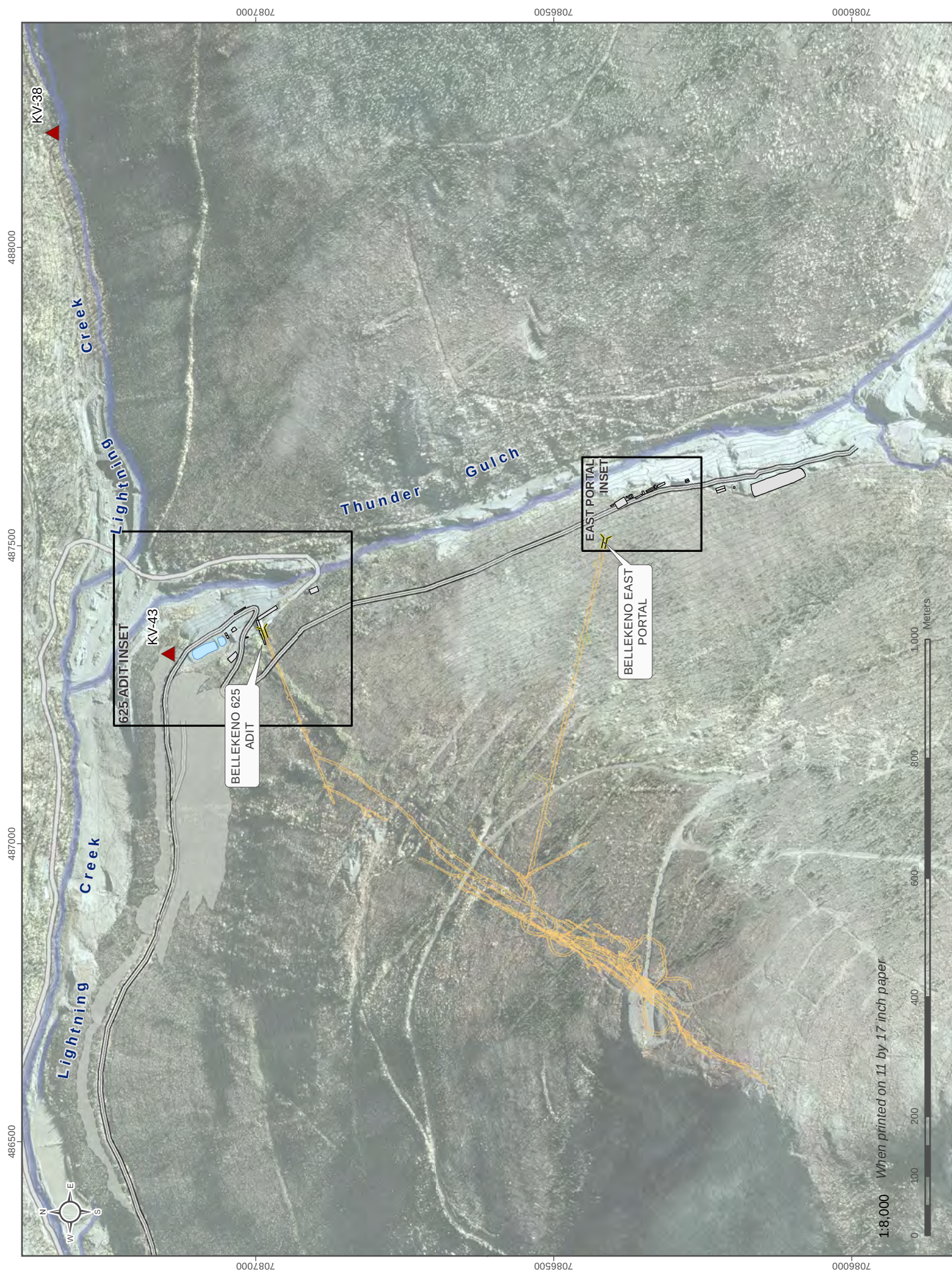
The Bellekeno deposits' modern mining era began in 1984 with the development of the adit at the 625 level, which was collared and driven to cross-cut approximately 200 meters to the "48" vein. Over the years, the 625 level workings were connected to the 400 level and the 500 level. This was used to mine ore from the 500, 625, 700, 750 and 800 levels from 1984 through to 1989. Dewatering and rehabilitation of the 700 through 800 levels, from the 625 adit, began in 1994. Internal mechanized ramps were developed to reach the 700 and 800 levels and a mechanized ramp was driven towards but stopped short of the 500 level. The property was maintained until 2001, when it was declared abandoned. The lower Bellekeno workings were allowed to flood in 2003.

2.2 BELLEKENO MINE OPERATIONS

In 2006, Alexco initiated a broad surface exploration program (Class 3 Mining Land Use Approval LQ00186) in the historic Keno Hill silver district with surface diamond drilling focused primarily toward systematic testing of numerous targets, validating and expanding historic mineral resources and acquiring a better understanding of the local geology and ore controls. Based on broadly successful 2006 results, Alexco in 2007 expanded its exploration to a two phase district exploration program; the first phase focused on following up prior results in the area of the historic Bellekeno mine and the second phase continuing the broad information gathering drill program elsewhere across the district. In 2008 Alexco conducted surface exploration at a number of targets throughout the district and proceeded with advanced underground exploration and development at Bellekeno (Mining Land Use Approval LQ00240, and Water Licence QZ07-078). On July 9, 2008, Alexco released a Preliminary Economic Assessment (PEA) of Bellekeno prepared by SRK Consulting (SRK, 2008). The economics suggested by the PEA led Alexco to proceed with a positive production decision.

The Bellekeno mine is comprised of one primary vein, the 48 vein, a subsidiary structure, the 49 vein and at least 9 other ancillary structures present in the Southwest, 99, and East zones. Supporting surface infrastructure consists of office, dry, shop etc. and water treatment facilities (Figure 2.1). Most of the historical mining (totalling approximately 40,000t) at Bellekeno occurred on the 48 vein in the 99 zone, intermittently between the 1950s and mid 1980s. The veins have variable dip, strike, and thickness. Dips range from 60° to 80° to the east or west. The average strike direction is approximately 030 azimuth. Vein thickness varies from a few centimetres to several meters in an apparent "shoot-like" configuration.

Initial mine development began in 2010 and consisted of excavating central remucks in the Bellekeno East Decline and widening and heightening the existing ramps down to the Southwest Zone. By March 2010 the majority of this work was completed and a new incline and decline had been driven from a central location in the Southwest portion of the mine, from which various ore accesses were also driven. At the bottom of the mine the existing 850 Decline was



extended and an exploration drilling platform was excavated. During this time, minor ore access development in the 99 Zone was ongoing. Pre-production mining of mineralized vein material commenced in September 2010 and continued through December 2010 in stopes located throughout the mine. Based on the geotechnical and physical characteristics of the veins, cut-and-fill mining methods were selected as the most appropriate for Bellekeno. Cut-and-fill and shrinkage stopping methods typically offer a high degree of selectivity that generally translates into high mineralization extraction and low waste dilution. Significant geotechnical study and design has been completed by SRK and a ground control management plan has been developed to address potential unstable ground conditions encountered in the vein material. Backfill of mined out stopes will be accomplished through cemented rock and tailings fill. Filtered tailings from the mill process will be backhauled underground and used as backfill.

Waste rock produced by the mine that is not potentially acidic or metal leaching or “non-AML” is used for general construction including repairs and surface capping of the existing Power Line Road that runs along the north slope of Sourdough Hill, above the left limit of Lightning Creek and as fill and construction for the mill and ancillary facilities. Additional non-AML waste rock will be deposited along the northeast flank of Sourdough Hill, northwest of the current Bellekeno 625 waste rock storage areas, if necessary.

Potentially acid-generating and/or metal leaching not suitable for general construction purposes is stored in a waste containment facility near the Bellekeno mine portal area or underground in the Bellekeno mine below the previous static water level (defined as the Bellekeno 625 portal elevation). The waste containment facility design includes a geosynthetic liner to allow for collection of drainage and is surface graded to divert any water flow around the storage area. The HDPE liner is covered by a 0.3 m protective sand and gravel overliner/drainage layer to permit rock dumping by truck or loader. Sumps are built into the low points of these storage facilities to allow for collection of any drainage or meteoric accumulation, which is conveyed to the Bellekeno 625 treatment facility. All waste rock is immediately classified and moved to the appropriate disposal area or storage facility depending on type.

2.3 CURRENT BELLEKENO MINE WATER USE

The Bellekeno mine is a zinc-rich mine which produces moderately zinc rich mine drainage. Adit discharge flow is also moderate and therefore untreated Bellekeno water produces moderate loads to the receiving environment. The Bellekeno mine requires continual dewatering through the Bellekeno 625 portal, with flows typically ranging between 3.0 to 8.0 litres per second (lps), generally less than 2 mg/L zinc, and suspended solids from mining activities. Treatment in the first part of 2010 consisted of lime slurry mixing into the adit water, addition of a small amount of iron in the form of ferric chloride, and settling in sludge settling ponds.

The quality of effluent from the mine fails to comply with water licence QZ09-092; therefore water treatment is required on an ongoing basis. Treatment operations employ a simple lime-addition and sludge settling circuit. The treatment objective is to reduce zinc effluent concentrations to less than 0.50 mg/L, as required under Water Licence QZ09-092. Historic correlations between

zinc concentrations and other metals (i.e. arsenic, lead and cadmium) indicate that the zinc discharge treatment objective ensures that other metals are also managed. For the management of ammonia and suspended solids, there are other measures that have been employed at the treatment facility.

After the issuance of WL QZ09-092 in late August 2010, AKHM began production drilling and removal of ore from the mine in early October. The water source for underground mine operations is recirculated underground mine water, plus any additional fresh water that leaks into the mine workings.

Water is collected in the underground in sumps located throughout the various mine levels and pumped up to the main water storage sumps at the underground 600 level. Here, a transfer process occurs to settle solids from the water. Water is first collected in a 'dirty' water sump with a capacity large enough to allow suspended solids to settle out. When the water has been polished, it flows into a 'clean' water sump where it is then returned to various working headings through piping, and may at this point be used in underground mine operations. Excess water from the clean water sump which is not returned to the underground is discharged through piping to the water treatment system. None of the water in the underground is discharged to the treatment facility before it travels through the main settling sumps.

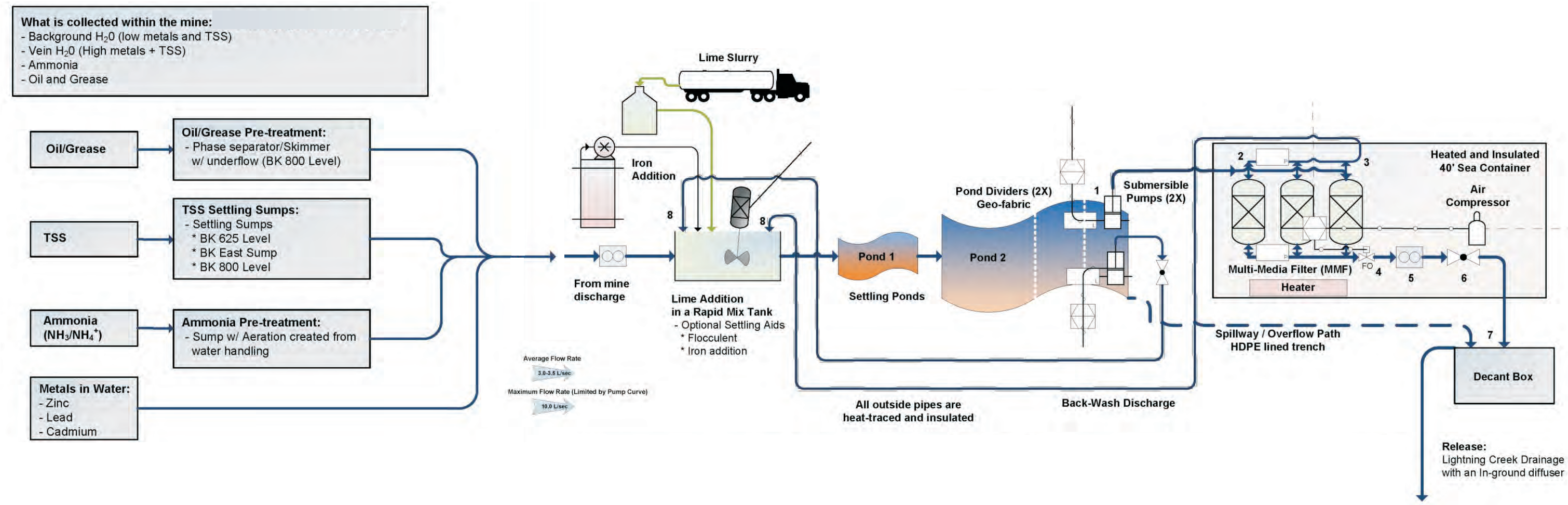
2.4 BELLEKENO MINE WATER TREATMENT SYSTEM

The Bellekeno 625 treatment system consists of the mechanical application of lime slurry ($\text{CaO}_{(s)} + \text{H}_2\text{O}_{(l)}$) to the mine discharge waters. Ferric chloride is sometimes added to the lime mix tank to improve particle flocculation and settling. The slurry acts to raise the pH, causing zinc and other metals to co-precipitate out of solution, forming solid metal hydroxide sludge. Two precipitate retention ponds are located at the treatment facility to assist metals precipitation and clarification of effluent prior to release into the receiving environment. Discharge to the environment occurs via a gravity-fed system through pond decants. Sludge is periodically removed from the primary settling pond and transported to a storage cell in the Valley Tailings.

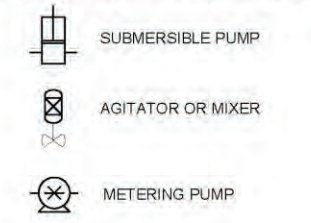
Water is dewatered from the mine and gravity flows into a rapid mix tank (Figure 2.2). There the water is agitated and mixed with lime slurry from a lime slurry tank. By raising the pH, ammonia in the mine water is transformed into a dissolved gas form allowing for volatilization to occur. Some additional treatment of ammonia occurs in the rapid mix tank and subsequent settling ponds.

Water flows from the rapid mix tank into pond 1, which provides residence time for the water to calm, thereby allowing larger particles to settle out. As the larger particles settle, they collect on the bottom of pond 1 as sludge. This sludge is then removed on a routine basis, typically weekly, by a vacuum truck. Water is then decanted from pond 1 and flows into pond 2, a larger pond that allows additional settling time. Alexco has divided pond 2 into three sections by

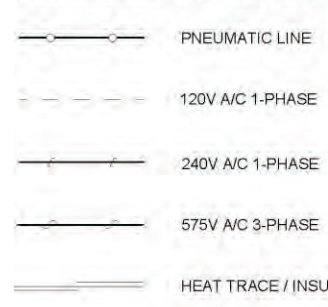
Figure 2.2 BELLEKENO 625 WATER TREATMENT SYSTEM



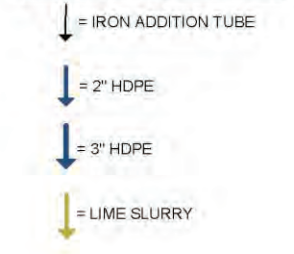
PRIME MOVERS FOR MOTOR DRIVEN EQUIPMENT



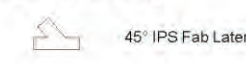
INSTRUMENT LINE SYMBOLS



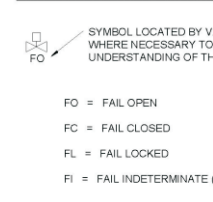
PIPE LINE DESIGNATIONS



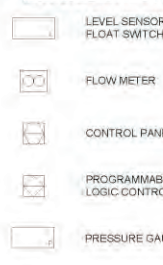
PIPING ACCESSORIES AND DETAILS



SYMBOLS FOR VALVE ACTION IN THE EVENT OF ACTUATOR POWER FAILURE



INSTRUMENTATION



VALVE SYMBOLS



ADDITIONAL COMPONENTS



extending two geo-fabrics across the pond, thereby limiting "short-circuiting" of larger particles which aids in settling.

Both open ponds allow for ammonia treatment by off-gassing in the higher pH mine water, and for variable amounts of sorptive removal in the treatment sludge. From the end of pond 2, water is pumped via a submersible pump into a three-tank Multi-media Filter (MMF) system, where the majority of particles are removed prior to release. These collected particles are then washed from the MMF tanks via a backwash system and re-deposited in the rapid mix tank for retreatment and settlement in Pond 1. A flow meter and totalizer has been installed after the MMF to measure instantaneous flow and track total discharge of water as it passes through the system.

Finally, water is discharged into a decant box and released towards Lightning Creek. The effluent goes to ground prior to reaching the creek but it is assumed that most of it eventually seeps into the system. This system is designed to operate and release up to a maximum flow rate of 10 lps. There has been no reportable spills at the mine site to date.

2.5 MILL OPERATIONS

In 2010, a conventional flotation mill was constructed at the historic Flame and Moth Site for processing ore and producing concentrate.

Construction of the mill included:

- Two stage crushing & screening plant
- Fine ore stacker conveyor and stockpile cover
- Fine ore reclaim tunnel

A 180m by 60m pre-engineered steel building to house processing equipment, including:

- Primary ball mill
- Lead flotation circuit
- Zinc flotation circuit
- Reagent preparation area
- Thickeners and pressure filters for lead concentrates, zinc concentrates, high pyrite tailing and low pyrite tailings
- Concentrate loading dock with truck scale
- Office trailers and wash room facilities
- Process water pond
- Dry-stack tailing facility

The mill is designed to run at an annualized average 250 tonnes per day in 2011, increasing to 400 tonnes per day thereafter. An increase in tonnage beyond an annualized average 250 tpd

may require a QML and WL amendment. Commissioning of the mill occurred throughout most of November and December 2010, therefore production volumes varied from those quoted.

The mill process employs conventional crushing, grinding, flotation, and dewatering processes. The primary valuable sulphides in the mill feed are recovered by conventional differential flotation with a cyanide-free zinc suppressing regime. Silver and lead minerals are recovered together to produce a silver-lead concentrate and zinc minerals with some silver value are recovered to a separate zinc concentrate.

Reagents used in the mill for processing include:

- Copper Sulphate
- Zinc Sulphate
- 3418A (aerophine)
- MIBC (Methyl Isobutyl Carbinol)
- SIPX (Xanthate)
- Sodium Sulphite
- Flocc (changing to the same type as used in water treatment)

Storage and disposal of mill tailings is in a dry-stack tailings facility (DSTF) located adjacent to the mill.

2.6 TAILINGS HANDLING

The Tailings Management Plan was designed for approximately 50% of final flotation tailings to be stored on surface by dry stacking and approximately 50% to be stored underground, most likely as cemented or paste backfill. This design allows final flotation tailings to be used as backfill to provide support for the excavated underground voids and to reduce surface environmental impact.

The mill was designed to produce a high and low pyrite tailings product, in the event high pyrite ore material was encountered during mining. If an appreciable amount of pyrite is contained in the mill ore it would be substantially removed and report to the zinc cleaner scavenger tailings stream which has been referred to as the high pyrite tailings product.

Since the mill was commissioned, no appreciable amount of pyrite has been encountered and consequently the mill is producing a single tailings product.

2.7 DRY STACK TAILINGS DISPOSAL PROCEDURE

Tailings are placed in 300 mm lifts and compacted with a 10-tonne vibratory compactor. Tailings are compacted to at least 95% of the maximum dry density using standards effort (as per American Society for Testing and Materials [ASTM] D698). The organic soils have been left in place beneath the DSTF to provide some insulation and slow the rate of permafrost thaw.

Construction of the DSTF will occur within a five year period, as the tailings are generated by the mill. A total of 8,061 tonnes of tailings were placed in the DSTF in 2010 at 11% water retention volume (~887 tonnes). No tailings have yet been placed underground.

The DSTF is designed with an impermeable cemented base layer for the purpose of collecting pore water and meteoric runoff that has come in contact with the tailings. The water is channelled to a sedimentation pond.

2.8 CURRENT MILL WATER USE

Mill water is retained in a sedimentation pond at the mill site, for the dual purpose of settling out sludge solids from treated water at times when treatment is necessary, and as a source of water storage for the mill. The mill pond also collects pore water and runoff from the DSTF, as mentioned above (Figure 2.3).

Currently, mill water is drawn from both the Galkeno 900 and Bellekeno 625 treatment facilities, operated under WL QZ06-074 and QZ09-092, respectively. Water is pumped from the treatment pond into a vacuum truck and transported to the mill pond where it is stored for use in the mill. It is anticipated that during times of high meteoric runoff and net water production by the mill, water in the sedimentation pond will have to be treated and excess water will be discharged to the environment via the land application system. To date there has not been a discharge from the mill pond.

In the event that the mill should produce a net surplus of water, a water treatment and land applicator system will be employed for effluent discharge to the Christal Creek drainage.

2.9 CURRENT MILL WATER USE

Water is also retained in a sedimentation pond at the Flame and Moth Mill Site, for the dual purpose of settling out sludge solids from treated water at times when treatment is necessary, and as a source of water storage for the mill. Currently, mill water is drawn from both the Galkeno 900 and Bellekeno 625 treatment facilities, operated under WL QZ06-074 and QZ09-092, respectively. Water is pumped from the treatment pond into a vacuum truck and transported to the mill pond where it is stored for use in the mill. It is anticipated that during times of high meteoric runoff and net water production by the mill, water in the sedimentation pond will have to be treated and excess water will be discharged to the environment via the land application system. However, to date there has not been a discharge from the mill pond nor has there been any reportable spills.

In the event that the mill should produce a net surplus of water, a water treatment and land applicator system will be employed for effluent discharge to the Christal Creek drainage.

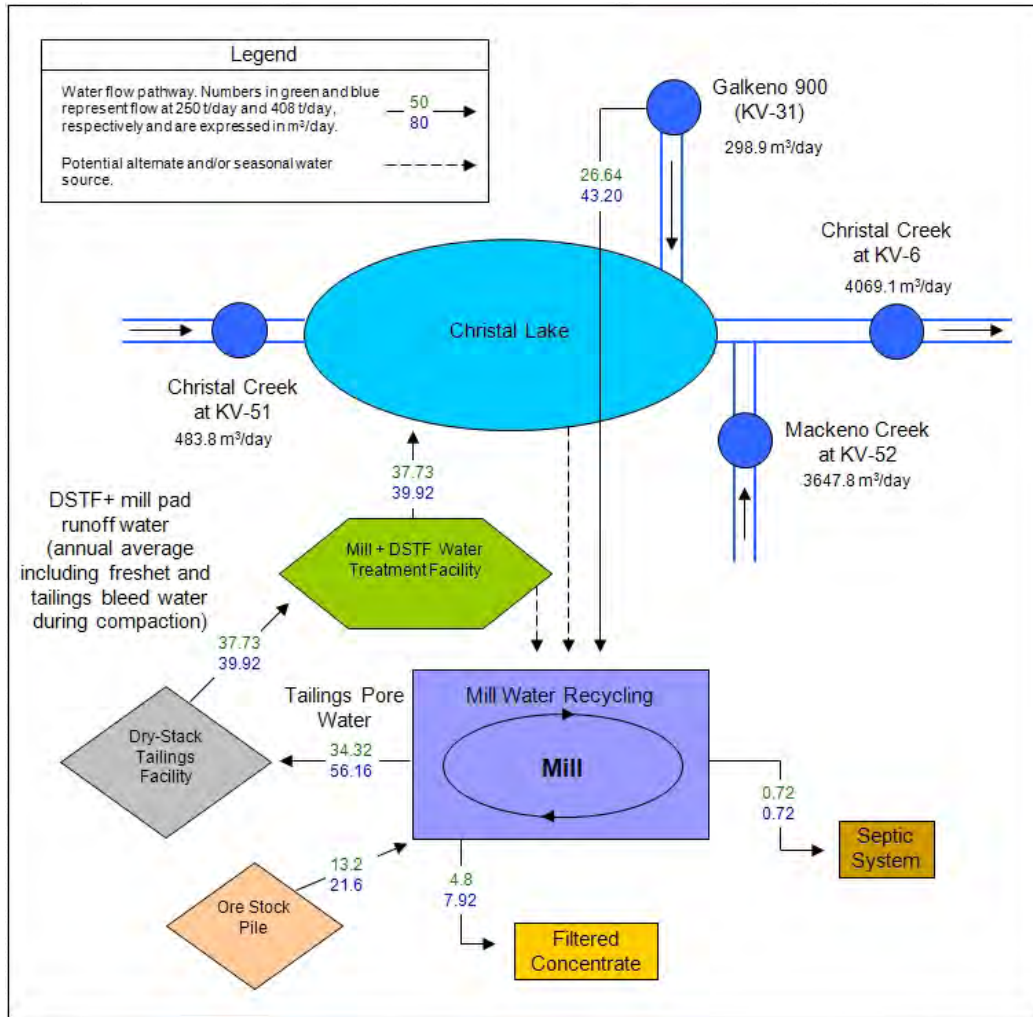


Figure 2.3 Bellekeno Mill Water Feed Process

2.10 EFFLUENT DISCHARGE POINT

Effluent quality monitoring is conducted at the point of compliance located at station KV-43, the Bellekeno 625 Treatment Pond Decant (7087147N, 487318E)¹. A second compliance point will be established at KV-83 Flame and Moth Mill treatment plant when or if there is discharge at the mill. No water has been discharged from the mill to date.

¹ These coordinates are UTM Zone 8, NAD 83.

2.11 APPLICABLE REGULATIONS

With respect to regulations that apply to the discharge of effluent from the Bellekeno Mine and Mill site, and in addition to the Federal MMER under the Fisheries Act, the Yukon Water Board issued a Type A Water Use Licence (QZ09-092) that came into effect on August 20th, 2010 and is due to expire on August 1st, 2020. This Type A Water Use Licence is a requirement under the Yukon Waters Act within Schedule 7 (Licensing Criteria for Quartz Mining Undertakings) of the Waters Regulations as follows:

- Direct water use for milling at a rate of 100 or more tonnes of ore per day
- Deposit of waste water from milling at a rate of 100 tonnes or more of ore per day

The limits in a Type A Water Use licence are generally more restrictive than those in the MMER (Table 2.1), and separate monitoring and reporting for effluent discharge and receiving water quality is required under the Water Licence's Water Quality Surveillance Program.

The points of compliance at the Bellekeno Mine and the Flame and Moth Site for the effluent quality standards included in this licence are the final points of control at stations KV-43 and KV-83 respectively (Figure 2.4). All test results for the effluent water quality parameters listed in this licence shall be provided by a laboratory accredited by the Canadian Association for Laboratory Accreditation (CALA). Effluent Characterization and water quality monitoring is undertaken as required under MMER.

To date, effluent quality monitoring as prescribed by the Yukon Water Board has been conducted through all three operational periods:

- Care and Maintenance (Nov. 14, 2007 to Oct. 2nd, 2008)
- Advanced Exploration (Oct. 3rd, 2008 to Sept. 6th, 2010) and
- Production (Sept. 7th, 2010 to July 31st, 2011).

The production period has also been subject to MMER and monitored accordingly.

The existing water quality surveillance network at the Keno Hill Property includes surface receiving waters in the Bellekeno, Onek and Christal Lake area. Most of the monitoring stations have been sampled extensively in the past. Past water quality monitoring was required under Water Licence QZ06-074, Schedule A as well as under Water Licence QZ07-078, Schedule A (Flow Monitoring Plan).

Additional monitoring stations that have been established and will continue to track receiving water quality from the Bellekeno mine/mill development and operations program. Water stations will be sampled weekly, monthly and quarterly during periods of discharge. This will include the two points of compliance at stations KV-43 and KV-83, located at Lightning Creek and Christal Creek, respectively (Figure 2.4).

2.12 EFFLUENT CHEMISTRY

Table 2.2 provides a summary of Bellekeno Mine effluent quality (station KV-43) between November 14, 2007 and July 31, 2011. During this time three different water licenses were in effect in recognition of the activities being undertaken at the site:

- November 14, 2007 Water License QZ06-074 came into effect in support of care and maintenance activities;
- October 3, 2008 Water License QZ07-078 came into effect in support of advanced exploration and preliminary development activities;
- August 19, 2010 Water Licence QZ09-092 came into effect to support mine production.

Effluent quality data has been summarized for each of these phases and compared with MMER standards and Water License QZ09-092 effluent quality standards (Table 2.2). Actual results from sampling events where these numbers were derived from are appended (Appendix B)

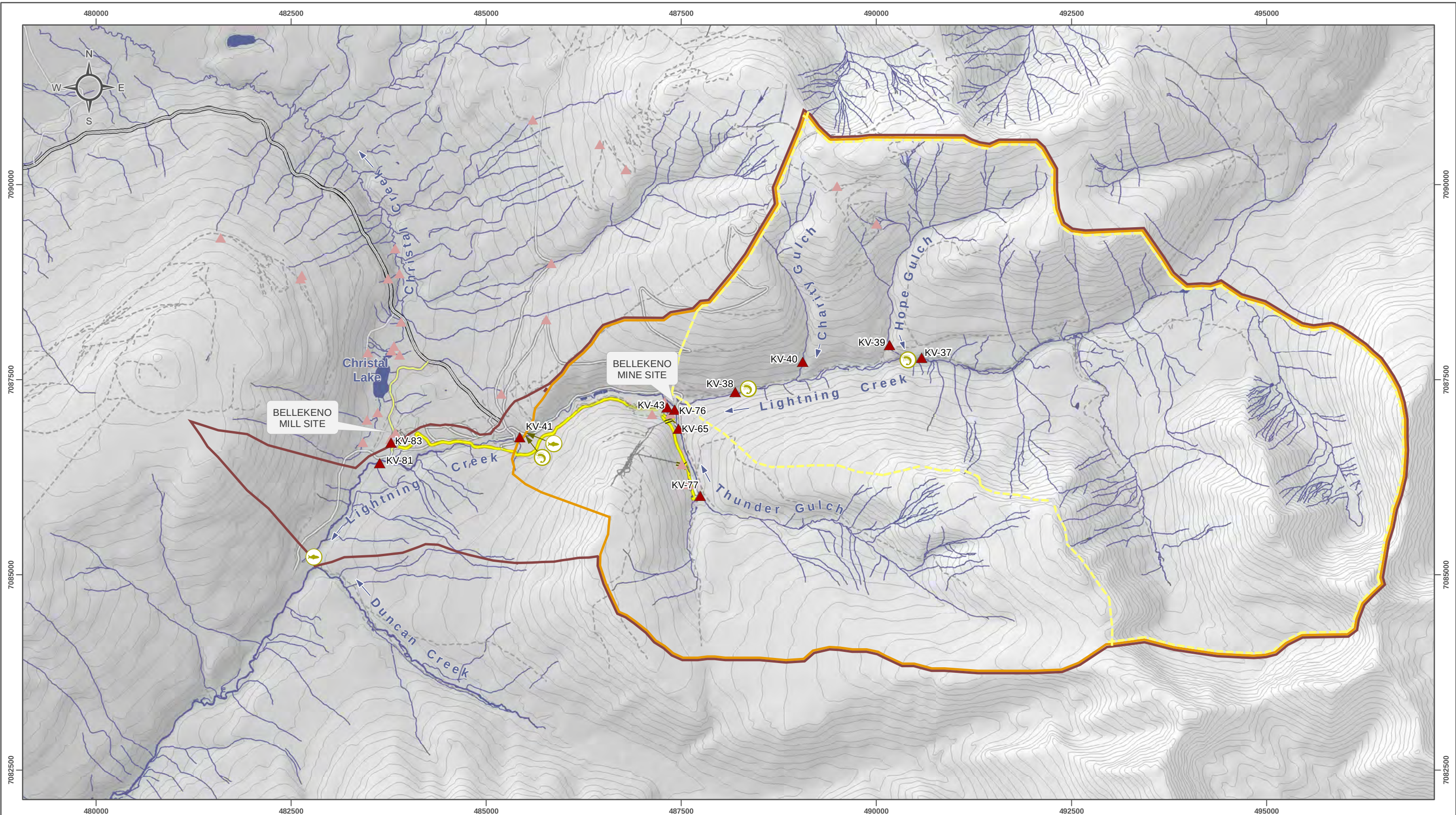
Sampling for Radium 226 was initiated in September 2011. Weekly sampling results have been consistently below 0.037 Bq/L (see Appendix B) and therefore AKHMC has submitted a letter to Environment Canada indicating that sampling frequency for Radium 226 would be reduced to quarterly as set out in the MMER.

Sampling for mercury has been ongoing at the final discharge point (KV-43) over a number of years however the method detection limit (MDL) for samples analysed to date has been 0.2 ug/l.

Although all samples have returned below detection (see Appendix B) the MDL was not set low enough (i.e. 0.1 ug/l or less) to determine if it is necessary to conduct a fish tissue analysis. Therefore as described in section 4.0 AKHMC will conduct a tissue fish tissue analysis program as part of this study and will also sample for mercury at the effluent discharge point (KV-43) using a detection limit of 0.1 ug/l or better.

2.12.1 Effluent Mixing and Discharge

Effluent discharged from the Bellekeno water treatment system reports to Lightning Creek (Figure 2.4). The discharged effluent goes to ground prior to reaching the creek but it is assumed that most of it eventually seeps into the creek. Therefore, effluent mixing here assumes that 100% of effluent discharged ends up mixing with Lightning Creek surface flow. Discharge from the mine and through the treatment system varies from about 2.0 lps to a maximum of 10 lps whereas Lightning Creek discharge at KV-41 varies from under 100 lps during winter months to over 2,000 lps during high flow periods in the open water season (Figure 2.5), therefore flow throughout most of the year Effluent contribution to the flow in Lightning creek is less than 1%. However during low flow periods such as in the month of January, effluent contribution to flows in Lightning Creek could be over 10% based on lowest actual flow recorded in Lightning Creek to date and average discharge from the Bellekeno mine operation during the month of January (see Table 2.3).



Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13 and 14 2006. Site hydrography provided by Aero Geometrics LTD, derived from aerial photograph. Contour data compiled by Natural Resources Canada at a scale of 1:50,000. Reproduced under license from Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources Canada. All rights reserved.

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

1:45,000 (when printed on 11 x17 inch paper)



- ▲ Surface Water Quality Station of Interest
- ▲ Other Surface Water Quality Monitoring Station
- 🐼 Previous Benthic and Invertebrate Study
- 🐟 Previous Fisheries Study

- Lightning Creek to Thunder Gulch confluence
- Lightning Creek to water quality monitoring station "KV-41"
- Lightning Creek up to Duncan Creek confluence

- Silver Trail Highway
- Local Road
- Haul Road
- Mill Access Road
- Contour (100 ft)
- Watercourse



BELLEKENO MINE PROJECT - ENVIRONMENTAL EFFECTS MONITORING PROGRAM - CYCLE I STUDY DESIGN

FIGURE 2.4

LIGHTNING CREEK CATCHMENTS AND ENVIRONMENTAL MONITORING STATIONS

DRAWN BY MD	SEPTEMBER 2011	VERIFIED BY DP
I:\ALEX-05-01\Bellekeno\GIS\mxd\Studies\EEM_Cycle_1\Fig2.4_LightningCreek_Catchments_and_WQ Monitoring20110907.mxd (Last edited by: mdchame, 07/09/2011 14:34 PM)		

Table 2.1 Compliance Monitoring frequency and limits applicable to the Bellekeno Mine

Parameter ¹	Units	MMER Effluent Quality standards			Water Use Licence QZ09-092 Effluent Quality Standards from Water Treatment Systems		
		Maximum Authorized Monthly Mean Concentration	Maximum Authorized Concentration in a Composite Sample	Maximum Authorized Concentration in a Grab Sample (~10 x MDL)	Frequency	Maximum Authorized Concentration in Grab Sample from Bellekeno 625 Adit	Maximum Authorized Concentration in Grab Sample from Flame and Moth Site
pH	pH units	-	-	6.0-9.5	weekly	6.0-9.5	6.0-9.5
Suspended Solids	mg/L	15	22.50	30.0	weekly	25	25
Ammonia Nitrogen	mg/L	-	-	-	weekly	5	5
Arsenic (total)	mg/L	0.50	0.75	1.0	-	0.1	0.1
Cadmium (total)	mg/L	-	-	-	-	0.01	0.01
Copper (total)	mg/L	0.30	0.45	0.6	weekly	0.1	0.1
Lead (total)	mg/L	0.20	0.30	0.4	weekly	0.2	0.2
Nickel	mg/L	0.50	0.75	1.0	weekly	0.5	0.5
Radium-226	BQ/L	0.37	0.74	1.11	quarterly	0.37	0.37
Silver (total)	mg/L	-	-	-	weekly	0.01	0.02
Zinc	mg/L	0.50	0.75	1.0	weekly	0.5	0.5
Oil and Grease	Visibility	-	-	-	weekly	-	-
Acute Toxicity Testing							
96-hour Rainbow Trout		Pass ₅₀ ¹			monthly	Non-toxic, LC ₅₀ (100%)	Non-toxic, LC ₅₀ (100%)

¹A pass results is <50% mortality in 100% effluent

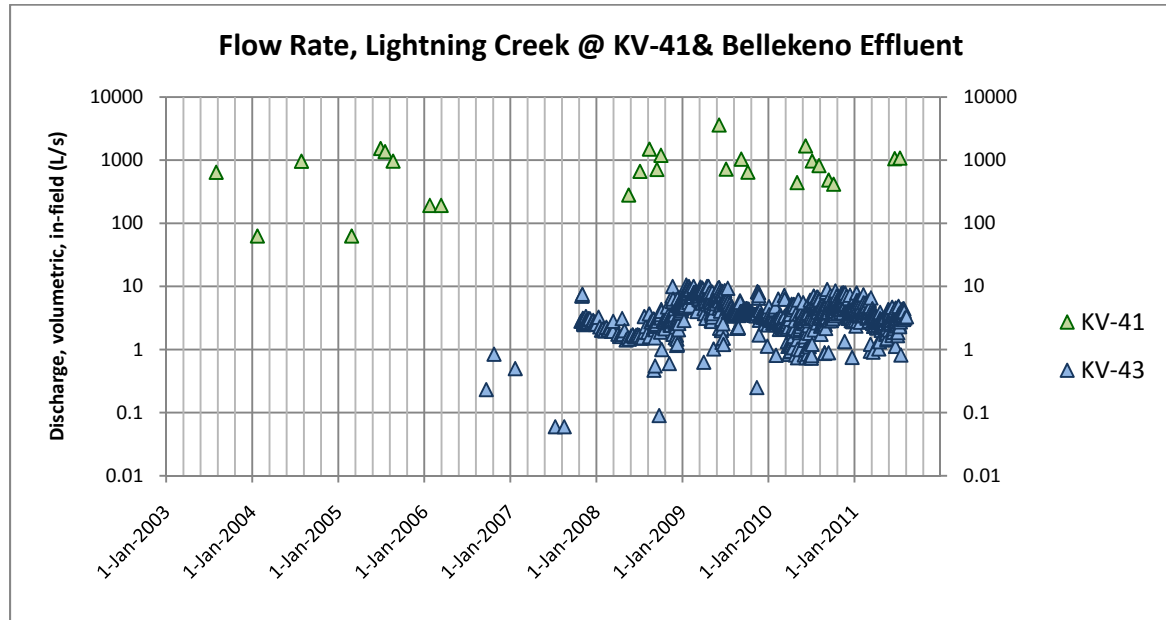


Figure 2.5 Effluent discharge rate at KV-43 vs flow at KV-41(Lightning Creek) 2003 through 2011

Table 2.2 Summary of Bellekeno Mine Effluent Quality (Station KV-43)^a

Parameter	Units	MMER Authorized Monthly Mean	MMER Authorized in Grab	WUL QZ09-092 Effluent Quality Standard	Averages			Count			Count<DL			Count & %>MMER Grab Limit		
					care and maintenance ^b	advanced exploration ^c	production ^d	care and maintenance	advanced exploration	production	care and maintenance	advanced exploration	production	care and maintenance	advanced exploration	production
MMER Parameters																
pH (field)	pH units	-	6.0-9.5	6.5-9.5	8.19	8.49	8.44	9	18	54	0	0	0	0	0	n = 1; 2%
pH (lab)	pH units	-	6.0-9.5	6.5-9.5	8.67	8.32	7.93	11	61	55	0	0	0	0	0	0
Total Suspended Solids	mg/L	15	30	25	11	27	9	11	68	54	2	7	28	n = 1; 9%	n = 16; 24%	n = 4; 7%
Arsenic (total)	mg/L	0.5	1	0.1	0.0018	0.013	0.0039	11	58	56	0	0	4	0	0	0
Copper (total)	mg/L	0.3	0.6	0.1	0.001	0.0041	0.0022	11	58	56	10	28	29	0	0	0
Lead (total)	mg/L	0.2	0.4	0.2	0.0022	0.0227	0.0464	11	58	56	0	2	1	0	0	0
Nickel (total)	mg/L	0.5	1	0.5	0.0107	0.0213	0.006	11	58	56	0	0	3	0	0	0
Zinc (total)	mg/L	0.5	1	0.5	0.205	0.2	0.044	11	58	56	0	3	27	0	0	0
Radium-226	Bq/L	0.37	1.11	0.37	-	-	0.006	-	1	48	-	1	30	-	0	0
Additional Effluent Quality Characterization Parameters																
Hardness (total)	mg/L	-	-	-	-	859	707	-	40	56	-	0	0	-	-	-
Alkalinity (total)	mg/L	-	-	-	-	51	52	-	3	55	-	0	0	-	-	-
Ammonia Nitrogen (total)	mg/L	-	-	5	-	1.328	1.724	-	62	55	-	0	0	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	2.91	-	-	53	-	-	2	-	-	-
Nitrite (as N)	mg/L	-	-	-	-	-	0.608	-	-	53	-	-	2	-	-	-
Aluminum (total)	mg/L	-	-	-	0.031	0.054	0.039	11	58	56	0	11	17	-	-	-
Cadmium (total)	mg/L	-	-	0.01	0.00102	0.00065	0.00034	11	58	56	0	16	25	-	-	-
Chromium (total)	mg/L	-	-	-	0.0007	0.0016	0.002	11	58	56	2	30	41	-	-	-
Iron (total)	mg/L	-	-	-	0.07	1.252	1.265	11	58	56	8	5	8	-	-	-
Mercury (total)	mg/L	-	-	-	-	0.0001	0.00009	-	39	55	-	39	54	-	-	-
Molybdenum (total)	mg/L	-	-	-	0.0006	0.00242	0.005	11	58	56	8	3	0	-	-	-
Selenium (total)	mg/L	-	-	-	0.0022	0.0019	0.0014	11	58	56	0	14	25	-	-	-
Silver (total)	mg/L	-	-	0.01	0.00006	0.00104	0.00037	11	58	56	7	30	27	-	-	-
Thallium (total)	mg/L	-	-	-	0.00003	0.00009	0.00011	11	55	56	10	6	13	-	-	-

^a Internal daily site data not included in data summary.

^b Care and maintenance data from November 14, 2007 to October 2, 2008.

^c Advanced exploration data from October 3, 2008 to September 6, 2010.

^d Production data from September 7, 2010 to July 31, 2011.



Table 2.3 Minimum expected dilution of effluent in Lightning Creek based on minimum winter flows recorded to date

			10-Day Average, Jan 19-29, 2008 ¹	10-Day Average, Jan 19-29, 2009 ²	10-Day Average, Jan 19-29, 2010 ³	10-Day Average, Jan 19-29, 2011 ³
		KV-43 Flow rate (Lps)	2.02	7.94	3.22	4.38
KV-41 Flow rate, Jan 24, 2004	63 lps	KV-43 as percent of KV- 41 discharge	3.21%	12.61%	5.12%	6.95%
KV-41 Flow Rate, Jan 25, 2005	192 lps	KV-43 as percent of KV- 41 discharge	1.05%	4.14%	1.68%	2.28%
1. Pre mine-dewatering conditions 2. Mine dewatering conditions 3. Post mine-dewatering						

2.12.2 Effluent Sublethal Toxicity Testing

As required under the MMER, sublethal toxicity testing has been initiated and will occur semi-annually on water taken at KV-43, the final discharge point from the Bellekeno Mine. The first test was conducted on water collected on December 13, 2010. Results from the test are presented below (Table 2.4). This first test indicates that the effluent is non-toxic to Early life stage Rainbow trout and *Lemna minor*. Some toxicity was noted for *C. Dubia* and *P. Subcapitata* but at concentrations of effluent much greater than what is expected in Lightning Creek following mixing.

Table 2.4 First Sub-lethal Toxicity Test Results (Sample taken December 2010)

Analysis	Results	95% Confidence Interval
Rainbow Trout Early life stage ¹ 7 Day LC ₂₅	>100%	-
Rainbow Trout Early life stage ¹ 7 Day LC ₅₀	>100%	-
<i>Ceriodaphnia dubia</i> ² LC ₅₀	>100%	-
<i>Ceriodaphnia dubia</i> ² IC ₂₅	70.81%	56.19% - 97.8%
<i>Ceriodaphnia dubia</i> ² IC ₅₀	>100%	-
<i>Pseudokirshneriella subcapitata</i> ³ 72 Hour IC ₂₅	88.9%	54.26% - 100%
<i>Pseudokirshneriella subcapitata</i> ³ 72 Hour IC ₅₀	>90.9%*	-
<i>Lemna minor</i> ⁴ 7 Day IC ₂₅	>97%*	-
<i>Lemna minor</i> ⁴ 7 Day IC ₅₀	>97%*	-

*Highest concentration tested

LC₂₅= Concentration which would cause a 25% mortality

LC₅₀= Concentration which would cause a 50% mortality

IC₂₅= Concentration which would cause a 25% inhibition in reproduction or growth

IC₅₀= Concentration which would cause a 50% inhibition in reproduction or growth

1. Standard Operating Procedure for Rainbow Trout Early Life Testing
2. Standard Operating Procedure for *Ceriodaphnia dubia* Testing and Culturing
3. Standard Operating Procedure for *Pseudokirshneriella subcapitata* Testing and Culturing
4. Environment Canada protocol for conducting toxicity tests using *Lemna minor*

A second test was scheduled for spring of 2011 however the lab that was to run the tests did not have viable rainbow trouts eggs available. The second test is now scheduled for September 17, 2011.

2.12.3 Toxicity Testing

As required under the MMER and WUL applicable to the site acute toxicity testing has been conducted on a monthly basis using water collected at KV-43, the final discharge point at the Bellekeno Mine. Specifically bioassay tests for acute toxicity have been conducted monthly using

rainbow trout (*Onchorhynchus mykiss*, 96h pass/fail) and *Daphnia magna* (48 h pass/fail) since January 2011. All 7 received to date have returned non-toxic results. As the discharge point has been subject to WUL's over the years an additional 30 acute toxicity tests have been conducted using rainbow trout and water collected at KV-43. All of these previous tests passed (i.e. < 50% mortality). Monthly results are presented in Appendix B.

2.13 OTHER AREA CHARACTERISTICS

2.13.1 Climate and Weather Monitoring

The location in the interior of Yukon, south of the Wernecke Mountains, is semi-arid but subject to occasional heavy rainstorms. Precipitation is common throughout the year, with the wettest months being July and August and the driest month usually being April. Snow cover is light and blankets the area from October to May. Temperature extremes are characteristic of the area. Winters are long, cold and dark. Summers are mild to cool, often rainy and grey but occasionally interrupted by hot, dry, clear spells. Stream flows generally peak in May with the spring snow melt, but heavy flows also occur in summer and fall during thunderstorms. Long daylight hours in summer are conducive to lush plant growth but the short growing season limits the overall growth rate and size of most vegetation.

2.13.2 Historical Data Collection

The climate data has been collected in the vicinity of the Bellekeno Mine Site using a Campbell Scientific weather station that was established, as part of the mine closure plan for the Keno Hill Property on Galena Hill, in June 2007 by Alexco. The station measures air temperature, relative humidity, barometric pressure, rainfall, wind speed and direction, solar radiation, and soil temperature.

The region around the Keno Hill Silver District has been served by a network of climate monitoring stations (Table 2.5). At least three climate stations have been operated within the boundaries of the silver district. Two of these stations were maintained by the Atmospheric Environment Service (AES) and were located at the Elsa town site and on the southern flank of Keno Hill. The third station was operated on a seasonal basis by DIAND at a site in the Flat Creek catchment near the Elsa town site. In addition to these stations, the AES operate a principal climate station at the Mayo Airport, located some 40 km southwest of Elsa. The data from the Mayo Airport can be combined with that of two discontinued stations in the near vicinity of the airport (i.e. Mayo Landing and Mayo) to construct a long-term climate record.

Mean annual precipitation (MAP) within a mountainous region typically increases with a rise in elevation. The region around the Keno Hill Silver District is no exception to this rule as illustrated by the graph of MAP versus elevation shown on Figure 2.6. The data points on this graph were obtained from the information assembled in Table 2.5 for the regional AES climate stations. The Keno Hill Silver District is in an area of significant relief. Accordingly, MAP can be expected to vary considerably within the boundaries of the district. Figure 2.xx shows the relationship between

MAP and elevation. The slope of this line indicates that MAP increases by an average of 27 mm for every 100 m of ascent, a value not too dissimilar from that observed in other regions of the Yukon interior.

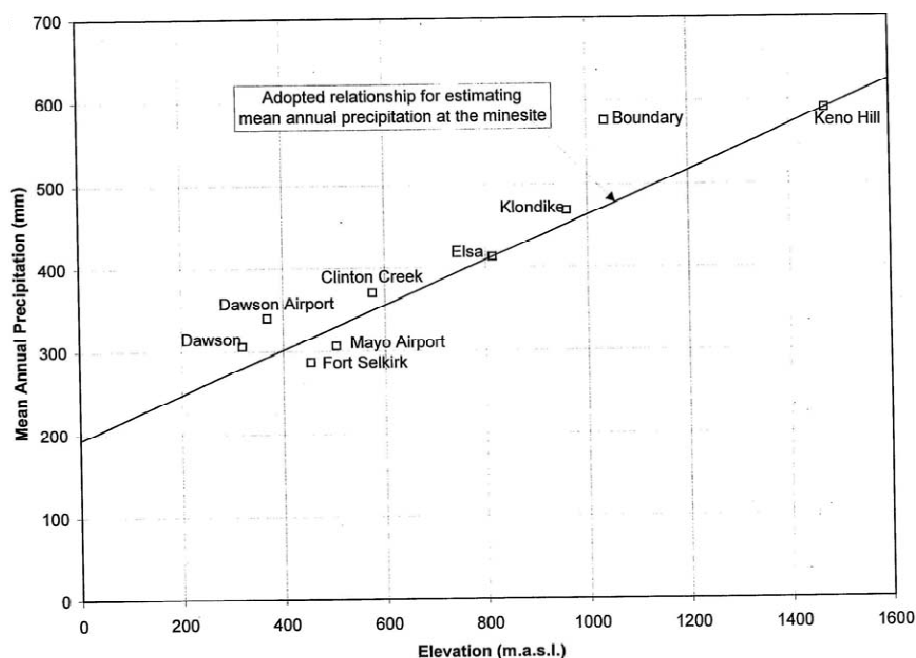


Figure 2.6 Mean Annual Precipitation as a Function of Elevation

Table 2.5 Precipitation and Evapotranspiration at Select Keno Hill District Locations

Site	Mean Annual Precipitation (mm)	Mean Annual Evapotranspiration (mm)	Annual Net Precipitation (mm)	Data Source
Keno Hill (1472 m elevation)	585	205	380	AES Climate Station, UKHM Site Characterization Report, 1996
Elsa Townsite (814m Elevation)	420	230	190	AES Climate Station, UKHM Site Characterization Report, 1996
Bellekeno Mine (1050 m Elevation)	479	221	258	Calculated based on site elevation-precipitation relationship
Flame and Moth mill site (901 m Elevation)	443	227	215	Calculated based on site elevation-precipitation relationship

2.13.3 Geological Setting

The Keno Silver District lies within the Yukon Plateau, just south of the rugged Wernecke Mountains. The terrain consists of concordant, rolling, upland areas separated by wide valleys. Alpine mountain peaks extend above the uplands locally. The area has been influenced by the latest glaciation but shows more subtle evidence of an earlier event as well. The Keno Hill Silver District is located in the western part of the Selwyn Basin in an area dominated by deformed and metamorphosed Upper Proterozoic to Mississippian sedimentary rocks formed at the edge of a continental margin. During the Jurassic and Cretaceous, the area was subjected to compressional tectonic forces producing two major thrust sheets (*Robert Service* and *Tombstone*) and widespread folding. Early large scale deformation produced recumbent folds, resulting in local structural thickening of strata. A second (and possibly third) deformational event produced gentle south westerly plunging syn- and antiform pairs.

The Robert Service Thrust Sheet in the south is composed of Late Proterozoic to Cambrian sandstone, locally with inter-bedded limestone and argillite, a Cambrian to Middle Devonian succession of siltstone, limestone and chert, and Upper Devonian argillite, chert, and chert pebble conglomerate. The latter unit uncomfortably overlies the lower units.

The Tombstone Thrust Sheet to the north consists of Devonian phyllite, felsic meta-tuffs and metaclastic rocks, overlain by Carboniferous quartzite. This latter rock unit is locally thickened due to folding and or thrusting and hosts the mineralization of the Keno Hill Silver District. Intrusive rocks formed during four episodes of plutonism.

Early Palaeozoic fine-grained diabase occurs as metre-scale dikes and sills in the Upper Proterozoic to Lower Cambrian rocks. During the Mid-Triassic, gabbros to diorites formed pods of various sizes, primarily in the Devonian and Mississippian rocks of the Tombstone thrust sheet. A third phase of plutonism took place around ninety-two million years ago in the early Cretaceous and resulted in widespread and voluminous Tombstone intrusions of commonly granitic to granodioritic composition. The youngest magmatic activity occurred around sixty-five million years ago in the Upper Cretaceous and resulted in the formation of peraluminous megacrystic potassium feldspar granite. In addition to where polymetallic veins were exploited, the area hosts a number of occurrences, and showings of tungsten, copper, gold, lead, zinc, antimony and barite. Tin, tungsten, and molybdenite occurrences are possibly related to the suite of Cretaceous intrusion, whereas lead, zinc, and barite occur in stratiform calcareous sedimentary rocks of early to mid-Palaeozoic age typical of sediment-hosted deposits.

3.0 RECEIVING ENVIRONMENT

Lightning Creek (Figure 2.4) encompasses both the reference and receiving environment aquatic habitat where both the fish and benthic invertebrate EEM studies will occur (see section 4.0). The following describes the physical and water quality characteristics of Lightning Creek and factors influencing that quality. Specific details regarding both the reference and receiving areas are presented and include water quality relevant to MMER and this EEM study design. Also included in this section is a summary of previous benthic invertebrate and fish studies conducted in the creek.

3.1 PHYSICAL CHARACTERISTICS

Lightning Creek is situated within a narrow valley with a steep gradient flowing from the north side of Sourdough Hill into Duncan Creek, which drains into the Mayo River. Hope and Thunder Gulches flow into Lightning Creek within the bounds of the Keno Hill Silver District (KHSD). Using the Cowardin et al. (1979) classification, Lightning Creek is an upper perennial riverine system with a sand-gravel-cobble substrate. No natural water storage basins occur along the system.

Lightning Creek is approximately 17.2 km in length (Table 3.1) with an approximate catchment area of 6,200 Ha. from its headwaters to Duncan Creek (Figure 2.4). Mean annual runoff (MAR) was determined to be 0.645 m³/s based on data collected between 2004 -2007 (McCreath and Bryan 2008). Table 3.1 shows relative lengths of the creek and relevant catchment areas within the Lightning Creek catchment basin.

Table 3.1 Stream length and catchment for specific areas within Lightning Creek

Area Description	Basin Area (ha) ^a	Stream Length (m) ^b
Lightning Creek to Thunder Gulch Confluence (not including Thunder Gulch Catchment)	3,796	11,481
Lightning Creek to SWQ Station KV-41	5,695	13,651
Lightning Creek to Duncan Creek Confluence (not including Duncan Creek Catchment)	6,209	17,209
a. Catchment tracing (manual) based on 5 meter contour and hydrology data derived from 2006 aerial imagery (version obtained in 2009) b. measurements based on National Hydrological Network data; data derived from the aerial imagery contained too many intermittent stream. This measurement is the length of the creek from its "most distance" source, which is somewhat arbitrary. See map for more information		

Water is swift flowing in much of the creek which has a gradient ranging from 7.4 % in the upper reaches (source to Thunder Gulch confluence) to 3.3 % between Thunder Gulch and the Water quality sampling site at KV-41 (see Figure 3.1). The gradient between KV-41 and Duncan Creek averages 5.13%.

LIGHTNING CREEK PROFILE

Source to Duncan Creek Confluence

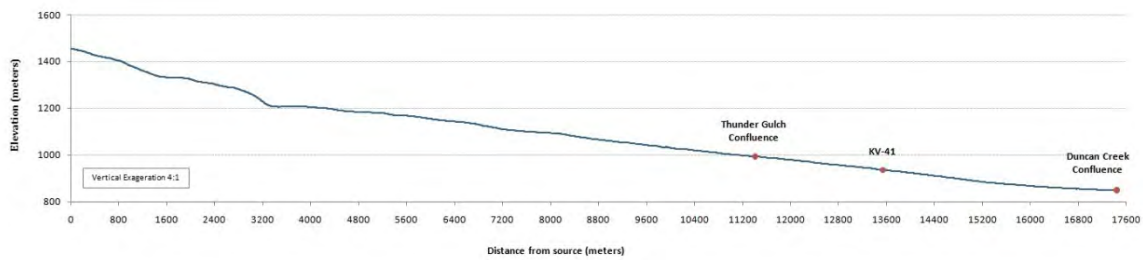


Figure 3.1 Lightning Creek Gradient Profile

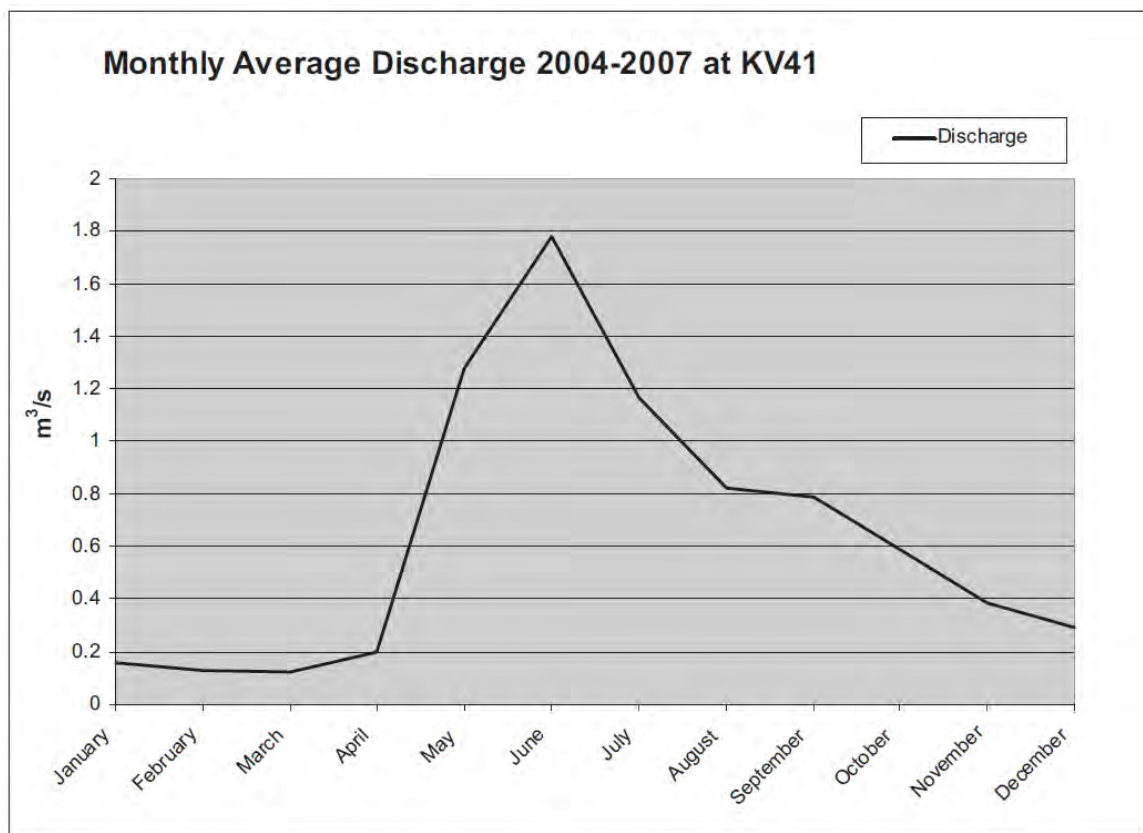


Figure 3.2 Lightning Creek Monthly Average Discharge 2004-2007 at KV41

Discharge in Lightning Creek measured at KV-41 varies from an average low of 0.1 m³/s during winter months to approximately a 1.8 m³/s average during spring/early summer (Figure 3.2). The system is responsive to high rainfall events and can experience very high flows during freshet.

In addition to current and previous quartz mining activity over the years Lightning Creek has also been the site of extensive placer mining upstream of Keno City both historically and at present time. Mine adit drainages from Bellekeno 625 (north side of Sourdough Hill) and Keno 700 (south side of Keno Hill) eventually report to the Lightning Creek drainage.

3.2 HISTORICAL WATER QUALITY

Lightning Creek is notable as it is the only large watershed in the KHSD not connected to the South McQuesten River. There are 9 regularly monitored sites between the background baseline station at KV-37, to the station at the Lightning Creek Bridge near Keno (KV-41), and now the recently added downstream station KV-81, southwest of the Flame and Moth mill (Table 3.2).

Table 3.2 Lightning Creek Catchment Water Quality Monitoring Sites

SITE	SITE DESCRIPTION	MONITORING FREQUENCY
KV-37	Lightning Creek u/s Hope Gulch	Q
KV-38	Lightning Creek u/s Thunder Gulch	Q
KV-39	Hope Gulch u/s Lightning Creek	Q
KV-40	Charity Gulch u/s Lightning Creek	Q
KV-41	Lightning Creek u/s bridge at Keno City	M
KV-65	Thunder Gulch upstream of Bellekeno	M
KV-76	Thunder Gulch d/s of Bellekeno 625 Adit	Q*
KV-77	Thunder Gulch u/s of Bellekeno East	Q
KV-81	Lightning Creek Southwest of Mill Site	Q

* Monthly bioassay

Background water quality data on Lightning Creek is collected at station KV-37. Two creeks, Hope Gulch and Charity Gulch, flow from the south side of Keno Hill into Lightning Creek upstream of Thunder Gulch and the Bellekeno 625 adit flow.

Of these stations, data were investigated for KV-37, KV-38, KV-39, KV-40 and KV-41 during Minnow's water quality assessment (Minnow, 2008). Data for the 4 downstream stations were examined to determine which parameters regularly exceed background concentrations and applicable water quality guidelines. Parameters that exceeded the highest benchmark (background or guideline) in more than 50% of samples included:

- KV-39 – arsenic, cadmium, zinc;
- KV-40 – selenium.

Additional parameters that exceeded both the background concentrations and water quality guideline (if available) in more than 10% of samples collected at each station include:

- KV-38 – silver;
- KV-39 – lead;
- KV-40 – sulphate;
- KV-41 – aluminum, arsenic, chromium, iron, lead, nitrite, silicon, silver, total suspended solids and zinc.

Table 3.3 summarizes total zinc and cadmium levels for the period between 2004 and 2010. while Table 3.4 provides a data summary for 2010 only. Trends for Arsenic and Selenium are charted (Figures 3.3 and 3.4).

Table 3.3 Lightning Creek Catchment 2004 to 2010 Water Quality Summary Statistics

	KV-37	KV-38	KV-39	KV-40	KV-41	KV-65	KV-76	KV-77	KV-81
Zinc, Total (mg/L)									
Average	0.0134	0.024	0.264	0.0078	0.0262	0.0079	0.0192	1.2985	0.0073
Count	23	23	15	12	46	23	13	8	1
Minimum	0.0005	0.0037	0.133	0.0023	0.0074	0.0015	0.003	0.0004	0.0073
Maximum	0.239	0.051	0.468	0.019	0.144	0.065	0.098	9.42	0.0073
Count <DL	3	0	0	0	0	0	0	0	0
Standard Deviation	0.0493	0.0114	0.086	0.0057	0.0219	0.0138	0.0266	3.2876	0
1st Quartile	0.0011	0.0151	0.214	0.003	0.0137	0.0022	0.0052	0.0025	0.0073
Median	0.002	0.0203	0.256	0.0066	0.0202	0.004	0.0061	0.0995	0.0073
3rd Quartile	0.005	0.03	0.29	0.0097	0.0304	0.0054	0.019	0.2722	0.0073
Count Over Standard	1	5	15	0	12	1	3	5	0
% Over Standard	4.3	21.7	100	0	26.1	4.3	23.1	62.5	0
Cadmium, Total (mg/L)									
Average	0.000125	0.00022	0.00312	0.000062	0.000188	0.000068	0.000197	0.013074	0.000075
Count	23	23	15	12	46	23	13	8	1
Minimum	0.000005	0.000033	0.00153	0.00003	0.00004	0.000005	0.000031	0.000005	0.000075
Maximum	0.00255	0.000476	0.00606	0.00016	0.000695	0.0007	0.0009	0.0916	0.000075
Count <DL	11	0	0	0	1	2	0	1	0
Standard Deviation	0.000529	0.000117	0.00104	0.000039	0.000157	0.000144	0.00026	0.031903	0
1st Quartile	0.000005	0.000146	0.00255	0.000037	0.000069	0.000019	0.000045	0.000009	0.000075
Median	0.000012	0.00019	0.00284	0.000045	0.000121	0.000023	0.000074	0.000865	0.000075
3rd Quartile	0.00002	0.000295	0.00359	0.000073	0.000268	0.000043	0.00023	0.003485	0.000075
Count Over Standard	19	23	15	9	46	12	12	6	1
% Over Standard	82.6	100	100	75	100	52.2	92.3	75	100

Table 3.4 Lightning Creek Catchment 2010 Water Quality Summary Statistics

	KV-37	KV-38	KV-39	KV-40	KV-41	KV-65	KV-76	KV-77	KV-81
Zinc, Total (mg/L)									
Average	0.0017	0.0124	0.161	0.0037	0.0118	0.0032	0.0092	9.42	0.0073
Count	4	4	3	2	13	9	3	1	1
Minimum	0.0012	0.0037	0.133	0.0029	0.0074	0.0015	0.005	9.42	0.0073
Maximum	0.0024	0.0203	0.191	0.0045	0.0204	0.0057	0.0167	9.42	0.0073
Count <DL	0	0	0	0	0	0	0	0	0
Standard Deviation	0.0005	0.0068	0.029	0.0011	0.0037	0.0015	0.0065	0	0
1st Quartile	0.0014	0.0104	0.146	0.0033	0.0085	0.0017	0.0055	9.42	0.0073
Median	0.0016	0.0129	0.158	0.0037	0.0112	0.0028	0.006	9.42	0.0073
3rd Quartile	0.002	0.015	0.174	0.0041	0.0141	0.004	0.0113	9.42	0.0073
Count Over Standard	0	0	3	0	0	0	0	1	0
% Over Standard	0	0	100	0	0	0	0	100	0
Cadmium, Total (mg/L)									
Average	0.000013	0.000147	0.00212	0.000051	0.000093	0.000026	0.00016	0.0916	0.000075
Count	4	4	3	2	13	9	3	1	1
Minimum	0.000007	0.000033	0.00153	0.000037	0.000041	0.000018	0.000065	0.0916	0.000075
Maximum	0.000017	0.000242	0.00254	0.000065	0.000267	0.00005	0.000342	0.0916	0.000075
Count <DL	0	0	0	0	0	0	0	0	0
Standard Deviation	0.000004	0.000087	0.00053	0.00002	0.000064	0.000011	0.000157	0	0
1st Quartile	0.000012	0.000115	0.00191	0.000044	0.000049	0.000019	0.000069	0.0916	0.000075
Median	0.000015	0.000157	0.00229	0.000051	0.00006	0.00002	0.000074	0.0916	0.000075
3rd Quartile	0.000016	0.000189	0.00242	0.000058	0.000113	0.000027	0.000208	0.0916	0.000075
Count Over Standard	1	4	3	1	13	2	3	1	1
% Over Standard	25	100	100	50	100	22.2	100	100	100

The Lightning Creek watershed is largely impacted by the Keno 700 adit (and associated waste rock dump). Treatment is not carried out at Keno 700 due to a number of factors, not least of which is the site's extremely remote location. Analysis of data from the Keno 700 adit shows variability in seasonal flows, and a large margin of error in terms of the predicted impacts to Lightning Creek (Minnow 2008).

Zinc concentrations at the background station on Lightning Creek (KV-37) are a small percentage of what they are downstream of mining influences at KV-38 (Table 3.5). Mine related influences from Hope Gulch enter Lightning Creek upstream of KV-38, with the primary source being the Keno 700 adit, which drains directly into Hope Gulch. At KV-38, zinc concentrations are more than four times the background concentration. Cadmium concentrations are also higher at KV-38 by more than ten times. At KV-41, cadmium concentrations fluctuate relative to the concentrations upstream at KV-38. The data suggest that cadmium is generally stable or decreasing between KV-38 and KV-41 (Table 3.5). Zinc between these two stations is also comparable, suggesting that impacts from Thunder Gulch between these sites is minimal relative to the large influence of Hope Gulch (and the Keno 700 Adit) on the overall chemistry of Lightning Creek. It should be noted that the relative impacts of COCs from Hope and Thunder Gulches are not fully understood as a result of the impacts of placer mining activities on Thunder Gulch and mainstem Lightning Creek. The relative impact of the Bellekeno mine has not thus far been discretely detected in Lightning Creek. Treatment of effluent is effective and upstream concentrations/loads of metals are relatively high and variable. Ammonia is the only parameter which is produced solely from Bellekeno Mine operations, because of its origin in blasting.

Figure 3.3 Lightning Creek Catchment, Total As

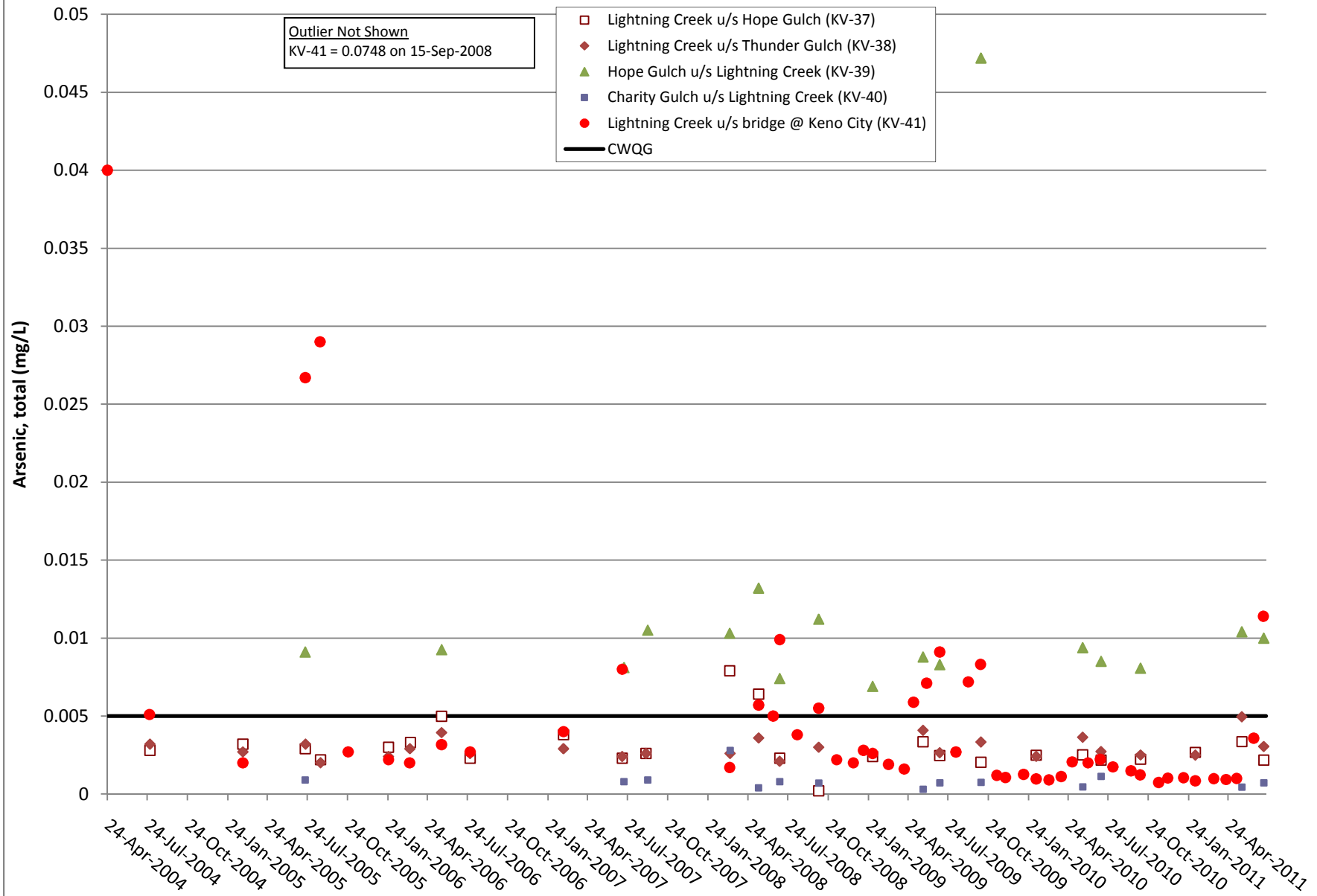


Figure 3.4 Lightning Creek Catchment, Total Se

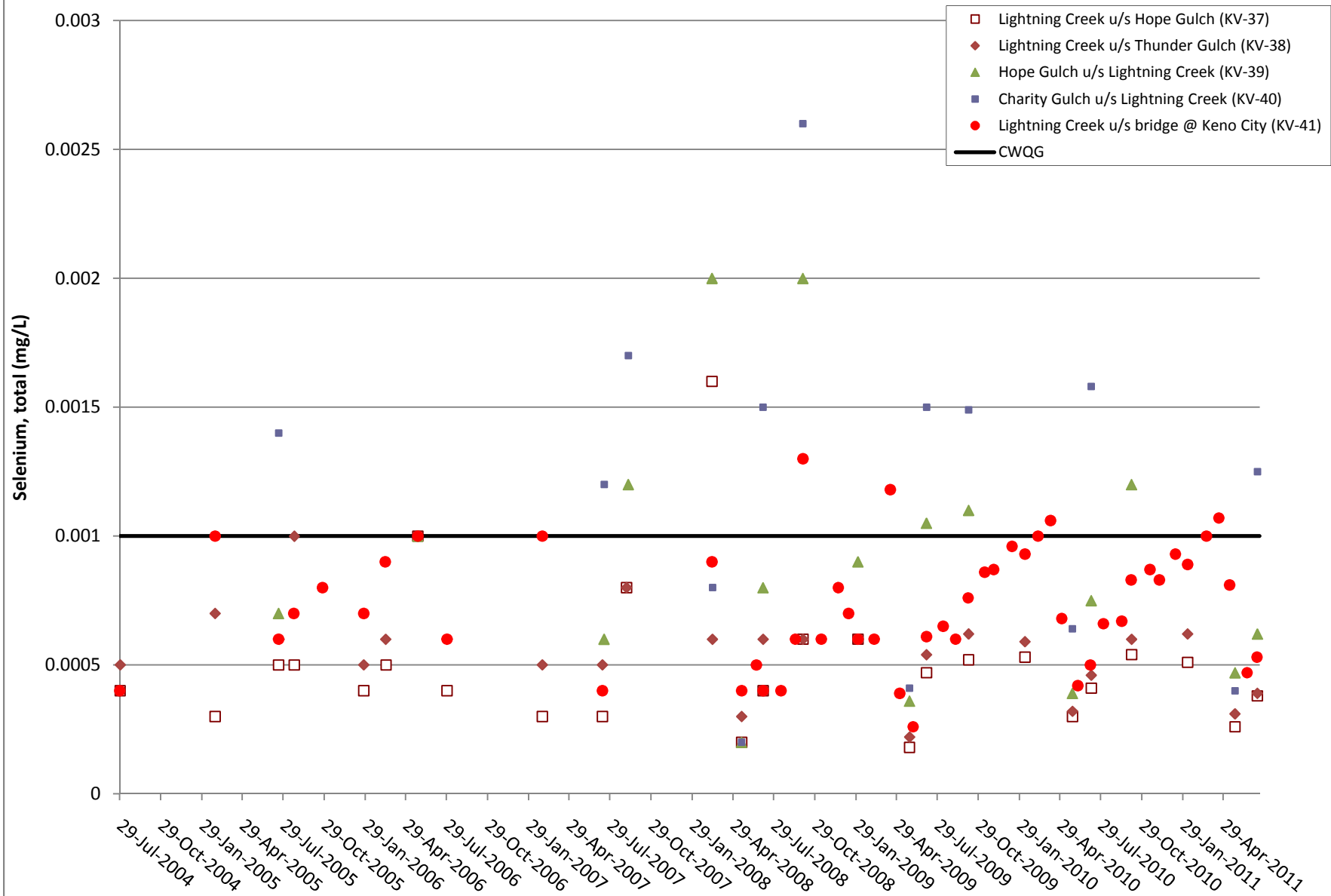


Table 3.5 Change in Zinc, Cadmium and TSS Concentrations along Lightning Creek

Parameter	Year	KV-37	KV-38	KV-41	% change in conc. between KV-37 and KV-38	% change in conc. between KV-38 and KV-41
Zn, total (mg/L)						
	2004	0.008	0.051	0.04	538	-22
	2005	0.001	0.03	0.03	2900	0
	2006	0.006	0.025	0.021	353	-14
	2007	0.006	0.021	0.032	250	52
	2008 ²	0.005	0.026	0.043	478	65
	2009	0.001	0.025	0.026	1854	2
	2010	0.002	0.012	0.012	629	-5
Cd, total (mg/L)						
	2004	0.00001	0.00044	0.00051	4300	16
	2005	0.00001	0.00023	0.00021	2200	-9
	2006	0.00002	0.00023	0.00017	927	-27
	2007	0.00001	0.00016	0.00016	1500	0
	2008	0.00004	0.00022	0.00022	450	0
	2009	0.00002	0.00027	0.00024	1300	-8
	2010	0.00001	0.00015	0.00009	1031	-37
TSS *(mg/L)						
	2004	5	5	20	—	—
	2005	2	2	25	—	—
	2006	6	4	8	—	—
	2008	7	4	72	—	—
	2009	4	5	76	—	—
	2010	2	3	9	—	—

* TSS is not presented showing % change in conc. between the two sites as it fluctuates according to conditions at the time of sampling (i.e. rainfall events).

The lowest levels of cadmium and zinc in Lightning Creek were generally observed in 2010, likely due to the decreasing trend in these contaminants from Hope Gulch (Table 3. 5). Although the influence of the tributaries to Lightning Creek is significant, they do not singularly control the level of metals and total suspended solids in Lightning Creek; placer mining upstream of the property in Lightning Creek contributes significantly to the amount of contaminants entering the creek, particularly total metals.

² 2008 dataset contains an outlier greater than 3 standard deviations from the mean and has been removed from analysis.

Placer mining has taken place on Lightning Creek and Thunder Gulch since at least the 1960s. Placer mining has a significant effect on water quality; however, the extent to which Lightning Creek is impacted by placer mining on the mainstem and tributary is not known, but it can be reasonably accepted that natural water quality has been altered as a result.

Total zinc loading to the watershed from the Keno 700 Adit is approximately 420 kilograms of zinc per year calculated using a hydrologically-based loading model. According to the hydrology model of the KHSD developed in 1996, loadings over the last 10 years have fallen in the range of 320-420 kg/year. In 2010, loading from Keno 700 adit was 323 kg (367 kg in 2009).

3.3 EFFLUENT EXPOSED AREA

For the purposes of this study The Lightning Creek effluent exposed area (EEA) is considered extending from Thunder Gulch to Duncan Creek confluence or approximately 6.0 km of the creek (Figure 2.4). Stream gradient varies from about 3.3 % to 5.13 %. At KV-41 (located approximately midway in the receiving environment) the wetted width of the creek on May 15, 2009 was 4.5 meters. The Ordinary High Water Mark (OHWM) is estimated to be about 10 meters at this location. Substrate within the EEA generally consists of sand, gravel, cobble and boulders with little aquatic vegetation present

Table 3.6 provides a summary of the Lightning Creek exposure station (KV-41) water quality between November 14, 2007 and July 31, 2011. Data are presented for the three phases of activity during this timeframe: care and maintenance, advanced exploration and production. Although no standards are in effect at this location, data are compared with CCME. Actual results from sampling events where these numbers were derived from are appended (Appendix C).

3.4 REFERENCE AREA

The Lightning Creek reference station is located at KV 37 (Figure 2.4) upstream of Hope Gulch and any historical quartz or placer mining activities. The creek at this location is characterized by a relatively steep gradient (> 7%) with swift flows. According to Cowardin et al (1979) this section of Lightning Creek is an upper perennial riverine system with a sand-gravel-cobble substrate. Little or no aquatic vegetation is present in the creek in this upper reach.

Water Quality (Table 3.7) provides a summary of the Lightning Creek reference station (KV-37) water quality between November 14, 2007 and July 31, 2011. Actual results from sampling events where these numbers were derived from are appended (Appendix D).

Table 3.6 Lightning Creek Exposure Station KV-41 Summary of Water Quality

Parameter	Units	CWQG	Averages			Count			Count<DL			Count & %>CWQG		
			care and maintenance ^a	advanced exploration ^b	production ^c	care and maintenance	advanced exploration	production	care and maintenance	advanced exploration	production	care and maintenance	advanced exploration	production
MMER Parameters														
pH (field)	pH units	6.5-9.0	7.89	7.87	7.86	6	15	10	0	0	0	n = 1; 17%	0	0
pH (lab)	pH units	6.5-9.0	7.76	7.86	7.7	7	22	11	0	0	0	0	0	0
Total Suspended Solids	mg/L	-	91	46	12	7	22	11	1	3	1	-	-	-
Arsenic (total)	mg/L	0.005	0.0152	0.00309	0.00211	7	22	12	0	0	0	n = 4; 57%	n = 5; 23%	n = 1; 8%
Copper (total)	mg/L	0.002 - 0.004 ^d	0.013	0.00262	0.00304	7	22	12	1	3	0	n = 6; 86%	n = 7; 32%	n = 2; 17%
Lead (total)	mg/L	0.001 - 0.007 ^d	0.041	0.004984	0.002738	7	22	12	0	0	0	n = 6; 86%	n = 13; 59%	n = 2; 17%
Nickel (total)	mg/L	0.025 - 0.15 ^d	0.0061	0.0013	0.00169	7	22	12	0	4	0	0	0	0
Zinc (total)	mg/L	0.03	0.048	0.0217	0.0123	7	22	12	0	0	0	n = 4; 57%	n = 3; 14%	n = 1; 8%
Radium-226	Bq/L	-	-	-	-	-	-	-	-	-	-	-	-	-
Additional Effluent Quality Characterization Parameters														
Hardness (total)	mg/L	-	-	92.7	108	-	17	12	-	0	0	-	-	-
Alkalinity (total)	mg/L	-	-	-	51	-	-	11	-	-	0	-	-	-
Ammonia Nitrogen (total)	mg/L	0.239 ^e	-	0.04	0.027	-	2	11	-	1	2	-	0	0
Nitrate (as N)	mg/L	2.935	-	-	0.19	-	-	11	-	-	1	-	-	0
Nitrite (as N)	mg/L	0.06	-	-	0.007	-	-	11	-	-	9	-	-	0
Aluminum (total)	mg/L	0.1	1.91	0.2791	0.3959	7	22	12	0	0	0	n = 6; 86%	n = 10; 46%	n = 3; 25%
Cadmium (total)	mg/L	0.000017 ^d	0.00025	0.000182	0.000112	7	22	12	0	0	0	n = 7; 100%	n = 22; 100%	n = 12; 100%
Chromium (total)	mg/L	0.001	0.0041	0.0007	0.0011	7	22	12	0	1	0	n = 6; 86%	n = 4; 18%	n = 2; 17%
Iron (total)	mg/L	0.3	4.71	0.506	0.698	7	22	12	1	0	0	n = 6; 86%	n = 8; 36%	n = 2; 17%
Mercury (total)	mg/L	0.000026	-	0.00001	0.00001	-	14	12	-	7	8	-	0	n = 1; 8%
Molybdenum (total)	mg/L	0.073	0.00051	0.00024	0.00028	7	22	12	5	2	0	0	0	0
Selenium (total)	mg/L	0.001	0.0006	0.00067	0.00082	7	22	12	1	3	0	n = 1; 14%	n = 2; 9%	n = 1; 8%
Silver (total)	mg/L	0.0001	0.00075	0.000046	0.000061	7	22	12	1	7	4	n = 5; 71%	n = 4; 18%	n = 2; 17%
Thallium (total)	mg/L	0.0008	0.00004	0.000007	0.000007	7	21	12	5	12	7	0	0	0

^a Care and maintenance data from November 14, 2007 to October 2, 2008.

^b Advanced exploration data from October 3, 2008 to September 6, 2010.

^c Production data from September 7, 2010 to July 31, 2011.

^d Cadmium, copper, lead and nickel guidelines more accurately determined when taking into consideration water hardness.

^e Conservative ammonia guideline based on pH and temperature not exceeding 8.5 and 15°C respectively.

Table 3.7 Lightning Creek Reference Station KV-37 Summary of Water Quality

Parameter	Units	CWQG	Averages			Count			Count<DL			Count & %>CWQG		
			care and maintenance ^a	advanced exploration ^b	production ^c	care and maintenance	advanced exploration	production	care and maintenance	advanced exploration	production	care and maintenance	advanced exploration	production
MMER Parameters														
pH (field)	pH units	6.5-9.0	7.38	7.57	7.82	4	6	4	0	0	0	0	0	0
pH (lab)	pH units	6.5-9.0	7.48	7.68	7.47	4	7	4	0	0	0	0	0	0
Total Suspended Solids	mg/L	-	5	3	4	4	7	4	2	2	0	-	-	-
Arsenic (total)	mg/L	0.005	0.0042	0.00249	0.00261	4	7	4	1	0	0	n = 2; 50%	0	0
Copper (total)	mg/L	0.002 - 0.004 ^d	0.001	0.00057	0.00073	4	7	4	3	1	0	n = 1; 25%	0	0
Lead (total)	mg/L	0.001 - 0.007 ^d	0.0006	0.0002	0.000734	4	7	4	1	1	0	n = 1; 25%	0	n = 1; 25%
Nickel (total)	mg/L	0.025 - 0.15 ^d	0.0013	0.00042	0.00054	4	7	4	1	1	0	0	0	0
Zinc (total)	mg/L	0.03	0.062	0.0014	0.0023	4	7	4	1	1	0	n = 1; 25%	0	0
Radium-226	Bq/L	-	-	-	-	-	-	-	-	-	-	-	-	-
Additional Effluent Quality Characterization Parameters														
Hardness (total)	mg/L	-	-	50.4	50.4	-	6	4	-	0	0	-	-	-
Alkalinity (total)	mg/L	-	-	-	27	-	-	4	-	-	0	-	-	-
Ammonia Nitrogen (total)	mg/L	0.239 ^e	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	2.935	-	-	-	-	-	-	-	-	-	-	-	-
Nitrite (as N)	mg/L	0.06	-	-	-	-	-	-	-	-	-	-	-	-
Aluminum (total)	mg/L	0.1	0.204	0.0239	0.0286	4	7	4	1	0	0	n = 1; 25%	0	0
Cadmium (total)	mg/L	0.000017 ^d	0.00066	0.000016	0.000026	4	7	4	1	1	0	n = 4; 100%	n = 4; 57%	n = 1; 25%
Chromium (total)	mg/L	0.001	0.0007	0.0003	0.0004	4	7	4	2	1	0	n = 1; 25%	0	0
Iron (total)	mg/L	0.3	0.28	0.063	0.077	4	7	4	1	0	0	n = 1; 25%	0	0
Mercury (total)	mg/L	0.000026	-	0.00001	0.00001	-	5	4	-	5	4		0	0
Molybdenum (total)	mg/L	0.073	0.00038	0.00009	0.00011	4	7	4	4	1	0	0	0	0
Selenium (total)	mg/L	0.001	0.0006	0.00039	0.00042	4	7	4	2	1	0	n = 1; 25%	0	0
Silver (total)	mg/L	0.0001	0.00002	0.000005	0.000008	4	7	4	3	5	3	0	0	0
Thallium (total)	mg/L	0.0008	0.00002	0.000002	0.000001	4	7	4	4	7	3	0	0	0

^a Care and maintenance data from November 14, 2007 to October 2, 2008.

^b Advanced exploration data from October 3, 2008 to September 6, 2010.

^c Production data from September 7, 2010 to July 31, 2011.

^d Cadmium, copper, lead and nickel guidelines more accurately determined when taking into consideration water hardness.

^e Conservative ammonia guideline based on pH and temperature not exceeding 8.5 and 15°C respectively.

3.5 BENTHIC INVERTEBRATE COMMUNITY SURVEY

Benthic invertebrate sampling has taken place sporadically over the years in the KHSD, dating back to 1975. Environmental Protection Services carried out biological monitoring in the area in 1975, 1985 and 1990. In compliance with past water licences, various consultants have carried out annual benthic sampling (between 1986 and 1990) at four separate locations. As part of a biological monitoring survey conducted in 1994 by Laberge Environmental Services (LES), benthic invertebrate sampling was also conducted. On behalf of ERDC, Access Consulting Group (ACG) contracted Laberge Environmental Services (LES) to conduct stream sediment and benthic invertebrate monitoring in the summer of 2007. Stream sediment samples and benthic invertebrates were collected from each of the receiving water sites during the August sampling period.

In general, from surveys of the Lightning Creek drainage, benthic invertebrate communities have been found to be both robust and healthy, being comprised of a good representation of pollution sensitive insects, indicating healthy environments in these areas (Table 3.8; Laberge Environmental Services, 2008).

The following data was collected in Lightning Creek, at sites KV37, KV38, and KV41, in 2007. All supporting information may be found in Keno Valley Stream Sediment and Benthic Invertebrate Programs, 2007 Report. Triplicate samples for benthic invertebrates were collected at each site with attempts made to collect samples representative of that site. The number of organisms of the triplicates was summed to give a total abundance value for that site.

Table 3.8 Taxonomic Richness Index of Benthic Invertebrates

Lightning Creek Sites	Total benthic invertebrates collected	Community Diversity	Taxonomic Richness Index
KV 37	2392	39	4.9
KV 38	8684	49	5.3
KV 41	3800	47	5.6

(LES, 2008: Keno Valley Stream Sediment and Benthic Invertebrate Monitoring Programs, 2007)

Many variables contribute to invertebrate productivity, such as water temperature, air temperature, rainfall, canopy cover, substrate type and size, stream depth and velocity, as well as water and sediment quality. The life cycles of various organisms can dictate population size if an emergence is captured during the time of sampling.

The communities on Lightning Creek were diverse with good representation of sensitive taxa (Table 3.9). Water quality and stream sediment metal concentrations were relatively similar to those of the South McQuesten River, and do not appear to be causing any adverse effects to the benthic communities. The sites on Lightning Creek had good representation with 9 or 10 sensitive groups present. The table below classifies taxa with respect to their dominance within the community.

Table 3.9 Taxa community occurrence

Site	KV 37	KV 38	KV 41
Dominant (≥25%)	Diptera Plecoptera	Diptera	Hydracarina
Subdominant (10% - 24.9%)	Hydracarina	Plecoptera Hydracarina	Diptera Plecoptera
Common (1.0% - 9.9%)	Ephemeroptera Trichoptera	Ephemeroptera	Trichoptera Ephemeroptera
Rare (0.1% - 0.9%)		Trichoptera	-

(LES, 2008: Keno Valley Stream Sediment and Benthic Invertebrate Monitoring Programs, 2007)

All study methodologies used artificial substrate samplers with a colonization period of five to six weeks with triplicate samples collected at each site. As the same methodologies were employed for the various sample events, legitimate comparisons can be made.

3.6 FISH SURVEYS ON LIGHTNING CREEK

Fisheries resource data for Lightning Creek and surrounding drainages is limited to information collected by Access Consulting Group (Access) in September 2008 and White Mountain Environmental Consulting (WMEC) in 1995 and 2006. Investigations of fish and fish habitat at numerous sites, including two sites located on Lightning Creek has confirmed the presence of slimy sculpins (*Cottus cognatus*), Arctic grayling (*Thymallus arcticus*)(Access, 2008), and round whitefish (*Prosopium cylindraceum*)(WMEC, 2006). It is suspected that these fish likely winter in downstream of Duncan Creek where flows are higher and more likely to be suitable to sustain the fish.

It was determined by WMEC that Lightning Creek had undergone significant channel changes during the 12 year span between sampling events (1995 and 2006) as a result of placer mining. The locations of the sample sites used in 1995 were no longer available for sampling as the creek channel had recently been altered and active placer mining was occurring adjacent to the old site. Two new sample locations downstream of the original sites were selected; each site provided different habitat types allowing more representative sampling for Lightning Creek.

Access Consulting Group's fisheries investigations in 2008 were conducted at the two sampling sites that WMEC had re-established in 2006. These investigations were comprised of fish sampling, habitat assessments and fish surveys to identify the presence of species and utilization of the area. Fish and fish habitat investigations were conducted on September 18, 2008 at the two previously established sampling sites on Lightning Creek. The primary method of assessment was via minnow trapping. Electrofishing was conducted at only three sites due to the lack of suitable electrofishing habitat and potentially unsafe conditions. These sites included two locations on Lightning Creek and one site on Christal Creek. Seining was also conducted by White Mountain Environmental Consulting in 2006.

During the 2008 sampling event completed by Access, the sample area had just experienced a considerable period of above normal precipitation and, as a result, most sample locations were exhibiting elevated discharge rates and increased turbidity. These two factors limited the extent of electrofishing attempted during this investigation, and likely had a negative effect minnow trapping results.

Both Gee minnow trapping and electrofishing methods were employed at two sites on Lightning Creek. One site (LgT K) is located adjacent to the Keno City campground which is located in the heart of Keno City and the second site (LgT D) is located downstream of LgT K, just above the confluence of Lightning Creek and Duncan Creek.

3.6.1 Results of Previous Investigations

Lightning Creek – LgT K (near KV-41): no fish were captured via the minnow trapping. Electrofishing was conducted (100 s.) however no fish were captured or observed (Table 3.10; Access, 2008). Site LgT K consists of fast flowing rapids ($v = >1.5$ m/sec) over highly compacted boulders with plunge pools associated with both the culvert and the old bridge. A pool upstream of the culvert creates the widest section of this reach.

Lightning Creek – LgT D (at Duncan Creek Confluence): four (4) slimy sculpins (*Cottus cognatus*) were captured via minnow trapping (Access 2008). Electrofishing was conducted (402 s) resulting in the capture of four juvenile Arctic grayling (*Thymallus arcticus*) and two slimy sculpins (*Cottus cognatus*) (WMEC, 2006). The lower reach, site LgT D has a much slower flow ($v = <1$ m/sec) with unconsolidated gravel substrates.

As stated in the White Mountain Environmental Consulting report issued for 2006, the Lightning Creek sites differed in fish species composition (Table 3.10). Site LgT K had only Arctic grayling, both adults and juveniles during June, August and September. Site LgT D had a greater diversity of speciation with slimy sculpins, round whitefish and Arctic grayling common during both August and September. Electrofishing at site LgT D was not conducted during the spring investigation due to high water.

Table 3.10 Previous fish sampling effort and results on Lightning Creek

Year, Study	Month	Stream /Site	Method	Effort		Round Whitefish	Slimy Sculpin	Arctic Grayling
White Mountain Environmental Consulting 2006	Jun	LgT K	Electrofishing	497s	number	-	-	7
					#/min	-	-	0.84
		LgT D	Minnow Trap	3	number	-	-	-
			Electrofishing	270	number	-	-	-
					#/min	-	-	-
			Minnow Trap	NR	number	-	-	-
	Aug	LgT K	Electrofishing	659s	number	-	-	25
					#/min	-	-	2.3
		LgT D	Minnow Trap	3	number	1	1	
			Electrofishing	340s	number	-	2	-
					#/min	-	0.35	-
			Minnow Trap	3	number		1	
	Sept	LgT K	Electrofishing	265s	number	-	-	11
					#/min	-	-	2.6
		LgT D	Minnow Trap	NR	number	-	-	-
			Electrofishing	NA	number	-	-	
					#/min	-	-	
Access Consulting Group 2008	Sept	LgT K	Electrofishing	100	number	-	-	-
					#/min	-	-	-
			Gee Trap	2	number	-	-	-
					#/min	-	-	-
		LgT D	Electrofishing	402	number	-	2	4
					#/min	-	0.3	0.6
			Gee Trap	3	number	-	-	-
					#/min	-	4	-

4.0 EEM STUDY DESIGN – CYCLE ONE

The Bellekeno Mine Cycle 1 EEM will include benthic invertebrate community and fish population surveys together with supporting measures required in data interpretation. Other EEM components implemented by the Bellekeno Mine are briefly discussed as part of this study design (sublethal toxicity testing, effluent characterization and water quality monitoring). A fish usability assessment is also required at the Bellekeno Mine because mercury concentrations in final effluent were less than the detection limit but the detection limit was greater than 0.10 g/L (Section 2.3.3; per Environment Canada 2002a).

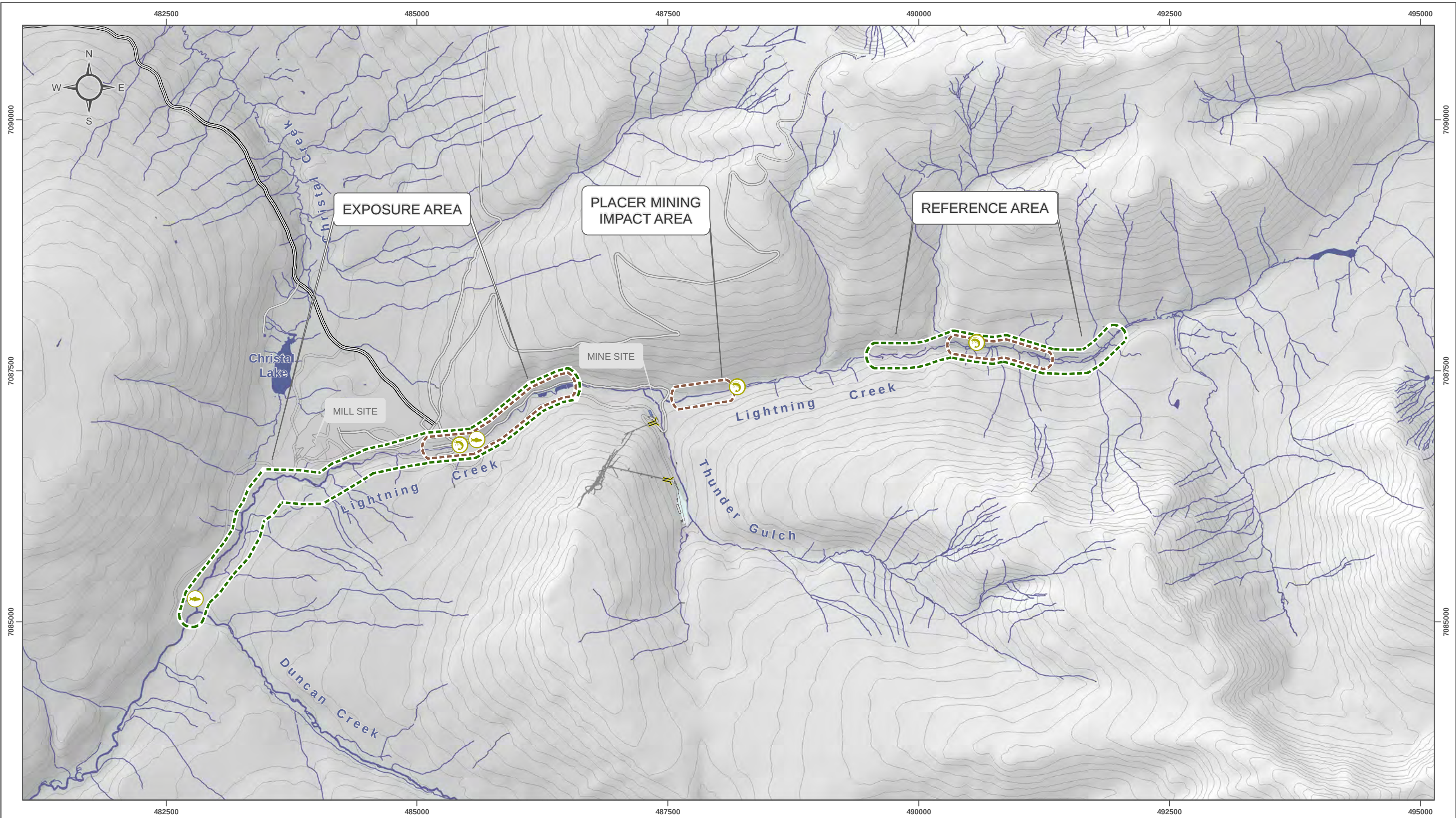
Lightning Creek is the immediate receiver of the Bellekeno Mine effluent, and therefore biological monitoring study areas will be established in this watercourse. Three EEM study areas are proposed, including one effluent-exposed area located downstream of the mine discharge and two reference areas located upstream of the Bellekeno Mine discharge in Lightning Creek (Figure 4.1). Placer mining is conducted immediately upstream of the Bellekeno Mine discharge in Lightning Creek and in Thunder Gulch (i.e., a tributary that discharges into Lightning Creek immediately upstream of the mine). Therefore, the reference areas will be located within and upstream of the area of placer mine disturbance (Figure 4.1) in order to distinguish any Bellekeno Mine effluent biological influences from those potentially associated with the placer mine operations. Benthic invertebrate community sampling will be conducted in erosional habitat at all three proposed study areas (Figure 4.1). Because no physical barriers separate the effluent-exposed and reference areas and fish densities are expected to be low (see section 3.5), fish population sampling will only be conducted at the effluent-exposed area and upstream-most (i.e., uninfluenced by placer mining) reference area (i.e. area uninfluenced by placer mining; Figure 4.1). Detail on all components of the Bellekeno Mine Cycle 1 EEM is provided in the following sections.

4.1 BENTHIC INVERTEBRATE COMMUNITY SURVEY

The Bellekeno Mine Cycle 1 EEM benthic invertebrate community survey will follow a multiple-Control/Impact (MCI) design with quantitative sampling to be conducted in erosional habitat of the Lightning Creek effluent-exposed area and two upstream reference areas (i.e., at placer mining influenced and uninfluenced areas; Table 4.1). The benthic invertebrate community survey will be conducted in late August/early September 2012, which is consistent with the seasonal timing of previous studies (e.g., Laberge 2008).

4.1.1 Sample Collection

Benthic samples will be collected using a 0.1 m² Hess Sampler outfitted with 250-µm mesh. Five stations will be sampled at each study area to provide adequate statistical power to detect differences of $\pm$ two standard deviations at an α and β of 0.10 (Environment Canada 2002a). Stations will be established at a minimum distance of three bankfull widths from adjacent stations at each study area, consistent with the spacing suggested by Environment Canada (2002a).



Aerial photograph obtained from Geodesy Remote Sensing Inc., Calgary Alberta. Imagery acquired September 13 and 14 2006. Site hydrography and contours provided by Aero Geometrics LTD, derived from aerial photograph.

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

1:35,000 (when printed on 11 x17 inch paper)



-  Proposed Benthic and Invertebrate
-  Proposed Fisheries Survey

-  Previous Benthic and Invertebrate Study
-  Previous Fisheries Study



**BELLEKNO MINE PROJECT - ENVIRONMENTAL
EFFECTS MONITORING PROGRAM - CYCLE I STUDY DESIGN**

**FIGURE 4.1
BENTHIC, INVERTABRATE AND FISHERIES
SAMPLING AREAS**

DRAWN BY MD	SEPTEMBER 2011	VERIFIED BY VB
-------------	----------------	----------------

I:\ALEX-05-01\Bellekno\GIS\mxd\Studies\EEM_Cycle_1\Fig4.1_LightningCreek_Study Area_20110907.mxd
(Last edited by: mducharme, 07/09/2011 1:44:42 PM)

At each station, one sample representing a composite of three sub-samples (i.e., 0.3 m² total area) will be collected to ensure that each sample is representative of the resident benthic invertebrate community. Each sub-sample will be collected by carefully inserting the base of the Hess sampler into undisturbed substrate to a depth of approximately 10 cm. All gravel and cobble contained within the sampler will be carefully washed, allowing the current to carry dislodged organisms into the collection net. After all substrate within the sampler has been completely washed and all organisms have been rinsed into the collection net, the sampler will be moved to the next sub-sample location and the procedure repeated. Following collection of the third sub-sample using the above procedure, all material and organisms retained in the collection net will be carefully transferred into pre-labeled wide-mouth plastic jars. As a precautionary measure, internal sample labels will also be used to ensure correct sample identification at the lab. All samples will then be preserved to a level of 10% buffered formalin in ambient water.

Substrate size, water depth and water velocity will be carefully controlled among areas, stations and sub-samples to minimize natural influences on benthic invertebrate community variability. All sampling stations will be marked using a handheld global positioning system (GPS), with coordinates recorded in latitude and longitudes to nearest decimal second using the North America Datum (NAD) of 1983. A number of additional supporting measures will be recorded at each benthic invertebrate sampling station as outlined in Section 4.4.

4.1.2 Sample Processing

Benthic invertebrate samples will be shipped to and processed by a qualified laboratory using standard sorting methods which adhere to EEM Quality Assurance/Quality Control (QA/QC) protocols (i.e., Environment Canada 2002, 2011). Sample material greater than 250 µm in diameter will be examined under a stereomicroscope at a magnification of at least ten times by a technician. All benthic organisms will be removed from the sample debris and placed into vials containing 70% ethanol according to major taxonomic groups (i.e., phyla and orders). A senior taxonomist will then enumerate and identify the benthic organisms to the lowest practical level (typically genus or species) using the most up-to-date taxonomic keys, which exceeds minimum “family level” requirements of Environment Canada (2011). Following identification, representative specimens of each taxon will be preserved in a 75% ethanol-3% glycerol solution in separately labeled vials to create a Bellekeno Mine voucher benthic invertebrate collection that will be retained for possible future reference.

4.1.3 Data Analysis

Benthic invertebrate communities will be compared using EEM primary metrics of mean taxon richness (as identified to the lowest practical level), mean invertebrate density (average number of organisms per m²), Simpson’s Evenness Index (E) and the Bray-Curtis Index of Dissimilarity as required by Environment Canada (2011). Additional comparisons may be conducted based on EPT taxa (i.e., number of taxa represented by the insect orders Ephemeroptera, Plecoptera and Trichoptera), percent composition of dominant/indicator taxa (calculated as the abundance of each respective taxon group relative to the total number of organisms in the sample) and/or

correspondence analysis. All required and selected benthic invertebrate community endpoints will be summarized by separately reporting mean, median, minimum, maximum, standard deviation, standard error and sample size for each study area.

For each of the benthic invertebrate community endpoints, statistical comparisons between effluent-exposed and reference areas will be conducted using Analysis of Variance (ANOVA) and post-hoc tests. Data will be assessed for normality and transformed as required to stabilize variances and satisfy assumptions of ANOVA. Non-parametric techniques will be used in instances in which transformation is unsuccessful in normalizing data or homogenizing variances. All benthic indices will be plotted to explore spatial patterns and illustrate differences between effluent-exposed and reference areas as part of the data interpretation. For each benthic invertebrate metric in which a significant difference is found between effluent-exposed and reference area means, the magnitude of difference between areas will be calculated based on the number of reference area mean SDs as follows:

$$(\text{effluent-exposed area mean} - \text{reference mean}) / \text{SD of the reference mean}$$

If a significant difference between areas is not detected for a benthic metric, then the minimum effect size that could be detected will be calculated using the mean square error generated from the ANOVA as an estimate of variability, with alpha and beta equal to 0.10. The minimum detectable effect size will be based on the minimum number of reference area standard deviations, according to the following equation:

$$\delta = [(t_{\alpha} + t_{\beta})(\sqrt{\text{MSE}})(\sqrt{2/n})] / \text{SD}_{\text{ref}}$$

where, δ = minimum detectable effect size,

MSE = mean square error

n = sample size per area (in this case = 5), and

SD_{ref} = standard deviation of the reference area mean

Correlation analysis will then be used to determine significant relationships between benthic invertebrate community metrics and supporting physical and chemical measures. Lastly, data from the Cycle 1 EEM benthic invertebrate community survey will be compared to any applicable historical information for Lightning Creek.

4.2 FISH POPULATION SURVEY

The Bellekeno Mine Cycle 1 EEM fish population survey will follow a lethal design targeting one small-bodied sentinel fish species collected at the Lightning Creek effluent-exposed area and the upstream-most reference area (Figure 4.1). Based on available historical data, slimy sculpin (*Cottus cognatus*) is the only species likely to be found in relatively high abundance and at a suitable life-history stage (i.e., adult) for evaluation of all EEM endpoints in Lightning Creek, and therefore will serve as the sentinel species for the fish population survey. Slimy sculpin are demersal benthivores with relatively short age-to-maturation (Scott and Crossman 1998) and

small home range size, making them an ideal sentinel species for EEM studies. At each of the effluent-exposed and upstream-most reference study areas, 20 sexually mature male and 20 sexually mature female slimy sculpin will be targeted to support a lethal EEM fish population survey. Although the technical guidance for the EEM program (Environment Canada 2011) stipulates two species be evaluated as part of the fish population survey, arctic grayling (*Thymallus arcticus*) and round whitefish (*Prosopium cylindraceum*), the only two other species historically captured in Lightning Creek are not likely to be present in sufficient numbers and/or at a suitable life stage for evaluation of EEM fish population endpoints. Moreover, adult arctic grayling typically overwinter in large water bodies and thus individuals are unlikely to be resident to Lightning Creek (i.e., a relatively small watercourse) throughout the year. Therefore, this species would not likely be exposed to mine effluent for substantial periods, precluding their usage for the fish population assessment.

The proposed timing for the fish population survey is late-May to early-June 2012, corresponding to the period prior to freshet and to slimy sculpin spawning. Slimy sculpin generally spawn at a water temperature of approximately 10°C (Scott and Crossman 1998) and therefore the proposed survey timing should allow collection of reproductive endpoint data for this species.

4.2.1 Sample Collection

Fish communities of each study area will primarily be sampled semi-quantitatively using a battery-powered backpack electrofishing unit. An electrofishing team, consisting of the electrofisher operator and a single netter, will conduct passes (or “sweeps”) within each sampling area as required to yield the targeted numbers. All fish captured during each pass will be placed in aerated buckets of water. At the conclusion of each pass, total shocking effort (i.e., electrofishing seconds) will be recorded. Additional fishing methods, including use of minnow traps, will be used should electrofishing not yield sufficient numbers of mature slimy sculpin to meet EEM requirements. For each sampling method, all captured fish will be identified and enumerated, with all non-target fish species subsequently released to the waters from which they were captured and all sentinel species retained in aerated buckets of water for further processing. The study will target 20 mature male and 20 mature female slimy sculpin (for lethal measurements) from each study area. A reasonable fishing effort will be employed to collect the requisite number of fish, however based on low fish abundance documented in previous studies (Sparling 2006, Sparling and Connor 1996) a full complement of male and female slimy sculpin are not expected in either the reference or exposure area.

Supporting information collected for each fish sampling method will include duration of sampling, mean sampling depth, distance/area sampled, habitat features of the area sampled (see Section 4.4) and GPS coordinates (latitude and longitude recorded in decimal seconds) of each net set or at the upstream and downstream boundary of each sampled reach.

4.2.2 Fish Processing

Physiological measurements collected from each fish will include all those recommended for the EEM program (Environment Canada 2011). Specifically, body length, fresh body weight, external condition, sex, fresh gonad and liver weight, fecundity and egg-size (females only), and age will be measured/assessed from freshly sacrificed, sexually mature slimy sculpin (total of 20 males and 20 females) from each study area as part of the lethal survey. Total length of all mature slimy sculpin will be measured to the nearest hundredth of a millimetre using digital calipers. Fresh body-weight will then be measured using an analytical balance with an accuracy of 0.001 g. For slimy sculpin subject to lethal measures, the visceral cavity of each sacrificed fish will be opened and the gender and/or sexual maturity level determined and recorded. Whole gonads and livers will subsequently be excised and weighed to the nearest milligram (0.001 g) using an analytical balance with a surrounding draft shield. Following removal and weighing, whole ovaries from each female will be placed in individually labeled sampling jars, preserved with 10% buffered formalin, and subsequently submitted to a qualified laboratory for determination of fecundity and egg size. Whole carcasses of sacrificed individuals will then be placed separately into labeled plastic bags and frozen prior to laboratory submission for age analysis using extracted otoliths. For all sampled slimy sculpin, any visible external or internal abnormalities will also be noted and recorded on data sheets.

4.2.3 Laboratory Processing

All ageing structures will be processed by a qualified fish age determination laboratory. Otoliths will be removed from each fish, sectioned using a crack-and-burn method, mounted on a glass slide and aged under a compound microscope using transmitted light. For each otolith sample, the age and edge condition will be recorded along with a confidence rating for the age determination.

All fish ovary samples will be processed by a qualified biological laboratory. Methods utilized for fecundity estimation will be fully consistent with available technical guidance (Environment Canada 2011), with the number of eggs in each sample enumerated using stereo-microscopes and ten percent of egg samples re-counted to verify the precision of fecundity estimates. For quality control purposes, fecundity re-counts will be conducted on 10% of the processed fecundity samples.

4.2.4 Data Analysis

Data analysis methods will follow those recommended for EEM fish surveys (Environment Canada 2011). All catch data will be tabulated, and catch-per-unit-effort (CPUE) will be calculated for each study area and fish collection method. Variables measured on the sacrificed sentinel species (Section 4.2.2) will be summarized by separately calculating the mean, standard deviation, standard error, minimum, maximum and sample size by study area (effluent-exposed and reference) and sex (male and female). These variables will be used to evaluate endpoints associated with survival, energy use (growth and reproduction) and energy storage between

effluent-exposed and reference populations (Table 4.1). Each data set will be assessed for normality and equality of variance in order to determine the suitability of parametric statistical procedures. If data significantly violate the assumption of normality following transformation, non-parametric statistics will be applied. For each of the calculated endpoints, statistical differences between effluent-exposed and reference study areas by fish sex will be made using Analysis-of-Variance (ANOVA), Mann-Whitney U-tests or Analysis-of-Covariance (ANCOVA) as appropriate and following technical guidance (Table 4.1; Environment Canada 2011). An effect on the fish population will be evaluated for each of the calculated endpoints, which is defined as a statistically significant difference between the effluent-exposed area and the reference area (sharing like-habitat) at an alpha level of 0.10 (Environment Canada 2011).

4.3 FISH TISSUE SURVEY

A fish tissue survey is required as part of the EEM program for the Bellekeno Mine because while effluent mercury concentrations are below the detection limit, the detection limit was above the trigger level of 0.10 µg/L. The fish tissue assessment will be conducted to document and compare fish tissue mercury concentrations between the effluent-exposed area and upstream-most reference area in Lightning Creek to evaluate whether human consumption of fish is (or should be) limited by tissue mercury concentrations (Environment Canada 2011). Fish tissue samples will be collected from the effluent-exposed area and upstream-most reference area (Figure 4.1). The proposed timing for the fish tissue survey is late-May to early-June 2012, corresponding to the same period used for the fish population survey. Arctic grayling will be targeted for the fish tissue assessment, mainly due to its regional importance as a sport fish, but also because this species represents a top predator (i.e., likely to incorporate highest contaminant body burdens within aquatic ecosystem). Given that densities of arctic grayling are expected to be low (see Section 3.5), non-lethal collection of fish tissue samples is proposed.

4.3.1 Field Collection

Fish tissue samples will be taken from arctic grayling by-catch collected during sampling for the fish population assessment based on the methods described previously (Section 4.2.1). To the extent possible given potentially low fish abundances, eight arctic grayling will be retained from each study area for non-lethal muscle tissue sampling with attempts made to sample fish reflecting a similar size range from both study areas.

4.3.2 Fish Processing

Catch results permitting, eight juvenile arctic grayling from each area will be subjected to a non-lethal sampling technique (Baker et al. 2004). Specimens used for sampling will be maintained in a dilute anaesthetic clove oil-based bath until stage five of anaesthesia is reached (i.e., when fish reactivity and reflexes are absent and opercular movements are slow and irregular; Summerfelt and Smith 1990). Once each individual fish is sufficiently anaesthetized, each individual will be subject to measurement of length (fork and total) and weight, examination for any abnormalities, and collection of ageing structures (scales). The fish will then be placed onto a

Table 4.1 Endpoints to be examined as part of the Bellekeno Mine Cycle 1 EEM fish population survey

Response		Endpoint	Statistical Procedure ^{c,d,e}
Effects on Fish ^a	Survival	Age	ANOVA
	Energy Use	Size-at-age (body weight against age)	ANCOVA
		Relative gonad size (gonad weight against body weight)	ANCOVA
	Energy Storage	Condition (body weight against length)	ANCOVA
		Relative liver size (liver weight against body weight)	ANCOVA
Supporting Response Variables ^b	Survival	Age-frequency distribution	K-S Test
	Energy Use	Body weight (whole)	ANOVA
		Length	ANOVA
		Size-at-age (length against age)	ANCOVA
		Relative fecundity (# of eggs/female against body weight)	ANCOVA
		Relative fecundity (# of eggs/female against age)	ANCOVA
		Fecundity	ANOVA
		Relative egg size (mean egg weight against body weight)	ANCOVA
		Relative egg size (mean egg weight against age)	ANCOVA
		Egg weight	ANOVA

^a Endpoints to be used for determining "effects" as designated by statistically significant differences between exposure and reference areas (Environment Canada 2002).

^b These analyses are for informational purposes and significant differences between exposure and reference areas are not necessarily used to designate an effect (Environment Canada 2002).

^c ANOVA - Analysis of Variance

^d ANCOVA - Analysis of Covariance; For the ANCOVA analyses, the first term in parentheses is the endpoint (dependent variable Y) that is analyzed for an effluent effect. The second term in parentheses is the covariate, X (age, weight, or length).

^e K-S Test - Kolmogorov-Smirnov test.

secure fish board and a small area of scales above the lateral line posterior to the dorsal fin will be cleared using a scalpel and retained for subsequent reattachment. A 4-mm diameter biopsy punch will be inserted into the cleared area to remove the tissue sample. After the punch is removed, the skin will then be removed from the musculature using a scalpel. The resulting skinless, boneless tissue plug sample will be placed into a pre-labelled vial, stored on ice while in the field and subsequently frozen. A biological adhesive will be used to seal the biopsy hole and re-attach the scales to the underlying muscle and skin tissues in the biopsy area of the fish. The fish will then be placed into a recovery tub filled with fresh aerated water and, once the fish regains equilibrium (holding an upright position), it will then be released back into the watercourse at the area in which it was captured.

4.3.3 Laboratory Analysis

The analysis of total mercury in fish tissue will be completed by a qualified laboratory capable of low-level mercury analysis in small samples using a variant of “EPA Method 1631-Mercury in Water by Oxidation, Purge and Trap, and Cold Vapour Atomic Fluorescence Spectrometry”. Method detection limits will be approximately 1 ng mercury per gram wet tissue weight. Laboratory QA/QC will include spike and reference recoveries to a level of $\pm 10\%$.

4.3.4 Data Analysis

Fish tissue mercury concentrations will be statistically compared between effluent-exposed and reference areas and relative to applicable human health consumption guidelines (Environment Canada 2011). ANOVA and ANCOVA (mercury concentrations relative to fish age) will be used to assess for any significant differences in tissue mercury levels between study areas, with each data set assessed for normality and equality of variance (transformed as required) prior to applying any parametric statistical procedures. Significantly higher mercury concentrations at the effluent-exposed area *or* tissue mercury levels exceeding the human health consumption guidelines would indicate an effect on the usability of the fisheries resource (Environment Canada 2011). As indicated by Environment Canada (2011), the arctic grayling tissue mercury data will be compared to a tissue consumption restriction limit of 450 μg mercury/kilogram wet weight (ww).

4.4 SUPPORTING ENVIRONMENTAL VARIABLES

A number of environmental measures and/or observations will be collected to support the benthic invertebrate community and fish population surveys. At each benthic invertebrate sampling station, substrate characteristics (e.g., type and approximate size), water velocity and sampling depth will be assessed. For each fish sampling location, the dimensions (length, wetted and bankfull width) and mean depth of the sampled reach will be determined. Habitat descriptions, including general stream morphology, substrate features, riparian vegetation species, percent canopy coverage, available in-stream cover and any other observations relevant to the biological surveys will be recorded at each station/study area.

Supporting water quality measures will include *in-situ* water temperature, dissolved oxygen, pH and conductivity measured at the sediment-water interface at each benthic invertebrate station and fish sampling reach. One water sample for chemical analysis will also be collected from each study area (i.e., the effluent-exposed area and both reference areas) during both the spring fish population/tissue survey and the late summer benthic invertebrate community survey. During each sampling event, one duplicate water sample will be collected as a quality control and quality assurance measure. All water samples will be collected from approximately mid-depth with care taken to ensure that the collection bottle faces upstream to avoid any potential influence of the sampler. Any required sample preservatives will be added immediately following collection. The samples will then be placed into a cooler and later transported to and stored in a refrigerator. Water samples will be shipped to an accredited laboratory for analysis of EEM-related variables including hardness, alkalinity, aluminum, arsenic, cadmium, copper, iron, lead, mercury, molybdenum, nickel, zinc, total suspended solids, ammonia, nitrate and ²²⁶radium (Environment Canada 2011).

Statistical comparisons between respective effluent-exposed and reference areas for all *in-situ* water quality measures will be conducted using ANOVA and post-hoc testing as required, with all necessary transformations completed to satisfy assumptions of normality and homogeneity of variance prior to analysis. *In-situ* and analytical water quality data from the effluent-exposed area will be compared to reference area values as well as to applicable Canadian Environmental Quality Guidelines for the protection of aquatic life (CCME 1999). All *in-situ* measures will also be used in correlation analysis with the benthic invertebrate community results (Section 4.1.3).

4.5 EFFLUENT AND WATER QUALITY MONITORING

Effluent and water quality monitoring studies consist of effluent characterization, sublethal toxicity testing and water quality monitoring. The Bellekeno Mine continues to conduct effluent characterization at least four times per calendar year at the discharge location in accordance with MMER requirements (see Section 2.3). Effluent characterization samples will continue to be shipped to a CALA accredited laboratory for analysis of the same suite of EEM parameters outlined above (Section 4.4) using appropriate method detection limits and quality assurance protocols as stipulated by Environment Canada (2011).

Bellekeno Mine staff has been conducting and will continue to conduct annual sublethal toxicity testing on final effluent to fulfill EEM requirements as outlined by Environment Canada (2011). Testing is completed using fathead minnow (7-day survival and growth test; Environment Canada 2011), the invertebrate *Ceriodaphnia dubia* (7-day survival and reproduction test; Environment Canada 2007a), the alga *Pseudokirchneriella subcapitata* (3-day growth inhibition test; Environment Canada 2007b) and the plant *Lemna minor* (7-day growth inhibition test; Environment Canada 2007c). Effluent samples are collected as specified by Environment Canada (2001, 2011). All sub-lethal toxicity tests are performed by a qualified laboratory. Sub-lethal toxicity data are reported to Environment Canada as part of Bellekeno Mine annual reporting and will be synthesized in the Cycle 1 EEM Interpretive Report.



Bellekeno Mine staff has been conducting and will continue to conduct water quality monitoring in Lightning Creek effluent-exposed and reference areas four times per year as part of their EEM requirements. During the implementation of the Cycle 1 EEM, water samples will be collected from areas of biological sampling as described in Section 4.4. All water quality sampling methods, analytical parameters, quality assurance/quality control sampling and analysis, sample storage and shipping methods will be conducted in accordance with Environment Canada (2011). Routine water quality monitoring data are reported to Environment Canada as part of the Bellekeno Mine's annual reporting. Similar to effluent characterization samples, water quality monitoring samples will continue to be shipped to a CALA accredited laboratory and analyzed for the same suite of variables outlined above. All water quality monitoring results collected up to the time of preparation of the Cycle 1 EEM Interpretive Report will be summarized and discussed therein.

5.0 SCHEDULE

The Bellekeno Mine Cycle 1 EEM biological survey will be conducted in two stages, with the fish population/tissue survey being undertaken after river ice-out in late-May/early-June 2012 and the benthic invertebrate community survey conducted in late August/early September 2012. An early spring fish survey will allow the collection of slimy sculpin with gonadal development that is sufficiently advanced to allow an assessment of all EEM reproductive endpoints in addition to fish survival, growth and condition endpoints outlined under a lethal sampling design (refer to Table 4.1). The seasonal timing associated with the Cycle 1 EEM benthic invertebrate community survey will maintain consistency with the previous studies and will ensure that the benthic invertebrate communities are relatively stable and that organisms are sufficiently developed to allow identification to reasonable levels (i.e., genus or species). With submission of benthic invertebrate community samples for analysis shortly following completion of the fieldwork, all laboratory results should be available by early 2013. This will provide adequate time for data compilation, analysis and preparation of a Cycle 1 EEM Interpretive Report to be submitted to Environment Canada by March 7, 2013 within 30 months of the date in which the Bellekeno Mine became subject to the MMER as required (Government of Canada 2010).

6.0 REFERENCES

- Baker R.F., P.J. Blanchfield, M.J. Paterson, R.J. Flett and L. Wesson. 2004. Evaluation of nonlethal methods for the analysis of mercury in fish tissue. *Trans. Amer. Fish. Soc.* 133: 568 – 576.
- CCME (Canadian Council of Ministers of the Environment). 1999. Canadian Environmental Quality Guidelines. Canadian Council of Ministers of the Environment. Winnipeg.
- Cowardin, L. M., V. Carter, F. C. Golet and E. T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service, U.S. Dept. of the Interior, Washington, D.C. FWS/OBS-79/31.
- Environment Canada. 2001. Guidance Document for the Sampling and Analysis of Metal Mining Effluents. EPS 2/MM/5. April 2001.
- Environment Canada. 2002. Revised Guidance for Sample Sorting and Subsampling Protocols for EEM Benthic Invertebrate Community Surveys. National Environmental Effects Monitoring Office. National Water Research Institute. December 2002.
- Environment Canada. 2007a. Test of Reproduction and Survival Using the Cladoceran *Ceriodaphnia dubia*. Environmental Technology Centre, Ottawa, Ontario. Environmental Protection Series. Report EPS 1/RM/21. February 2007.
- Environment Canada. 2007b. Biological Test Method: Growth Inhibition Test Using a Freshwater Alga. Environmental Technology Centre, Ottawa, Ontario. Report EPS 1/RM/25. March 2007.
- Environment Canada. 2007c. Test for Measuring the Inhibition of Growth Using the Freshwater Macrophyte *Lemna minor*. Environmental Technology Centre, Ottawa, Ontario. Environmental Protection Series. Report 1/RM/37. January 2007.
- Environment Canada. 2011. Biological Test Method: Test of Larval Growth and Survival Using Fathead Minnows. Environmental Technology Centre, Ottawa, Ontario. Environmental Protection Series. Report 1/RM/22 Second Edition. February 2011.
- Environment Canada. 2011. 2011 Metal Mining Environmental Effects Monitoring (EEM) Technical Guidance Document. Environment Canada Report 2011 Revision.
- Government of Canada. 2002. Metal Mining Effluent Regulations. Canada Gazette, Part II. Vol. 136, No. 13. June 19, 2002.
- Government of Canada. 2010. Metal Mining Effluent Regulations. Canada Gazette. Consolidated version. SOR/2002-222. August 18, 2010. 57 pp.
- Laberge (Laberge Environmental Services). 2008. Keno Valley Stream Sediment and Benthic Invertebrate Monitoring Programs, 2007. Report Prepared for Access Consulting Group. March 2008.
-

- Minnow 2008. Water Quality Assessment Report for United Keno Hill Mines. Report prepared for Elsa Reclamation and Development Company.
- Scott, W.B. and E.J. Crossman. 1998. Freshwater Fishes of Canada. Galt House Publications, Oakville, Ontario.
- Sparling, P., 2006. Fisheries Assessments Conducted in the Keno Hill Mining Area, Including Metals Analysis of Fish Tissue Samples, 2006. White Mountain Environmental Consulting, Whitehorse, YT. January 2006.
- Sparling, P. and M. Connor, 1996. Fish and Fish Habitat Assessment Conducted Near Elsa, Yukon for United Keno Hill Mines August 1994 – September 1995. White Mountain Environmental Consulting, Whitehorse, YT, December 1995.
- SRK 2008. Bellekeno Preliminary Economic Assessment Technical Report. Keno Hill Mining District, Yukon. Prepared for Alexco Resource Corporation, June 2008.
- Summerfelt, R.C. and L.S. Smith. 1990. Anaesthesia, surgery, and related techniques. In: Methods for Fish Biology. Schreck, C.B. and Moyle, P.B. (Eds), American Fisheries Society. Bethesda, Maryland.
- White Mountain Environmental Consulting (WMEC). 2006. Fisheries Assessments Conducted in the Keno Hill Mining Area, Including Metals Analysis of Fish Tissue Samples, January 2006. Report prepared for Frank Patch Type II Project Manager Assessment and Abandoned Mines Government of Yukon.



ALEXCO KENO HILL MINING CORP.

QUARTZ MINING LICENCE

QML-0009

BELLEKENO MINE DEVELOPMENT

KENO HILL SILVER DISTRICT

YUKON

Appendix G



Alexco Keno Hill Mining Corp.

Bellekeno Mine Operations

Bellekeno Adaptive Management Plan

Water Use Licence QZ09-092

April 2011

Prepared by:



TABLE OF CONTENTS

1.	Introduction	1-6
2.	Update to District-Wide AMP	2-7
2.1	Alexco Activities in the KHSD	2-7
2.2	Existing Plans.....	2-9
3.	Adaptive Management Plan OVERVIEW	3-11
3.1	Adaptive Management Plan Objectives.....	3-11
3.2	AMP Events Summary.....	3-12
3.3	AMP Approach	3-13
4.	District AMP Update for Bellekeno Production Unit	4-16
4.1	Change in Water Quality or Quantity	4-16
4.2	Significant Change in Water Quality	4-16
4.2.1	Descriptions.....	4-16
4.2.2	Locations.....	4-16
4.2.3	Monitoring Requirements	4-16
4.2.4	Specific Thresholds	4-17
4.2.4.1	Water Treatment Facilities/ Licenced Effluent Discharges	4-17
4.2.4.2	Mine Water Quality Changes.....	4-19
4.2.4.3	Responses to Changes in Water Quality.....	4-19
4.2.4.4	Responses to changes in Treatment Plants.....	4-19
4.2.4.5	Responses to Changes in Mine Adit Chemistry	4-20
4.2.5	Significant Changes in Water Quantity.....	4-20
4.2.6	Monitoring Requirements and Specific Thresholds	4-21
4.2.7	Responses to Changes in Water Quantity	4-21
4.3	Waste Rock Seepage Exhibits AML	4-22
4.3.1	Description	4-22
4.3.2	Locations.....	4-22
4.3.3	Monitoring Requirements	4-22
4.3.4	Specific Thresholds	4-23

4.3.5	Approach to Responses	4-23
4.4	SLUDGE STORAGE AREA EFFECTIVENESS COMPROMISED	4-24
4.5	Seepage Observed Near Sludge Storage Area	4-24
4.5.1	Description	4-24
4.5.2	Locations.....	4-24
4.5.3	Monitoring Requirements	4-24
4.5.4	Specific Thresholds	4-24
4.5.5	Approach to Responses	4-24
4.6	Sludge Storage Area Approaching Capacity.....	4-25
4.6.1	Description	4-25
4.6.2	Locations.....	4-25
4.6.3	Monitoring Requirements	4-25
4.6.4	Specific Thresholds	4-25
4.6.5	Approach to Responses	4-25
4.7	PHYSICAL INSTABILITIES.....	4-25
4.7.1	Area of Significant Subsidence is Observed	4-25
4.7.2	Locations.....	4-26
4.7.3	Monitoring Requirements	4-26
4.7.4	Specific Thresholds	4-26
4.7.5	Approaches to Responses	4-26
4.8	Rock Fall or Landslide Occurs Within Monitored Area	4-27
4.8.1	Description	4-27
4.8.2	Locations.....	4-27
4.8.3	Monitoring Requirements	4-27
4.8.4	Specific Thresholds	4-27
4.8.5	Approaches to Responses	4-28
4.9	SITE SECURITY COMPROMISED.....	4-29
4.9.1	Gate, Fence or Sign Damaged	4-29
4.9.2	Locations.....	4-29
4.9.3	Monitoring Requirements	4-29

4.9.4	Specific Thresholds	4-29
4.9.5	Approaches to Responses	4-30
5.	Additional Adaptive Management Triggers for Bellekeno Production Unit.....	5-31
5.1	High Pore Pressure Underneath DSTF	5-31
5.2	Significant Erosion of Exposed DSTF Surfaces.....	5-32
5.3	Erosion at the Flame and Moth Discharge Site.....	5-34
5.4	Transport of Sediments from Mill Facility to Christal Lake.....	5-35
5.5	Large Differential Settlements at DSTF.....	5-35
5.6	Large Differential Settlements from DSTF to Stormwater Collection Pond	5-36
5.7	Exceedence of Water Quality Standard in Receiving Environment.....	5-37
5.7.1	Descriptions.....	5-37
5.7.2	Locations.....	5-37
5.7.3	Monitoring Requirements	5-37
5.7.4	Specific Thresholds	5-38
5.7.5	Responses to Changes in Receiving Environment Water Quality	5-38
5.8	Identification of Groundwater Quality Impact at F&M or BK.....	5-39
5.8.1	Description	5-39
5.8.2	Locations of Groundwater Monitoring Wells.....	5-39
5.8.3	Monitoring Requirements	5-40
5.8.4	Thresholds	5-40
5.8.5	Responses.....	5-40
5.9	Water Quality Impact to Keno City Water Wells	5-41
5.9.1	Description	5-41
5.9.2	Location of Groundwater Monitoring Well.....	5-41
5.9.3	Monitoring Requirements	5-41
5.9.4	Thresholds	5-41
5.9.5	Responses.....	5-42
6.	Review of Existing Monitoring and Management Plans	6-43
6.1	QML and WUL Plans.....	6-43
6.2	Physical Inspection and Reporting Plan	6-43

6.2.1	Inspection Checklists	6-43
6.3	Bellekeno 625 Water Treatment Systems Operations Manual	6-44
6.3.1	Future Improvements.....	6-44
6.3.2	Ion Exchange System – Ammonia Reduction Pilot Study	6-45
6.3.3	Clarifier	6-46
6.3.4	Organic Polymer	6-46
6.4	Water Management Plan and Water Balance Report	6-47
6.4.1	Drought Conditions	6-47
6.4.2	Flood Conditions.....	6-48
6.4.3	High Mine Inflow Conditions	6-48
6.5	Groundwater Monitoring Plan.....	6-49

LIST OF FIGURES

Figure 6-1. Floc Formation	6-47
----------------------------------	------

LIST OF TABLES

Table 3.1 Overall AMP Summary	3-14
Table 4.1 Bellekeno 625 Licenced Effluent Quality Standards	4-18
Table 4.2 Flame and Moth Site Licenced Effluent Quality Standards.....	4-18
Table 5.1 High pore pressure event.....	5-32
Table 5.2 Significant Erosion	5-34
Table 5.3 Large Differential Settlements	5-36

APPENDICES

Appendix 1	Keno Hill Silver District, Adaptive Management Plan – 2011 Update
------------	---

1. INTRODUCTION

The Bellekeno Mine WUL QZ009-092 specifies the following licence conditions:

#90. Within six months of the effective date of this licence, the Licensee shall submit to the Board an AMP dealing specifically with Bellekeno Undertaking and shall implement that plan. The AMP should be based on the contents of the existing district-wide AMP submitted as exhibit 1.3.10, but customized for the specific activities and developments of the Bellekeno Undertaking.

#91. In addition to these relevant events already identified in the district wide AMP, the Bellekeno AMP should specifically include adaptive management triggers and responses to the following events:

- a. Development of high pore pressures underneath the DSTF;*
- b. Development of significant erosion of exposed DSTF surfaces;*
- c. Development of erosion at the Flame and Moth Site discharge area;*
- d. Transport of sediment from the Flame and Moth discharge area into Christal Creek;*
- e. Development of large differential settlements at the DSTF;*
- f. Development of large differential settlements along the conveyance flume from the DSTF to the Flame and Moth Site collection and sediment pond;*
- g. Exceedence of recommended water quality standards in the receiving environment occurring irrespective of compliance with effluent discharge standards;*
- h. Identification of groundwater quality impacts at the Flame and Moth or Bellekeno mill sites; and*
- i. Identification of water quality impacts to Keno City water wells.*

This report is submitted to fulfil these licence conditions.

2. UPDATE TO DISTRICT-WIDE AMP

The district-wide AMP has been updated several times to reflect the changing status of activities in the Keno Hills Silver District (KHSD). The March 2011 update is attached as Appendix 1 to this Bellekeno AMP.

2.1 Alexco Activities in the KHSD

Alexco and its subsidiary companies are undertaking care and maintenance, exploration and development, active mining and mill processing activities, and closure studies in the Keno Hill Silver District which includes various activities:

Principal activities Bellekeno Mine and Mill:

- Mining ore and waste rock from Bellekeno mine;
- Placement of potentially acidic/metal leachate (PAML) rock within engineered facilities;
- Placement of non-PAML rock in permitted waste rock storage areas;
- Construction of earthworks and erosion control protection;
- Crushing, grinding, flotation, thickening, filtration, and production of a lead concentrate, zinc concentrate, and two tailings streams related to the lead flotation circuit and the zinc flotation circuit;
- Placement of tailings in the engineered Dry Stack Tailings Facility;
- Placement of tailings and PAML rock in a cemented rock backfill within the former vein areas;
- Water treatment of water from Bellekeno mine and potentially from District Mill;
- Use of water for camp purposes and quartz mining undertakings;
- Use of water and wastewater for lime mixing operations;
- Use of water for milling operations; and
- Environmental monitoring, including dust, surface water, groundwater and treated mine water prior to discharge.

Principal activities Exploration, Development, Care and Maintenance and Closure:

- Surface drilling and advanced underground exploration with view to mine development;

- Direct use of water for camp purposes and quartz mining undertakings;
- Direct use of water and wastewater for lime mixing operations;
- Deposit of waste into water and receiving environment;
- Waste rock storage;
- Construction and upgrades to access roads;
- Operation and maintenance of existing four wastewater treatment facilities and associated settling ponds using lime treatment (Silver King 100, Galkeno 900, and Galkeno 300 and the Valley Tailings Area);
- Deposit of waste as lime treatment sludge;
- Construction of earthworks and erosion control protection;
- Storage of wastewater in the treatment settling ponds and Valley Tailings Area; and
- Maintenance of existing diversion channels (Porcupine Creek) and ditches.

Accessory activities:

- Maintenance and operation of site infrastructure related to water treatment systems and access roads;
- Site security and maintenance of site facilities and structures for public health and safety;
- Transport of milk of lime solutions to treatment sites;
- Periodic desludging of treatment settling ponds and transportation or pumping to sludge storage areas which are periodically decanted;
- Mine dewatering for care and maintenance purposes and to advance underground exploration or development;
- Water sampling (effluent and receiving waters);
- Waste rock analysis and classification;
- Environmental monitoring, inspections and sample programs, including monitoring and inspection of physical structures;
- Removal of blockages that have formed naturally or cofferdams that have been constructed as temporary structures to avoid uncontrolled discharge of mine pool water;

- Removal and clean up of infrastructure related to adits, adit structures and facilities;
- Wastewater treatment studies and test programs related to potential closure design options; and
- Operation, inspection and maintenance of the Valley Tailings Area.

2.2 Existing Plans

Alexco recognizes that the activities of Bellekeno Mine and the District Mill are being performed in a historic mining district which includes waters and physical workings at the Keno Hill Silver District that could potentially become an environmental risk or hazard that do not yet require immediate attention. The existing discharge from the Bellekeno mine of treated water, the potential future discharge of water from the DSTF mill area, and placement of water treatment sludge is being performed in watersheds that are impacted by historic mining operations. The development of a Keno Hill District Closure Plan is intended to address these water discharges and workings which require further intervention over the long term. As the closure work is implemented, it is expected that changes in the environmental status of the KHSD will be observed.

Several plans are currently in place pursuant to the existing licences and approvals and are referenced throughout this AMP. These plans have been prepared or will be prepared pursuant to Water Licences QZ09-092 and the Quartz Mining Licence QML-009 to guide the management of activities and monitoring associated with operation of the Bellekeno Mine and District Mill:

QML Plans

- Emergency Response Plan
- Hazardous Materials Management Plan
- Heritage Resources Protection Plan
- Monitoring and Surveillance Plan
- Noise Abatement Plan
- Spill Contingency Plan
- Traffic Management Plan
- Waste Management Plan
- Wildlife Protection Plan

WUL Plans

- Sludge Management Plan
- Groundwater Monitoring Plan
- Water Balance Report and Water Management Plans
- Tailings Characterization Plan
- Receiving Environment Study
- Physical Inspection and Reporting Plan
- Bellekeno 625 Water Treatment Systems Operations Manual
- Bellekeno Hydrogeology Plan
- Dry Stack Tailings Facility Design Report
- Dry Stack Tailings Facility Operation and Management Plan

This document builds on these plans and intended to summarize and augment the adaptive management activities already contained in the District-wide AMP and these plans.

3. ADAPTIVE MANAGEMENT PLAN OVERVIEW

3.1 Adaptive Management Plan Objectives

An adaptive management plan (AMP) is a management tool designed to guide responses to unforeseen or contingency events respecting for example, water quality and quantity and physical conditions of site workings and infrastructure. The adaptive management approach will provide for assessment of mitigation measures and their effectiveness, and guide the orderly implementation of responses. Since it is difficult to predict the specific environmental condition that may arise which requires a response from management, the AMP does not necessarily provide specific detailed descriptions of responses to a situation. The AMP provides a range of possible responses to use as a guide to respond to specific environmental conditions encountered. Management should use the information provided in the AMP and adapt the appropriate response from this guide, which is the sole purpose of an AMP.

The AMP framework encompassing Company management activities includes:

- routine inspection and environmental monitoring, maintenance and reclamation;
- routine assessment of monitoring and performance data;
- performance thresholds for implementation of appropriate levels of responses for planned contingency measures; and
- reporting of monitoring results and actions.

Results of the monitoring programs (Section 2.2 – Plans in Place), will be assessed on an ongoing basis to determine if any negative trends in water quality, quantity or other parameters are occurring. If the results indicate that there are no negative environmental impacts, then the frequency and length of monitoring and maintenance would continue as usual. Adaptive management will be implemented to respond to negative trends observed through the monitoring programs.

3.2 AMP Events Summary

The district-wide AMP identifies a number of “events” which represent potential environmental conditions that would require a management response, if they were to occur; these are the first 5 “events” listed below. The WUL clause 91 adds nine additional “events” which are in addition to the ones previously identified in the District-wide AMP, identified as “events” 6 through 14 listed below.

- 1. Change in Water Quality or Quantity**
- 2. Non-AML Waste Rock Disposal Area(s) Seepage Exhibits AML**
 - a. Waste Rock Disposal Area(s) (including where used for road and general construction) runoff trending to AML conditions
- 3. Sludge Storage Area Effectiveness Compromised**
 - a. Seepage Observed Near Sludge Storage Area
 - b. Sludge Storage Area Approaching Capacity
- 4. Physical Instabilities**
 - a. Area of Significant Subsidence is Observed
 - b. Rock Fall or Landslide Occurs Within a Monitored Area
 - c. Structure Failure or Portal Collapse
- 5. Site Security Compromised**
 - a. Gate, Fence or Sign Damaged
- 6. Development of high pore pressures underneath the DSTF**
- 7. Development of significant erosion of exposed DSTF surfaces**
- 8. Development of erosion at the Flame and Moth Site discharge area**
- 9. Transport of sediment from the Flame and Moth discharge area into Christal Creek**
- 10. Development of large differential settlements at the DSTF**
- 11. Development of large differential settlements along the conveyance flume from the DSTF to the Flame and Moth Site collection and sediment pond**
- 12. Exceedence of recommended water quality standards in the receiving environment occurring irrespective of compliance with effluent discharge standards**
- 13. Identification of groundwater quality impacts at the Flame and Moth or Bellekeno mill sites; and**
- 14. Identification of water quality impacts to Keno City water wells.**

The AMP response for each of these events is described individually in subsequent sections while Table 3-1 at the end of this section provides a summary of the approach to AMP events. This table summarizes the narrative triggers, indicators and response thresholds, monitoring locations and parameters.

3.3 AMP Approach

For each AMP event a methodical approach is provided:

1. Description of the event and possible environmental consequences - Addresses issues or information that trigger the AMP;
2. Location of possible event occurrence – Identifies specific working site locations if applicable to event;
3. Monitoring requirements – Identifies the parameters to be monitored, frequency and means for monitoring each parameter;
4. Specific indicators and thresholds - Defines the conditions when management actions should be taken. There may be a series of indicators and staged thresholds for an individual event; and
5. Approach to responses –Description of the approach to responses including a simplified flow chart to guide the implementation process if any specific thresholds have been crossed.

Table 3.1 Overall AMP Summary

Event	Narrative Trigger	Indicators	Thresholds	Monitoring Locations	Monitoring Parameters
1. CHANGE IN WATER QUALITY OR QUANTITY					
a. Significant change in water quality of treatment plant discharge	<u>Water Treatment Facilities</u> Decline in effluent pH noted or effluent quality trending towards possible exceedence of standards or exceeds licenced standards.	pH, Total zinc, ammonia, TSS	Treated effluent: TSS>20 mg/L for three consecutive days; OR Effluent quality standards exceeded. Ammonia > 4.0 mg/L and pH > 9.0 for three consecutive days; OR Total Zinc > 0.40 mg/L and pH <6.5 for three consecutive days; OR	Water Treatment Facilities	Routine in-situ, on-site total zinc, external multi-element ICP, hardness, pH, conductivity, TSS, ammonia, LT50
b. Significant change in water quality of adit discharge	Significant decline in pH or increase in conductivity from mine adit discharge to treatment plant	pH, conductivity	Adit discharge pH more than 1 pH standard unit lower or conductivity 2X higher than historic average	KV-42 Bellekeno adit discharge	Same as indicators
b. Adit discharge quantity significantly increases	Observed or measured flows display a sustained and statistically significant increase over historical flow conditions	Flow	Increase of flow to greater than 95% Upper Confidence Level when compared to the average for the previous 24 months or 90% Licence flow discharge criteria exceeded	KV-43 Bellekeno treatment plant; KV-XX Mill sediment pond discharge treatment plant	same as indicators
2. WASTE ROCK SEEPAGE EXHIBITS AML					
a. Waste rock seepage or runoff trending to AML conditions	Seepages from waste rock disposal areas or from works constructed or upgraded with non AML material show significant decline in pH and/or an increase in conductivity OR approaching licenced discharge standards	pH, conductivity	Significant decline in pH between measurements or pH <6.0 and/or conductivity showing a significant increasing trend or >2000 mS/cm; OR indicators approaching licenced discharge standards	Waste rock disposal areas and works or features constructed from non-AML material	pH, conductivity, Routine multi-element ICP
3. SLUDGE STORAGE AREA EFFECTIVENESS COMPROMISED					
a. Seepage observed near sludge storage areas	Routine inspection of sludge storage area shows seepage	Total zinc, pH	pH >8.5 and total zinc > 1.0 mg/L	Valley Tailings sludge storage cell	Same as indicator
c. Sludge storage area approaching capacity	Sludge storage area approaching minimum freeboard of 1.0 meter below the decant point	Visual observation of freeboard	Freeboard is at 1.5 meter below decant point	Valley Tailings sludge storage cell	Same as indicator
4. PHYSICAL INSTABILITIES					
a. Area of significant surface subsidence has occurred	An observed subsidence has exposed an opening to surface or resulting in slope failure	Visible slope failure, ground subsidence or opening on surface	Opening to underground workings or area of subsidence effects public safety or down gradient environment	Bellekeno Mine Production Unit Area	same as indicators
b. Rock fall or landslide is observed that affects road right-of-way or intrudes into stream	An observed rock fall or landslide effects a road right-of-way, infrastructure or intrudes into stream	Mine source material movement	Source material effects road or stream	Bellekeno Mine Production Unit Area	same as indicators
5. SITE SECURITY COMPROMISED					
a. Security gate, fence, sign damaged	Public health and wildlife safety measure damaged or removed	Sign, fence, gates, locks	Security feature damaged, removed, or compromised	Bellekeno Mine Production Unit Area	same as indicators
6. Development of high pore pressures underneath the DSTF					
a. High porewater pressure within groundwater monitoring wells in the DSTF	Porewater pressure is observed in groundwater monitoring wells in the DSTF	Porewater pressure	Tip @1.0m or 1.7m depth – Porewater pressure parameter (Ru) exceeds 0.15	Groundwater monitoring wells in the DSTF	same as indicators
7.0 Development of significant erosion of exposed DSTF surfaces					
a. Area of significant erosion on exposed DSTF surface	An observed movement of tailings caused by erosion on surface	Visual inspection of tailings surface	Geotechnical engineer or operator inspection identifies adverse operating condition	DSTF	Same as indicators

Event	Narrative Trigger	Indicators	Thresholds	Monitoring Locations	Monitoring Parameters
8. Development of erosion at the Flame and Moth Site discharge area					
To be developed once discharge system is designed					
9. Transport of sediment from the Flame and Moth discharge area into Christal Creek					
To be developed once discharge system is designed					
10. Development of large differential settlements at the DSTF					
a. Significant differential settlements are observed in the DSTF	An observation of significant differential settlements are observed at the DSTF	Displacement of survey monitors and slope indicators	Displacements greater than 25 mm in any direction	Survey monuments and slope inclinometers	Same as indicators
11. Development of large differential settlements along the conveyance flume from the DSTF to the Flame and Moth Site collection and sediment pond					
a. Significant differential settlements are observed in along the conveyance flume	An observation of significant differential settlements are observed the conveyance flume	Displacement of survey monuments	Displacements greater than 25 mm in any direction	Survey monuments	Same as indicators
12. Exceedence of recommended water quality standards in the receiving environment occurring irrespective of compliance with effluent discharge standards					
a. Water quality standards are exceeded in the receiving environment even though authorized licenced discharges are within discharge limits	Receiving environment discharge standards exceed CCME and do not have a history of exceedence, and waste related to the Bellekeno undertaking are contributing greater than 10% of the mass load.	Licensed discharge parameters	Exceedence of CCME at a receiving environment monitoring station, no previous trend of exceedence, and Bellekeno undertaking contributes >10% of mass load	Receiving environment monitoring stations	Same as indicators
13. Identification of groundwater quality impacts at the Flame and Moth or Bellekeno mill sites					
a. A significant increasing trend is observed in groundwater near the Flame and Moth or Non-AML Waste Rock Disposal Area	Total zinc significantly exceeds baseline measurements for a given monitoring well, and exceeds licenced effluent discharge standards	Total Zn	Total zinc exceeds the highest baseline measurement by a factor of 2x, and exceeds licensed effluent discharge standards	Groundwater monitoring wells	Same as indicators
14. Identification of water quality impacts to Keno City water wells					
a. A significant increasing trend is observed in groundwater near the Flame and Moth or Non-AML Waste Rock Disposal Area	Total zinc significantly exceeds baseline measurements for a given monitoring well, and exceeds licenced effluent discharge standards	Total Zn	Total zinc exceeds the highest baseline measurement by a factor of 2x, and exceeds licensed effluent discharge standards	Groundwater monitoring wells	Same as indicators

4. DISTRICT AMP UPDATE FOR BELLEKENO PRODUCTION UNIT

4.1 Change in Water Quality or Quantity

Results of water quality and quantity monitoring are assessed on an ongoing basis to determine if significant changes are occurring and if an adaptive management response is required. The following sections describe what constitutes a significant change to water quality or quantity and associated responses that would be implemented.

4.2 Significant Change in Water Quality

4.2.1 Descriptions

All data for current water sample stations required in the Bellekeno Mine WUL QZ09-092 are stored in an EQWin database that allows water quality to be tracked at each site such that conditions can be identified at any point in the season. In this way parameters can be seen to be fluctuating from the normal, and reaching levels where management is required to respond. Set point triggers can be placed in the database so that response parameters are flagged for notification and action.

4.2.2 Locations

Water quality is monitored from the Bellekeno water treatment facilities for potential effects to the receiving environment including loading of down gradient waters. These sites are listed below and shown in Figure 3-1 of the Environmental Monitoring Program in Appendix A.

Water Treatment Facilities:

- KV-43 - Bellekeno 625 Treatment Pond Decant
- KV-XX - District Mill Treatment Decant, location not yet established

Adits:

- KV-42 - Bellekeno 625 Adit
- KV74 - Bellekeno East Adit

4.2.3 Monitoring Requirements

Specific parameters from the monitored areas will be compared to specific thresholds to determine if they have been exceeded. Monitoring requirements will change should one of the AMP thresholds be triggered. This could include more frequent monitoring

of grab samples at the station location as well as more frequent monitoring of the receiving environment below the site where the trigger was initiated.

4.2.4 Specific Thresholds

Specific thresholds for the different categories of monitoring stations that will initiate a response are provided in the following sections.

4.2.4.1 Water Treatment Facilities/ Licenced Effluent Discharges

Water quality data from treatment facilities and other potential effluent discharge from Bellekeno East decline will be assessed to determine if the following thresholds have been exceeded:

- Daily sampling result for pH less than 7.0 units at a water treatment facility decant for more than 3 consecutive days;
- Daily sampling result for zinc or ammonia trending toward possible exceedence of discharge standard:
 - o Total zinc > 0.40 mg/l and pH < 7.0 units for three consecutive days; or
 - o Ammonia > 4.0 mg/l and pH > 9.0 for three consecutive days; and
 - o TSS > 20 mg/l for three consecutive days.
- Sample result exceeds effluent quality standard (Table 4-1 and Table 4-2).

Table 4.1 Bellekeno 625 Licenced Effluent Quality Standards

Parameter	Maximum Concentration in a Grab Sample (mg/L)
pH	6.5 to 9.5 pH Units
Suspended solids	25
Ammonia Nitrogen	5
Arsenic (Total)	0.5
Cadmium (Total)	0.01
Copper (Total)	0.1
Lead (Total)	0.2
Nickel (Total)	0.5
Silver (Total)	0.01
Zinc (Total)	0.5

Table 4.2 Flame and Moth Site Licenced Effluent Quality Standards

Parameter	Maximum Concentration in a Grab Sample (mg/L)
pH	6.5 to 9.5 pH Units
Suspended solids	25
Ammonia Nitrogen	5
Arsenic (Total)	0.5
Cadmium (Total)	0.01
Copper (Total)	0.1
Lead (Total)	0.2
Nickel (Total)	0.5
Radium 226	0.37 BQ/L
Silver (Total)	0.02

Zinc (Total)	0.5
--------------	-----

4.2.4.2 Mine Water Quality Changes

The thresholds for Bellekeno adit discharges that would be applied in order to determine if mine water source quality had been significantly altered:

- A monitoring pH concentration trend, 1.0 standard pH unit below historic average. A trend would be established comparing the prior month average to the historic average.
- A monitoring trend whereby there is an increase of two-times (2X) or more in conductivity (measured externally by an accredited lab) when compared to the average conductivity for the previous 24-months' water quality data prior to dewatering.
- Specific metals trends will be evaluated if either pH or conductivity trend has been triggered. Due to the nature of mining activities high concentration of suspended solids and metals found in the suspended solids are periodically expected as sumps are cleaned out or during dewatering changes; consequently metals concentrations will not be a primary trigger.

4.2.4.3 Responses to Changes in Water Quality

Responses to changes in water quality from treatment plants and changes in adits will be different to account for the level of control over the results of water quality, where treatment plants are actively managed, while a mine water quality is dependent on the native groundwater associated with veins, host rock, recharge, and other factors not directly under the control of the mine operator.

4.2.4.4 Responses to changes in Treatment Plants

If an adaptive management trigger associated with the treatment plants is identified as being triggered, the following steps will be performed:

- Notification to the Water Inspector that the trigger has been triggered within three working days.
- Investigation of the root cause of the exceedence.
- If a root cause of exceedence can be readily identified and remedied, the remedy will be implemented in a timely manner, and the water inspector notified of the remedy implementation in a timely manner according to permit requirements.
- If a root cause cannot be readily identified, a study plan will be outlined and communicated to involve qualified professionals to assist in the identification of the root cause.

- Water will be stored in underground sumps or the mill sediment pond to the extent practical to limit discharge until root causes have been identified and a solution implemented.

4.2.4.5 Responses to Changes in Mine Adit Chemistry

Monthly averages of pH and conductivity are considered good surrogate parameters to identify water quality changes that may affect the cost and feasibility of water treatment associated with the mine adits. If the trend analysis identifies specific changes then the following steps will be performed:

- Notification to the Water Inspector that the trigger has been triggered within three working days.
- Investigation of the root cause of the exceedence:
 - Due to the nature of underground mine workings, inflows to different areas of the mine may be different than other areas. A screening level water quality study will be implemented using field pH and conductivity equipment to identify mine areas that may be contributing to the change in water quality.
 - A review of recent mining practices and a study of specific rock lithologies in the area of recent mining activity will be performed to assess if the change is associated with specific rock types or if a mining practice could be associated with the change.
- If a root cause can be identified, plans will be implemented to manage the water quality, which may include modification of the water treatment plant design or operating approach.

4.2.5 Significant Changes in Water Quantity

The Bellekeno Hydrology Plan, and the Water Balance Report and Water Management Plans provide for a monitoring approach to identify water quantity and to determine if water quantity from the Bellekeno mine is showing long term trends that indicate sustained changes in water quantity. Short term temporary spikes in water quantity are to be expected as new mine areas with water transmissive features such as veins or fractures are encountered. However, experience from the advanced development and initial mining activities show that the amount of water associated with these initial drainage episodes is not significant, and in a short timeframe the water drains from the vein or fracture and the net contribution compared to the ongoing flow is minimal.

4.2.6 Monitoring Requirements and Specific Thresholds

The relevant flowmeter and totalizer that measures water quantity data from KV-42, the Bellekeno adit, is located just upstream of the rapid mix tank. The data from the flowmeter and totalizer will be downloaded on a frequent basis and analyzed monthly. The average daily totalized flow for each month will be compared with the trailing 24 months of water flow to establish trends and also to determine significant deviation from the trends.

Two thresholds for determining significantly increased water flow are:

1. If average flow from the adit for the month is significantly higher than the previous 24 months of flow data. This will be determined by comparing the current month flow with the 95% upper confidence level (UCL).
2. If the water discharge from KV-43, the water treatment plant discharge, is within 10% of 864m³/day, which is the licence condition in WUL QZ09-092. KV-43 shows the net adit outflow, and will not be affected by changes in water recycle usage.

4.2.7 Responses to Changes in Water Quantity

If a significant increase in water quantity is determined by the statistical test or if 90% of the WUL water quantity discharge is observed, the following response actions will be taken:

- Notification to the Water Inspector that the trigger has been triggered within 3 working days.
- Investigation of the root cause of the exceedence:
 - Due to the nature of underground mine workings, inflows to different areas of the mine may be different than other areas. A screening level water quantity study will be implemented using portable flow meter equipment such as portable flumes or a standard time to fill the bucket test to identify mine areas that may be contributing to the change in water quantity.
- If a root cause can be identified, plans will be implemented to manage the change in water quantity, which may include modification of the water treatment plant design or changing the mine operating approach such as increasing water recycle usage.

4.3 Waste Rock Seepage Exhibits AML

As mentioned previously in Section 2.2 (Plans in Place) a number of plans are in currently in place with respect to waste rock management and monitoring. The efficacy of these plans has been demonstrated through advanced exploration, development and production at the Bellekeno Mine. Although Alexco has a high level of confidence in the ability of these plans to accurately predict drainage chemistry and accurately designate waste rock appropriately, the following sections pertain to the possibility for acidic or metal leachate (AML) to occur as a result of seepage or runoff through waste rock disposal areas or areas where waste rock designated as non-AML has been used as a construction material. In addition, seeps from historic (unsegregated) waste rock piles are also considered.

4.3.1 Description

Waste rock seeps/runoff will be monitored to determine if water quality is trending to AML conditions and an adaptive management response is required.

4.3.2 Locations

- An observed seep has historically been monitored below Bellekeno 625 (KV-44).
- Any seepage from works constructed or upgraded with non-AML material, which currently includes Bellekeno East and Bellekeno powerline roads. Other Bellekeno East waste rock management areas as defined in the Waste Rock Management Plan are also monitored for drainage or seeps.
- Any other roads, facilities or structures built from non-AML material to be constructed under existing licenses.

4.3.3 Monitoring Requirements

Specific monitoring requirements for the Bellekeno 625 seep (KV-44) are outlined in the EMP (Appendix A). Monthly field measurements of pH, temperature and conductivity in will be taken between May and October, and flow at KV-44 will also be estimated. Samples will also be collected on an annual basis for KV-44 for the full suite of water quality analyses.

As per the Waste Rock Management Plan, any waste rock drainage or seeps observed between May and October will be monitored for estimated flow volume and basic field parameters of pH and conductivity. Evidence of sulphide oxidation such as snow melt areas or the presence of sulphide oxidations products will also be noted.

One geomembrane-lined lysimeter $\geq 5\text{m}^3$ will be installed in the non-AML storage areas (Bellekeno power line road). Drainage volume will be monitored, with field parameters (pH and conductivity) measured on a monthly basis from May to October. Providing there is sufficient quantity of drainage, a full suite of water quality analyses will be conducted at least twice per year.

4.3.4 Specific Thresholds

Field measurements of pH and conductivity will be monitored to determine if the following specific thresholds have been breached due to AML:

- pH significantly declining between measurements or dropping below 7.0; and/or
- conductivity showing a significant increasing trend or conductivity above 2,000 $\mu\text{S}/\text{cm}$.

4.3.5 Approach to Responses

Initial responses to an observed waste rock seep or runoff trending to AML conditions can include further inspection of the waste rock source material to ensure that the rock types used for construction are acceptable and mitigative measures such as ditching, berming, or pumping water, rock removal or whatever alternative is required to prevent degradation to the quality of water nearby. A full suite of water quality analysis will be performed by an external laboratory to verify the accuracy of field measurements.

The location of seepage or runoff will be documented with photos and GPS.

Downstream or down gradient locations will be monitored to ensure that AML runoff does not eventually reach fish bearing waters. If water quality analyses indicates runoff does deposit metal loading into a fish bearing stream or creek, the initial response of ditching, berming, pumping or selective waste rock removal to prevent this would be implemented. Once the seepage/runoff is diverted or removed, measures would be taken to prevent the AML from occurring. This may include removing the material responsible for producing the AML runoff and transporting it to a Potentially-AML Waste Rock Storage Facility, or installing a cover or water diversion system.

Weekly monitoring at the location trending to AML conditions would be implemented until seepage/runoff stops for two consecutive weeks or thresholds are not triggered for two consecutive months.

4.4 SLUDGE STORAGE AREA EFFECTIVENESS COMPROMISED

As mentioned previously in Section 2.2 (Plans in Place) a Sludge Management Plan is currently in place. The following sections pertain to the potential for the effectiveness of the Valley Tailings sludge storage area to become compromised. Sludge storage in the DSTF will be evaluated by DSTF monitoring programs.

4.5 Seepage Observed Near Sludge Storage Area

4.5.1 Description

Any seepage observed in the vicinity of the sludge storage areas will be monitored to determine if it is resulting from sludge deposition.

4.5.2 Locations

The Valley Tailings sludge storage areas will be routinely monitored for seepage.

4.5.3 Monitoring Requirements

Visual inspections will be conducted at the Valley Tailings Sludge Storage Cell when these facilities are in use. Any seepage will be documented and water quality assessed for pH and zinc.

4.5.4 Specific Thresholds

Any new identified seeps will be monitored and analyzed onsite for the pH and zinc thresholds:

- pH > 8.5 and zinc > 1.0 mg/L.

4.5.5 Approach to Responses

Seepage observed in the vicinity of the sludge storage areas will be documented with photos and monitored for flow, field pH and zinc. A full suite of water quality analysis will be performed by an external laboratory to verify the accuracy of field measurements. The flow path will be documented and an assessment of the down gradient environment conducted to determine if flow is reaching surface waters and whether or not they are fish bearing. If seepage is depositing a load into a fish bearing stream or creek, ditching, berming or pumping may be implemented to prevent this. Alternative sludge storage area would be assessed and use of the current one would cease.

The Sludge Management Plan would be revised to incorporate any new sludge storage areas and implemented.

4.6 Sludge Storage Area Approaching Capacity

4.6.1 Description

Sludge storage areas will be monitored daily during use to ensure sufficient capacity.

4.6.2 Locations

- The Valley Tailings Area Sludge Storage Cell.

4.6.3 Monitoring Requirements

Visual inspection of freeboard in Valley Tailings Sludge Storage Cell will be conducted when this facilities is in use.

4.6.4 Specific Thresholds

Freeboard is approaching capacity: 1.5 m. A minimum freeboard of 1.0 m below the decant point will be maintained.

4.6.5 Approach to Responses

Determine if there is seepage from the sludge storage area as per the visual inspection.

An investigation would be conducted of the ability to increase the facility capacity by increasing berm height for example.

Alternative sludge storage area would be assessed and use of the current one would cease.

The Sludge Management Plan would be revised to incorporate any new sludge storage areas and implemented.

4.7 PHYSICAL INSTABILITIES

The following sections pertain to potential physical instabilities that may be encountered in the Bellekeno Production Area, though specific DSTF triggers will be discussed separately.

4.7.1 Area of Significant Subsidence is Observed

Subsidence can be observed as a result of slope failure or erosion, which could potentially affect the down gradient environment, particularly surface water. Slope

failure could eventually result in a rock fall or landslide or lead to structure failure or portal collapse.

4.7.2 Locations

Throughout the Bellekeno Production Unit based on routine inspection throughout the property and as outlined in the Physical Inspection and Reporting Plan.

4.7.3 Monitoring Requirements

Maintenance personnel will routinely observe subsidence, slope failure, or erosion in the course of their daily site activities. Routine inspections will be performed in accordance with the Physical Inspection and Reporting Plan.

4.7.4 Specific Thresholds

The specific thresholds that will initiate an adaptive management response include:

- A depression with defined edges is noted in the ground with the potential to create a public safety concern;
- A cave-in has occurred allowing access to the underground workings of a mine site;
- Break in soil/ slope creep/ sediment transport observed from physical structure with perceived potential to effect nearby structures or down gradient surface water.

4.7.5 Approaches to Responses

As per the general approach to the adaptive management plan, a staged response to an observed area of subsidence, slope failure or erosion will be implemented if the threshold is triggered.

The initial response to observing an area of subsidence, slope failure or erosion will be to prevent a hazard to public health and safety and minimize sediment transport to surface waters. This could include installation of barriers such as dykes or silt fencing or construction of diversion ditches or berms.

If necessary, physical removal or physical repair of structure will be performed to remediate it to a safe status. Access to the area would be limited using fencing, barricades, or signage to alert the public and other maintenance personnel to the danger that may exist.

If there are no underground workings in the area, then it is possible that the subsidence, slope failure or erosion would be due to liquefaction of soil near the surface and may not be a cause for concern. The break or depression will be filled in with soil and monitored to see if the subsidence, slope failure or erosion continues. If the subsidence, slope failure or erosion continues to appear after repair, then further investigation by a mining engineer may be warranted, particularly if there is a risk to the stability of a nearby structure. Any physical repairs to slopes or embankments would involve an assessment in consultation with a mining engineer before implementation.

The final stage will be to implement the repair at the area of the subsidence, slope failure or erosion and to monitor the area to watch for signs of continued subsidence, slope failure or erosion at or around the previously identified area.

4.8 Rock Fall or Landslide Occurs Within Monitored Area

4.8.1 Description

The deposition of waste rock in the Bellekeno Production Unit is being done in areas where engineering assessments were performed for suitability. However, it is possible that waste rock piles can possibly shift due to changes in foundation conditions. Even though it is remote or unlikely, a significant amount of material can potentially block access to a site.

4.8.2 Locations

Monitoring locations are throughout the area of the Bellekeno Production Unit in accordance with the Physical Inspection and Reporting Plan.

4.8.3 Monitoring Requirements

At a minimum the locations identified in the Physical Inspection and Reporting Plan, and other areas as observed by site operators. Maintenance personnel will routinely observe soil or earth movement in the course of their daily site activities.

4.8.4 Specific Thresholds

The specific thresholds that will initiate an adaptive management response include:

- A rock fall or landslide has blocked access to a previously monitored site.
- A rock fall or landslide has blocked access to a roadway previously used by the public.

- A rock fall or landslide has blocked or re-directed the flow of water of a documented stream or watercourse.
- Liquefaction of a waste rock pile foundation has caused waste rock to migrate closer to a watercourse.

4.8.5 Approaches to Responses

As per the general approach to the adaptive management plan, a staged response to the presence of a rock fall or a landslide will be implemented if a threshold is breached.

The initial response to observing a rock fall or a landslide will be to determine if it impedes on a right-of-way or a water flow path. If the debris impedes on a right of way, access to the area will be limited using fencing, barricades, or signage to alert the public and other maintenance personnel to the debris' presence.

The next stage of the response will be to examine the area to assess the possibility of further erosion of the originating slope. This task may require the services of a registered engineer. If warranted, a plan will be developed to prevent future erosion in the area.

The final step in the response to debris from a rock fall or a landslide impeding on a right-of-way will be to remove the debris, likely with heavy machinery, and transporting it to an isolated waste pile where the debris will not affect any watercourse or physical stability.

If the rock fall or landslide debris enters a watercourse, then water quality testing will be implemented. This will be done to determine if the presence of the rock in the water is contributing any metal loading to the water. If the loading in the water is found to be effected by the source material, then a mitigation plan will be developed and implemented in consultation with technical experts and regulatory agencies until such time as the debris can be removed from the watercourse, and water levels return to their historical norm.

If the metal loading is determined to be not affected by the source material, then no mitigation treatment plan will be necessary, and the debris can be removed from the watercourse.

The final stage will be to continue monitoring water quality at that location for a period of time until it is determined that the rock fall or landslide had no lingering effects on the water quality.

4.9 SITE SECURITY COMPROMISED

4.9.1 Gate, Fence or Sign Damaged

In the Bellekeno Production Unit hazards to public safety exist. In order to alleviate these hazards, depending on the type of hazard and its accessibility, structures, gates, fences, or signs have been erected to prevent the public from entering these areas or draw their attention to the hazard.

Over the course of time, some of these deterrents may suffer damage or may degrade which impedes on their ability to perform as a safety deterrent. The most likely scenario is for the item to have fallen down, however, the items performance may have been degraded by weather erosion or possibly at the hands of vandals.

4.9.2 Locations

Throughout the Bellekeno Production Unit.

4.9.3 Monitoring Requirements

Since it is almost impossible to predict when or where a gate, fence, or sign will be damaged, there can be no specific monitoring requirements to observe these circumstances prior to their existence. The monitoring information required is observations of damage to any of these safety features throughout the Bellekeno Production Unit. Maintenance personnel will be familiar with the placement of gates, signs, and fences around the property and thus, during their routine site activities will be able to observe when one of these features requires attention.

4.9.4 Specific Thresholds

The specific thresholds that will initiate the action plan will be as follows:

- A gate is found open outside of a scheduled visit by authorised site personnel.
- A gate post is found to be damaged such that the gate is sufficiently disabled to prevent access to the site by authorised site personnel.
- A gate post is found to be damaged such that the gate no longer prevents unauthorised access to a site of concern.
- A fence is found to be damaged such that it no longer prevents unauthorised access to a site of concern.
- A fence or structure is found to be damaged such that it no longer prevents unauthorised access to a site of concern.

- The placard of a sign has been damaged either by environmental conditions or by vandalism such that the sign is no longer effective in relaying the information intended.
- A sign post has been damaged to an extent where the sign is in a position which renders it ineffective in relaying the information intended.

4.9.5 Approaches to Responses

As per the general approach to the adaptive management plan, a staged response to any one of the above circumstances will be implemented if the threshold is triggered.

The initial response to a gate being found open or a fence being damaged and allowing access to the site will first trigger an examination of the area in question in order to ascertain whether trespassers are in the vicinity and may have initiated the condition of the gate or fence. If trespassers are found and do not appear to impose a risk to the site personnel, they will be cordially escorted off the property and the gate will be locked. If site personnel feel that there may be a risk in confronting the trespassers, then the appropriate authorities will be contacted immediately and requested to attend to the situation. If the lock on the gate has been damaged or tampered with, it will be replaced in a timely fashion.

If the gate is found to be damaged such that it no longer prevents unauthorised personnel from accessing a site, then the same measures above will be implemented. Once the trespassers have been escorted off site or the area is deemed to not contain any trespassers, the gate will be repaired or replaced in a timely fashion to ensure it will prevent access to the site by unauthorised personnel.

If the placard of a sign has been damaged either by environmental conditions or by vandalism, or the sign post is broken such that the sign is no longer effective in relaying the information intended, then maintenance personnel should note this at the time of observation and this information should be passed on to the project manager.

5. ADDITIONAL ADAPTIVE MANAGEMENT TRIGGERS FOR BELLEKENO PRODUCTION UNIT

EBA Engineering Consultants (EBA) designed the Dry Stack Tailings Facility for Alexco. In September 2010, EBA developed the Operation, Maintenance, and Surveillance Manual (OMSM) for the Dry Stack Tailings Facility at the direction of Alexco for the Keno Hill District Mill. This manual will be referenced in response to some triggers.

5.1 High Pore Pressure Underneath DSTF

Located beneath the DSTF is a Drainage Blanket. This feature provides drainage beneath the facility and will allow excess water, whether in the stack or freed from thawing permafrost, to drain away and not allow porewater pressures to build underneath and/or within the tailings.

According to the DSTF design, the drainage blanket will be constructed with gravel material obtained from excavation near the toe of the DSTF. The drainage blanket is then covered with a properly bedded geosynthetic clay liner to act as a collection layer for any seepage leaving the tailings stack. This material will help prevent tailings and tailings porewater and from infiltrating the coarser gravel material of the drainage blanket.

The OMSM contains an adaptive management plan which can be triggered if the tailings handling and disposition is not meeting critical performance objectives according to specific conditions. Close monitoring of the DSTF is critical in determining if and when action is required. Section 9.0 of the OMSM contains a surveillance plan that provides for adequate monitoring to determine if and when adaptive management is required.

Specific to the development of high pore pressures identified underneath the DSTF, the OMSM presents the following table that lists triggers as well as response actions:

In the event that the above triggers occur, the Alexco staff will perform one or all of the listed actions to address the identified issue.

Table 5.1 High pore pressure event

Taken from Table 14 of EBA's OMSM			
Provision	Monitored Item	Triggers/Threshold	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. Monitoring and review will be increased to semiweekly 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 Facility designer will conduct a site visit and determine if tailings placement and/or construction plan requires modification Monitoring and review will be increased to daily until determined unnecessary. Facility designer will determine if additional instrumentation is required. Facility designer will complete analysis of mitigative measures should exceedance continue.

5.2 Significant Erosion of Exposed DSTF Surfaces

The OMSM presents a management plan to ensure that the DSTF is managed to create compacted tailings, to limit run-on of surface water that could cause erosion, and also a plan to operate the DSTF in adverse conditions. The OMSM plan (pgs 22-23) states:

Potentially adverse conditions must be accounted for in the operation of the DSTF. These conditions, along with mitigative measures of dealing with them, are as follows.

- High Rainfall
- Erosion control – grade control and compaction of tailings stack during construction to seal lifts and prevent pooling of water.
- Compaction – may require drying out material prior to achieving compaction. At the discretion of the Geotechnical Engineer, material requiring additional compactive effort will be moved to less critical areas of the DSTF; i.e. south portion of the placement area away from the ultimate tailings slope, if required.

- High snow accumulation
- Removal prior to lift placements.
- Snow dumps will be sited to minimize any erosional impacts during thaw conditions.
- Freezing temperatures
- Location of placement – east portion of placement area away from the ultimate tailings slope as compaction prior to freezing problematic.
- Compaction – must be completed prior to the tailings freezing.
- Tailings Characteristics (higher moisture)
- Location of placement – south portion of placement area away from the ultimate tailings slope
- Compaction – may require drying out material prior to achieving compaction. At the discretion of the Geotechnical Engineer, material requiring additional compactive effort will be moved to less critical areas of the DSTF; i.e. south portion of the placement area away from the ultimate tailings slope, if required.

The OMSM surveillance plan includes key parameters to determine if failure modes are occurring. A visual observation list includes (Section 9.3, pgs 27-28)

- Surface—cracking, bulging, depression, sinkholes
- Seepage—new seepage areas, changes in seepage areas
- Turbid water in the natural drainages around or downstream the facility
- Water or tailings flowing down the stack indicating improper grading, and
- A failure or breach of a component of the facility.

Other routine monitoring required by the OMSM plan includes:

- 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—displacement of survey monuments
- Measuring slope inclinometers located in the foundation soils
- Water sampling of Christal Creek, and
- Recording Weather conditions.

Erosion is an adaptive management plan which can be triggered if significant erosion of exposed DSTF surfaces occurs. Close monitoring of the DSTF is critical in determining if and when action is required.

Specific to these conditions, EBA has developed the following table that lists triggers as well as response actions:

Table 5.2 Significant Erosion

Taken from Table 13 of EBA's OMSM			
Provision	Monitored Item	Triggers/Threshold	Action
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 Apply appropriate runoff, erosion or sediment control measures

In the event that the above triggers occur, the Alexco staff will perform one or all of the listed actions to address the identified issue.

5.3 Erosion at the Flame and Moth Discharge Site

Discharge from the Flame and Moth facility is not anticipated to occur in the near future, as the size of the stormwater runoff pond has been oversized to provide for operational flexibility. When the discharge from the facility is designed, an adaptive management approach will be developed to account for erosion from this site. Specific elements of the design will allow for flexibility to spread out the discharge such that erosion can be prevented, or discharge will be adjusted to prevent continuous saturation of soils in the area of discharge.

5.4 Transport of Sediments from Mill Facility to Christal Lake

Discharge from the Flame and Moth facility is not anticipated to occur in the near future, as the size of the stormwater runoff pond has been oversized to provide for operational flexibility. When the discharge from the facility is designed, an adaptive management approach will be developed to account for erosion from this site. Specific elements of the design will allow for flexibility to spread out the discharge such that erosion can be prevented, or discharge will be adjusted to prevent continuous saturation of soils in the area of discharge.

5.5 Large Differential Settlements at DSTF

Included in EBA's OMSM is an adaptive management plan which can be triggered if differential settlements within the DSTF surfaces occur. Close monitoring of the DSTF as outlined in Section 5.2 will be implemented to determine if and when action is required.

Specific to these conditions, EBA has developed the following table that lists triggers as well as response actions:

Table 5.3 Large Differential Settlements

Taken from Table 14 of EBA's OMSM			
Provision	Monitored Item	Triggers/Threshold	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. Facility designer will conduct a site visit and determine if tailings placement and/or construction plan requires modification. Monitoring and review will be increased to semiweekly until determined unnecessary. Alexco to complete survey of area of interest to monitor any future displacement, if any. Facility designer will determine if additional instrumentation is required. 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

In the event that the above triggers occur, the Alexco staff will perform one or all of the listed actions to address the identified issue.

5.6 Large Differential Settlements from DSTF to Stormwater Collection Pond

The development of large differential settlements along the conveyance flume from the DSTF to the Flame and Moth Site collection and sediment pond will be identified and addressed through the same actions listed in Table 5-3 above.

5.7 Exceedence of Water Quality Standard in Receiving Environment

Sitewide monitoring of the entire KHSD, and specific monitoring of the Bellekeno Production Unit is being performed in accordance with WUL QZ06-074 and WUL QZ09-092 and the plans referenced in Section 2.2.

In addition to the historic impacts of mining in the KHSD and the Bellekeno undertaking, placer mining on Lightning creek, deposition of waste in the Keno City municipal dump facility, and other non-mining activities has the potential to impact the receiving environment.

5.7.1 Descriptions

With respect to the Bellekeno undertaking, it is imperative to identify the impact of the discharges authorized under this licence with the existing discharges occurring in the KHSD and other human activities in the area. Consequently, site-wide monitoring information must be compared with water quality information collected and compiled for the Bellekeno undertaking to assess the relative impacts of these various activities.

All data for current water sample stations required in the KHSD WUL QZ06-074 and Bellekeno Mine WUL QZ09-092 and are stored in an EQWin database that allows water quality to be tracked at each site such that conditions can be identified at any point in the season. In this way parameters can be seen to be fluctuating from the normal, and reaching levels where management is required to respond. Set point triggers can be placed in the database so that response parameters are flagged for notification and action.

Comparison of all water quality information is routinely done and a variance report is generated on at least a quarterly basis for site wide information that could identify site wide trends.

5.7.2 Locations

Water quality is monitored from the Bellekeno water treatment facilities for potential effects to the receiving environment including loading of down gradient waters. These sites are shown in Figure 3-1 of the Environmental Monitoring Program in Appendix A. The district-wide AMP also identifies all other monitoring locations in the district.

5.7.3 Monitoring Requirements

All water quality information in the KHSD and the Bellekeno undertaking is analyzed for exceedences of CCME criteria, as well as variances with the previous 6 months of data at

that location, which can assist in the determination of causes of water quality changes over time. All exceedences of water quality for licenced parameters will be compared with historic exceedences.

5.7.4 Specific Thresholds

Three cases to determine if a threshold has been exceeded:

Case 1: Sites that have a CCME exceedence will be flagged for additional analysis. If there is a long trend of exceedence at that site and the exceedence is within the 95% UCL for the last two years of data at that site, then no further action will be taken and it is assumed that the district-wide closure plan implementation will be the primary mechanism to improve the water quality at that site.

Case 2: If a new exceedence is detected in either the Lightning Creek or Christal Creek drainages, which are the two drainages where the Bellekeno undertaking is authorized to deposit waste, and the mass loading from the Bellekeno undertaking is contributing less than 10% of the mass load for the constituent causing the exceedence, then no further action will be taken and it is assumed that the district-wide closure plan implementation will be the primary mechanism to improve the water quality at that site.

Case 3: If a new exceedence is detected in either the Lightning Creek or Christal Creek drainages, which are the two drainages where the Bellekeno undertaking is authorized to deposit waste, and the mass loading from the Bellekeno undertaking is contributing to greater than 10% of the mass load for the constituent causing the exceedence, then further responses will be undertaken.

5.7.5 Responses to Changes in Receiving Environment Water Quality

Potential responses to Case 3 exceedences include the following:

- Notification to the Water Inspector that the trigger has been triggered within three working days.
- Increased sampling frequency may be required around the area of the exceedence will be implemented to help determine potential causes.
- Investigation of the root cause of the exceedence.
- If a root cause of exceedence can be readily identified and remedied, the remedy will be implemented in a timely manner, and the water inspector notified of the remedy implementation in a timely manner according to permit requirements.

- If a root cause cannot be readily identified, a study plan will be outlined and communicated to involve qualified professionals to assist in the identification of the root cause.

5.8 Identification of Groundwater Quality Impact at F&M or BK

The Groundwater Monitoring Plan provides data that can be utilized to assess groundwater quality impacts associated with mining and milling activities. The Groundwater Monitoring Plan identifies two areas of the Bellekeno undertaking where groundwater monitoring will be carried out.

5.8.1 Description

Groundwater in the vicinity of Keno City and the mill site flows in a north-westerly towards the Christal Creek. A network of shallow and deep groundwater monitoring wells is specified for the Flame and Moth mill site in order to determine if there are any impacts to groundwater as a result of deposition of waste authorized by the Licence and also to determine if upgradient users may be influencing groundwater which flows toward the site (i.e. the Keno City dump). The Flame and Moth site is located upgradient of Christal Creek, so understanding any impacts to groundwater as a result of the undertaking is important to help determine any risk to Christal Creek. Although groundwater flow direction has been demonstrated to flow away Keno City towards the northwest, a well in Keno City is also being monitored (See Section 5.9)

The second groundwater monitoring location specified by the Groundwater Monitoring Plan is downgradient of the proposed Non-AML Waste Rock Disposal Area along the north flank of Sourdough Hill to the west of the Bellekeno 625 adit. It is assumed that groundwater flow in this area follows surface topography and flows down slope towards Lightning Creek. Groundwater wells located below the toe of the Non-AML Waste Rock Disposal Area will be used to determine if seepage from Non-AML waste rock is having any impacts to downgradient groundwater quality, which might in turn, impact water quality in Lightning Creek.

5.8.2 Locations of Groundwater Monitoring Wells

Groundwater monitoring wells at the Flame and Moth Mill Site are shown on Figure 1 of the Groundwater Monitoring Plan. Conceptual monitoring well locations below the Non-AML Waste Rock Disposal Area are shown on Figure 2 of the Groundwater Monitoring Plan.

5.8.3 Monitoring Requirements

Monitoring requirements for groundwater monitoring are described in the Groundwater Monitoring Plan. Quarterly measurement field parameters including water level and measurement by an external laboratory of suite of standard parameters including total ICP metals, dissolved ICP metals, ammonia, phosphorous, sulphate, DOC, and hardness is specified by the Licence.

5.8.4 Thresholds

A trend based approach using a minimum of 5 data points for each monitoring well will be used to determine thresholds and triggers for adaptive management. This approach is deemed to be necessary because of the high degree of local variability in local aquifers due to mineralization.

Monthly sampling will be undertaken for each new monitoring well until a minimum of 5 data points are available to provide a baseline for each monitoring well. After these data points are collected, for each well, sampling will revert to quarterly sampling as per the groundwater monitoring plan. The trigger for adaptive management would be:

- Exceedence of the highest baseline measurement for Zn for any parameter by a factor of 2x and;
- Sample result exceeds effluent quality standard for wells located within each drainage (Table 4-1 for Lightning Creek, Table 4-2 for Christal Creek).

5.8.5 Responses

- Notification to the Water Inspector that the trigger has been triggered within three working days.
- Increased sampling frequency may be required around the area of the exceedence will be implemented to help determine potential causes.
- Investigation of the root cause of the exceedence.
- If a root cause of exceedence can be readily identified and remedied, the remedy will be implemented in a timely manner, and the water inspector notified of the remedy implementation in a timely manner according to permit requirements.
- If a root cause cannot be readily identified, a study plan will be outlined and communicated to involve qualified professionals to assist in the identification of the root cause.

5.9 Water Quality Impact to Keno City Water Wells

The Groundwater Monitoring Plan provides data that can be utilized to assess groundwater quality impacts associated with mining and milling activities. In addition to addressing groundwater monitoring in the immediate vicinity of the mill site and the Bellekeno Waste Rock Disposal Area, the Groundwater Monitoring Plan identifies groundwater sampling which will be undertaken within the townsite area of Keno City.

5.9.1 Description

Groundwater in the vicinity of Keno City and the mill site flows in a north-westerly towards the Christal Creek. Although groundwater flow direction has been demonstrated to flow away Keno City towards the northwest, a well in Keno City is also being monitored (KV-84).

Initial sampling as reported in the SRK Bellekeno Groundwater Study (SRK, 2010) used Keno City Well #3 which is owned by a private resident of Keno City. Well #3 and the Keno City Firehall well have been sampled since issuance of the Licence in order to fulfill monitoring requirements for KV-84, but because of difficulties coordinating sampling, this is not viewed as a satisfactory solution for the duration of the Licence. Alexco, through part of the District Closure Planning, has installed several wells around Keno City for a hydrogeology study as part of a hydrogeologic study of the Keno City area. These wells have just recently been installed; the final selection for KV-84 has not yet been made. A notification will be submitted to the YWB and Water Resources in order to provide notification to regulators of the final sampling location of the Keno City well.

5.9.2 Location of Groundwater Monitoring Well

Groundwater monitoring wells in the vicinity of Keno City are shown on Figure 3 of the Groundwater Monitoring Plan, including approximate location of the final location for the monitoring well which will be used as KV-84.

5.9.3 Monitoring Requirements

Monitoring requirements for groundwater monitoring are described in the Groundwater Monitoring Plan. Quarterly measurement field parameters including water level and measurement by an external laboratory of suite of standard parameters including total ICP metals, dissolved ICP metals, ammonia, phosphorous, sulphate, DOC, and hardness is specified by the Licence.

5.9.4 Thresholds

A trend based approach using a minimum of 5 data points for the Keno City monitoring well will be used to determine thresholds and triggers for adaptive management. This approach is deemed to be necessary because of the high degree of local variability in local aquifers due to mineralization.

Monthly sampling will be undertaken for KV-84 until a minimum of 5 data points are available to provide a baseline for each monitoring well. After these data points are collected, for each well, sampling will and sampling will revert to quarterly sampling as per the groundwater monitoring plan. The trigger for adaptive management would be:

- Exceedence of the highest baseline measurement for Zn by a factor of 2x and;
- Sample result exceeds effluent quality standard (Table 4-1).

5.9.5 Responses

- Notification to the Water Inspector that the trigger has been triggered within three working days.
- Increased sampling frequency may be required around the area of the exceedence will be implemented to help determine potential causes.
- Investigation of the root cause of the exceedence.
- If a root cause of exceedence can be readily identified and remedied, the remedy will be implemented in a timely manner, and the water inspector notified of the remedy implementation in a timely manner according to permit requirements.
- If a root cause cannot be readily identified, a study plan will be outlined and communicated to involve qualified professionals to assist in the identification of the root cause.

6. REVIEW OF EXISTING MONITORING AND MANAGEMENT PLANS

A review of existing monitoring and management plans was performed to identify the effects of these plans on the adaptive management framework, and to identify the commitments for adaptive management already made. The following summarizes this review:

6.1 QML and WUL Plans

1. Emergency Response Plan—No adaptive management plan elements.
2. Hazardous Materials Management Plan—No adaptive management plan elements.
3. Heritage Resources Protection Plan—No adaptive management plan elements.
4. Monitoring and Surveillance Plan—Provides monitoring information for AMP, but only summarizes site-wide AMP.
5. Noise Abatement Plan—No adaptive management plan elements.
6. Spill Contingency Plan—No AMP elements.
7. Traffic Management Plan—No AMP elements.
8. Waste Management Plan—No AMP elements.
9. Wildlife Protection Plan—No AMP elements.
10. Sludge Management Plan—No adaptive management plan elements.
11. Groundwater Monitoring Plan—Provides monitoring information for AMP, but no specific AMP commitments.
12. Tailings Characterization Plan—No adaptive management plan elements.
13. Dry Stack Tailings Facility Design Report—no adaptive management plan elements.

6.2 Physical Inspection and Reporting Plan

In section 5.2, pgs 5-6 of the Physical Inspection and Reporting Plan, the following commitments were made:

6.2.1 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. The site manager will then be responsible to immediately re-asertain whether or not the system or element is safe for use for the next 24 hours.

If issues are identified during the weekly inspections of structures, works and installations (e.g. waste rock storage area, overburden stockpiles, embankments, diversion ditches, sediment ponds, and pipelines) 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 also need to be implemented as required. If fair or poor conditions are noted during an inspection, NND will be notified of the details and of any planned mitigative action.

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.

6.3 Bellekeno 625 Water Treatment Systems Operations Manual

In Section 8 of the Water Treatment Systems Operations Manual, the following selection identifies the contingency plans and system flexibility associated with the treatment operation.

6.3.1 Future Improvements

One of the challenging aspects of processing water from inflows to the Bellekeno underground mine is that TSS and ammonia / ammonium spikes in the discharged water can occur based on variable underground conditions.

To address these issues, AKHMC is currently researching additional modifications to improve the water treatment system's responsiveness and flexibility to address potential spikes in detrimental water quality parameters. An example of these improvements is a pilot study evaluating the use of an inorganic resin specifically designed to remove ammonia / ammonium from water.

6.3.2 Ion Exchange System – Ammonia Reduction Pilot Study

In October 2010, AKHMC placed a portable treatment system at the Bellekeno 625 consisting of a small shed near the sea containers containing two tanks filled with an inorganic resin and gravel. These tanks were plumbed for water to flow between the tanks in series before final discharge back into the pond. This system is similar to the MMF system except that instead of a multi-layered media bed used to capture fine solids, the media bed is replaced with an ion exchange resin that preferentially removes ammonium, potassium, and cesium. Like the MMF system, water enters at the top of a tank and then flows downward through the resin. As water passes through this resin, ions (especially ammonium) are sorbed onto the resin thereby removing them from the water.

Once the resin has been in service for a certain amount of time (typically a few days), breakthrough can occur where the resin becomes saturated and ammonium ions are no longer collected. When this happens, the ion exchange system must complete a regeneration cycle during which all filtration is suspended and a brine consisting of 10% sodium chloride in water is pumped into the resin tank being regenerated.

This brine must contact the resin for a minimum of 30 minutes in order to desorb the ammonium that has sorbed onto the resin, thereby recharging the resin for future use. Once the brine solution has contacted the resin for the required time, it is pumped from the ion exchange tanks into a large holding tank and the system can be used again for treatment. The brine holding tank requires the addition of small amounts of sodium hydroxide as well as injected air that is bubbled through the solution. This injected air removes the collected ammonium through the process of off-gassing and recharges the brine for future use.

To date, the results of the ion exchange pilot study have been promising and a final report summarizing the results of this pilot study will be prepared once the pilot study has been completed. AHKMC may implement this system in the future if the performance of the resin in the pilot study is effective.

6.3.3 Clarifier

AKHMC is also considering the addition of a clarifier at the Bellekeno 625 water treatment facility. Clarifiers are currently in use at other adits within the Keno Hill Silver District that require active treatment and to date they have been very successful. Water passing through a clarifier is typically processed with the following steps:

Static Mixing- Chemicals (polymer and lime solution) may be added upstream of a static mixer, after which water flows into the flocculation tank.

Flocculation – The water passes sequentially through a two stage mechanical flocculator. Variable-speed drives on each paddle permit a wide variation in energy input and allow tapered flocculation to optimize floc formation.

Settling - The settling clarifiers currently under consideration are an up-flow solids contact unit complete with 60° settling tubes. The flow enters the bottom of the settler through a full length distribution manifold, and then passes upward as laminar flow. Heavier floc particles settle to the floor of the tank and lighter particles are retained within the tube settlers, coalesce into larger floc, and then settle to the floor. Clarified water is collected from the surface of the tank through two, full length collection launders. The tube settlers are fabricated out of light resistant polystyrene. The tube cell size and angle ensure self cleaning under normal operation. A sludge blanket is maintained in the lower portion of the clarifier and its position can be monitored through sampling valves installed in the cell wall. The lower portion of the tank has a sloped, “V” section to encourage sludge thickening and collection in the central hopper. Periodically, this sludge must be removed hydraulically through a full length, perforated sludge collector located at the foot of the “V”. The desludging operation may be controlled automatically by timer controlled operation of an actuated valve programmed into the plant Process Logic Controller (PLC).

It is this formation of heavier floc particles and coalescence of lighter flocs into larger heavier flocs described above, that differentiates the clarifier from an open pond. Although additional retention time in ponds would provide increased settling, the mechanics of floc formation do not occur in an open pond as efficiently as the clarification provided in the tube settlers of a clarifier. It is for this reason that the installation of a clarifier at Bellekeno 625 is under consideration.

6.3.4 Organic Polymer

In the future, ERDC may consider the addition of an organic polymer at the rapid mix tank to aid in flocculation. The polymer would be injected after the pH has been adjusted with the expectation that it would attach to the metal hydroxide particles and

improve settling. When the polymer is added, the hydroxide particles become entangled in the long chains of the polymer, causing the particles to increase in size and form flocs. As the flocs increase in size they become heavier and settle more quickly to the bottom of the pond. This floc formation is illustrated in the figure 6-1 below (University of Maryland, Engineering Research Center Report):

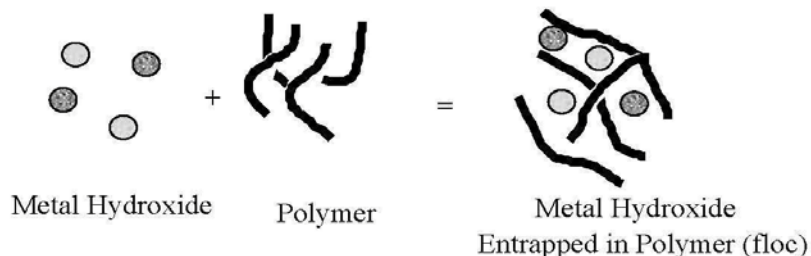


Figure 6-1. Floc Formation

If an organic polymer is used in the future, it would be stored in the treatment shed and added into the rapid mix tank via a small metering pump.

6.4 Water Management Plan and Water Balance Report

The water management plan and water balance report provides the following with respect to adaptive management of the Bellekeno Mine. Quote from Water Management Plan and Water Balance Report, pgs. 23-25:

Contingency Plans

Contingency plans for flood or drought conditions have been considered to ensure unexpected climatic conditions do not adversely affect mine/mill operations or result in significant environmental impact.

6.4.1 Drought Conditions

The current make-up water requirements at the mill are approximately 30,000 liters/day (0.35 L/s). This makeup water requirement is less than 5% of the combined flow emanating from Galkeno 900 and Bellekeno 625. The makeup water requirements at the mill also represent a very small portion of the Christal Creek drainage which has its headwaters near the mill site location. Given the relatively small volume of make-up water compared to current source levels, a reduction in make-up water available for mill operations due to a drought condition does not represent a concern from an

operational standpoint and therefore no unique contingency plans are in place for a drought scenario.

The Bellekeno Mine produces excess water that must be collected and treated. Although the Bellekeno Mine produces approximately 4 L/s of constant discharge, only about 50% of the mine recharge volume is required for mine development and operations (equipment, paste backfill). The amount of water required to sustain mine operations is a small portion (1-2%) of the flow at Lightning Creek where mine makeup water is currently permitted for withdrawal. Similar to the mill makeup water requirements, a drought scenario does not represent a current operational concern for the Bellekeno Mine and a contingency plan is currently not in effect.

6.4.2 Flood Conditions

High flow or flood conditions at the mill do not necessarily pose an extreme case from an operational perspective as the mill site water management design already incorporates ditching and pond volumes based on extreme precipitation events (design capacity in excess of 1:100 year event). In addition, the mill site location is situated with a very small, headwater drainage basin ($<3 \text{ km}^2$), effectively minimizing the potential for flooding conditions. In the case of a flood event, active milling operations may be temporarily suspended to ensure operations personnel and equipment are appropriately allocated to managing and maintaining ditches and conveyance structures until the peak flows have decreased to normal levels.

6.4.3 High Mine Inflow Conditions

Contingency and response plans for high or unexpected underground mine flows fall under the protocols of the company's emergency response plan.

The first priority in a high mine inflow condition is the safety and protection of the employees and contractors working underground at Bellekeno. If the water in-rush was of a nature that required immediate evacuation, the specific protocols for mine evacuation would be initiated by the Mine Manager or his designate (Section 8, Keno Hill Emergency Response Plan).

Once the safety of underground employees and contractors have been established, the nature of the water in-rush would be immediately investigated by the General Manager or his designate. Securing underground facilities and infrastructure would become the next priority after employee safety. Depending on the nature and level of the mine flow in-rush or high flow condition, a determination would be made if mobile equipment needed to be removed from certain levels and locations in the mine and brought to surface or to the central decline. Electrical utilities and infrastructure would be assessed

to determine if areas of the mine needed to be isolated or removed from electrical power distribution.

The cause and extent of the high mine water flow condition would then be assessed by the General Manager, Mine Manager and other specialist positions on the site (i.e. Chief Engineer) to determine if the extent of the high mine flow was expected to continue or if flow conditions are expected to recede. Based on the level of high mine flow, the rate of dewatering would be increased to the maximum levels permitted in order to reduce the volume of mine pool. Standby pumps would be established if necessary to increase the volume of water being pumped from the underground mine. The Bellekeno 625 water treatment plant is permitted and capable of treating 10 L/s which is approximately double the current steady state flow conditions of the Bellekeno Mine. If the volume required for dewatering were to exceed permitted levels or if the Bellekeno 625 water treatment plant was not meeting discharge standards due to high sustained flows, the appropriate regulatory agencies would be contacted and consulted. If necessary, consideration would be given to applying for an Emergency Amendment under QZ09-092 to manage the high inflow conditions if all other measures were not effective.

6.5 Groundwater Monitoring Plan

Section 7, page 17 states the following:

The licence requirement for monitoring of KV-84 requires that a Keno City Well be monitored on a quarterly basis. This monitoring is also subject to Clause 44, requiring that all wells be sampled monthly for the first twelve months that they contain water.

Initial sampling as reported in the SRK Bellekeno Groundwater Study (SRK, 2010) used Keno City Well #3 which is owned by a private resident of Keno City. Well #3 and the Keno City Fire Hall well have been sampled since issuance of the Licence in order to fulfill monitoring requirements for KV-84, but because of difficulties coordinating sampling, this is not viewed as a satisfactory solution for the duration of the Licence.

Alexco, through part of the District Closure Planning, is currently planning installation of several wells around Keno City for a hydrogeology study as part of a hydrogeologic study of the Keno City area. It is anticipated that this work will be carried out during February 2011, and that once installed, one of these wells will be selected for reporting for KV-84. A notification will be submitted to the YWB and Water Resources in order to provide notification to regulators of the final sampling location of the Keno City well.