Keno Hill Water Treatment Systems
Sludge Management Plan – Bellekeno Undertaking
QZ09-092

Prepared by:

Alexco Keno Hill Mining Corp.

February 2011
Revision No. 1

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

gpm.. Gallons per minute
l.. Litres
lps .... Litres per second
m... Meters
MMF.. Multi-Media Filtration System
TSS .... Total Suspended Solids
VFD... Variable Frequency Drive
WTSOM .... Water Treatment System Operations Manual

1.0 BACKGROUND

Alexco Resource Corp. (Alexco), through its wholly owned subsidiary Alexco Keno Hill Mining Corp. (AKHM) maintains and operates the water treatment facility for the Bellekeno Undertaking at Keno Hill under Type "A" Water Use License (WUL) QZ09-092. Pursuant to Part H, Condition 79-80 of WUL QZ09-092, AKHM must submit a **Sludge Management Plan** to the Board within 6 months of the effective water license date. This submittal fulfills those requirements of Conditions 79-80.

The Bellekeno water treatment system uses basic metal hydroxide precipitation technology and particulate removal technology including coagulation, settling, and filtration. In general, lime solution is added to the underground mine collected waters and a zinc hydroxide precipitate (sludge) is formed and settles to the bottom of two lined ponds. The suspended solids in the mine discharge and the zinc hydroxide particulates are removed by coagulation with lime, settling in ponds, and filtration in a multimedia filtration process. The purpose of the Sludge Management Plan is to outline the process by which the sludge that is produced as a byproduct of the water treatment system is managed.

This manual is intended to be an operational document that will require periodic updates as modifications and improvements are made to the current water treatment system process and sludge management. This document is released as Revision One (1).

1.1. PRECIPITATION CHEMISTRY

To help understand the system's functionality, it is important to outline the chemistry of metal hydroxide precipitation. With hydroxide precipitation, soluble heavy metal ions are converted to relatively insoluble metal hydroxide precipitates by adding an alkaline precipitating agent (e.g. lime slurry). Precipitation reactions, which originate in the rapid mix tank, form metal-hydroxide precipitates as shown below where M^+ is the soluble metal cation being removed.

$$\mathbf{M^+ + Ca(OH)_2 = M(OH)_2\,(s) + Ca^{2+}}$$

The metal ion combines with hydroxide ion to form the insoluble metal hydroxide solid. This reaction is pH dependent; as more base (e.g. lime solution) is added, the reaction is driven further to the right on the pH scale and more metals precipitate out of solution. Conversely, as the pH is decreased, the thermodynamic equilibrium moves to the left, which could allow metals to resolubilize. Generally, excess lime is added, which stabilizes the metal hydroxide precipitate, making this reaction practically irreversible.

The solubilities of the metal hydroxide precipitates (sludge) vary, depending on the metal ion being precipitated, the pH of the water, and to a limited extent the precipitating agent(s) being used. Typically the solubilities of most metal hydroxide precipitates decrease with increasing pH to a minimum value beyond which the precipitates become more soluble (i.e. amphoteric properties). The solubility trend of zinc hydroxide vs. pH is shown in Figure 1.

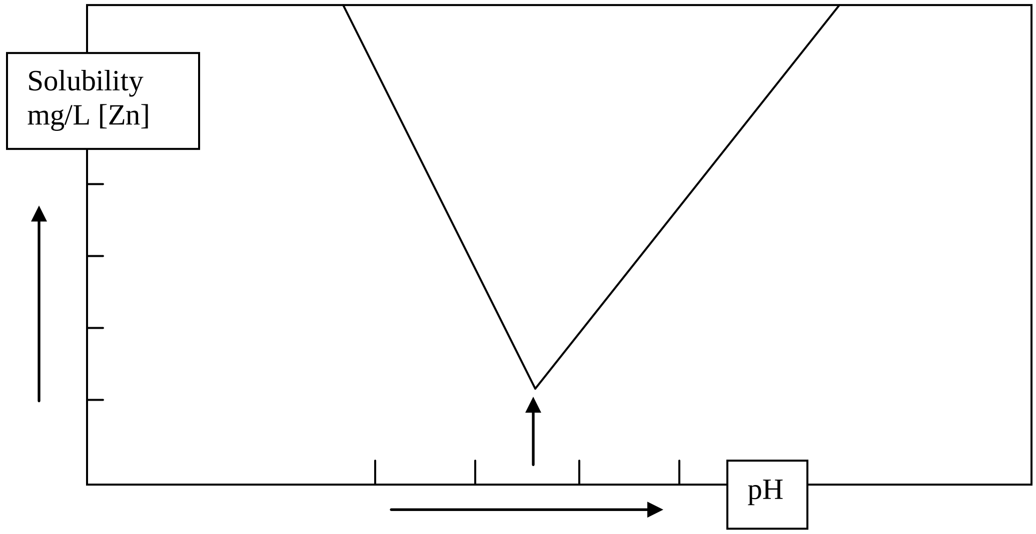


FIGURE 1 - ZINC HYDROXIDE SOLUBILITY VS. PH

It can be seen from the figure that by controlling the pH levels to within a specific range, the efficiency of metals removal can be maximized. The Bellekeno water treatment facility targets a pH range between 8.5 and 9.5.

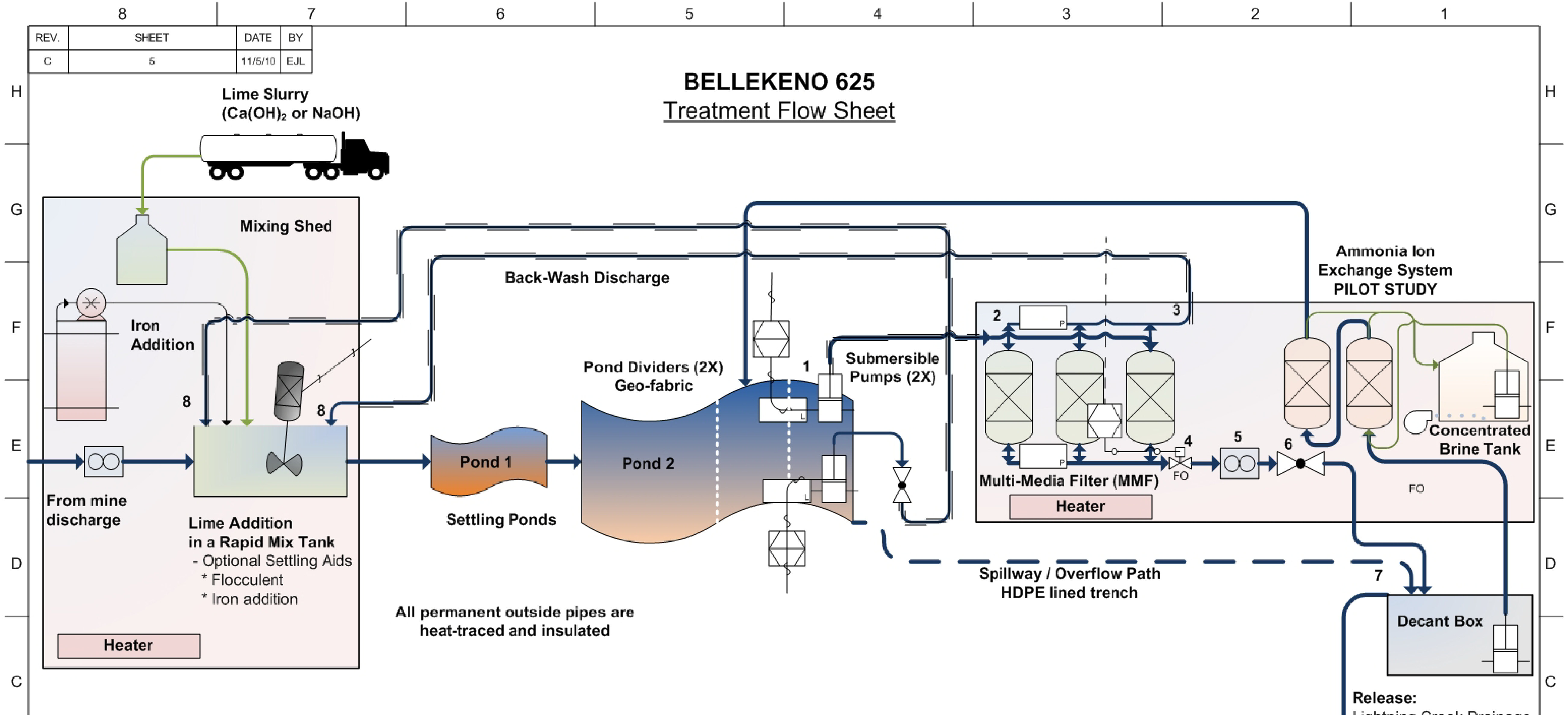
The addition of lime and ferric iron to the mine discharge also aids the settling rate and efficiency of the suspended solids that are in the water from the underground mining and exploration activities. Thus the sludge produced from this process will be a combination of metal hydroxides, residual lime, and fine rock particles that were suspended in the water removed from the underground.

2.0 TREATMENT SYSTEMS

2.1. WATER TREATMENT PROCESS

As with most underground mines, water inflows into the Bellekeno mine must be managed. The inflowing water pools and collects within the Bellekeno mine's drifts, stopes, and underground workings. To keep this water from slowly filling the mine, it is collected in sumps located underground at three different levels. Dewatering pumps suspended from the ceiling remove the top layer of water and send it through overhead steel pipes to the surface for treatment.

Figure 2 provides a diagram of the overall Bellekeno treatment system which should be used for reference.



Connection List

Connection #	Equipment	Part Number	Interface	Material	Description
1	BJM Submersible Pump	J37H	2" NPT-Male	Cast Iron	Verticle discharge, need conversion to 3" pipe as well as steel to HDPE
2	MMF - Influent	MM 2460-3A	3" 150# Flange	Cast Iron	Influent interface w/ MMF - requires 3" gasket and 4 bolts/nuts
3	MMF - Backwash	MM 2460-3A	2" NPT - Male	Cast Iron	Backwash interface w/ MMF - NPT to 2" HDPE line for return to mix tank
4	MMF - Effluent	MM 2460-3A	3" 150# Flange	Cast Iron	Effluent interface w/ MMF - requires 3" gasket and 4 bolts/nuts
5	Sea Metrics Flow Meter	WTP-101-300-18	3" 150# Flange	PVC	Interface w/ Flow Meter - requires 3" gasket and 4 bolts/nuts
6	3" Flanged Ball Valve	3700	3" 150# Flange	Steel	3" teflon coated ball valve - American Valve
7	Open Pipe	NA	Decant Box - Open Tank	HDPE	Release into Decant Box
8	Open Pipe	NA	Open Tank	HDPE	Release into Mix Tank - Fluid will pass back through the system

DESCRIPTION
PROCESS FLOW SHEET

FIGURE 2 - BELLEKENO WATER TREATMENT FLOW SHEET

After water is pumped to the surface, it enters a small water treatment shed seen in Figure 3 that is located near the Bellekeno 625 portal. The treatment shed houses a lime slurry tank and barrels of ferric chloride. On average, the flow is between 4.0 and 7.0 litres per second (lps). Downstream of the flow meter, the water reports to a circular rapid mix tank and mixer located underneath the treatment shed that ensures proper mixing of the water as the lime slurry and ferric chloride are added to the tank.

From the rapid mix tank, water passes into the first lined holding pond (Pond 1). It is in this pond that the majority of total suspended solids (TSS) and metal hydroxide flocculants settle out in the form of a grey sludge that collects at the bottom. To keep the pond from filling with sludge, a vacuum truck removes the sludge on a weekly basis.

FIGURE 3 - BELLEKENO WATER TREATMENT SHED

Pond 1 is connected to a much larger pond termed Pond 2 via a weir. Surface water is decanted from Pond 1 and spills into Pond 2 to allow for additional settling. To further increase the average residence time a geofabric is stretched across Pond 2 in two locations, thereby creating a tortuous path and reducing short-circuiting of water within the pond.

Once water slowly flows through Pond 2, it enters a submersible pump, filtered through a Multi-Media Filtration (MMF) system, and then discharged through a diffuser, where it flows down to join the Lightning Creek drainage system.

2.2. POND DESLUDGING

Sludge produced by the treatment system primarily settles out in Pond 1. As the amount of sludge increases, the residence time within the pond is decreased, thereby reducing the effectiveness of the treatment plant. Therefore, it is important that routine maintenance at the water treatment facility includes removing settled solids (desludging) from Pond 1. Normal desludging is accomplished with a vacuum truck as is shown in Figure 4. The sludge is removed by creating a vacuum within the holding tank and sludge is pulled into the tank via a 3” hose. Once the truck is filled, sludge is transported to the separate pond in the Valley Tails location, or to the mill.

FIGURE 4 - VACUUM TRUCK USED TO DESLUDGING PONDS

3.0 SLUDGE MANAGEMENT

3.1. SLUDGE VOLUMES

From past experience, AKHM has found that removing between three to five truckloads of sludge per week is needed from Pond 1 to maintain settling capacity in this pond. The maximum estimated sludge weight produced in a given week is approximately 2,400 kilograms. This calculation is based on the tank volume of the vacuum truck and an estimation of 4% solids in the collected sludge.

3.2. Sludge Characteristics

The characteristics of the sludge produced at Bellekeno were determined as part of the sludge management process. A sample of sludge was removed from the first settling pond on November 12, 2010, and submitted to Maxxam Analytics of Burnaby, BC. The results are summarized in the following tables:

Table 1. Summary of Physical and ABA Parameters of Bellekeno Sludge.

	BK625 Sludge	Detection Limits
Wet Sample Wt. (g)	948.22	-
Dry Sample Wt. (g)	121.01	-
Sample Type & Condition	Wet Tailings/Sediment	-
% Moisture (Wt.%)	83.9	-
Pulp Density (g/ml)	1.06	-
Paste pH	8.4	0.5
Total Sulphur (Wt.%)	0.85	0.02
Sulphate Sulphur (Wt.%)	0.29	0.01
Sulphide Sulphur* (Wt.%)	0.56	0.02
Maximum Potential Acidity (Kg CaCO3/Tonne)**	17.5	0.6
Neutralization Potential (Kg CaCO3/Tonne)	327.9	-
Net Nuetralization Potential* (Kg CaCO3/Tonne)**	310.4	-
Fizz Rating	Strong	-

These data show that the Bellekeno sludge is highly neutralizing (see “Net Neutralizing Potential” and “Neutralization Potential” data points) and that despite whatever sulfide sulfur the suspended solids in the mine discharge may have, the amount of lime added is sufficient to create a strongly alkaline sludge.

TABLE 2. MAJOR METALS, CATIONS, AND TRACE METALS, BELLEKENO SLUDGE. (INCLUDES QA/QC INFORMATION.)

Sample ID	Mo	Cu	Pb	Zn	Ag	Ni	Co	Mn	Fe %	As	U	Au	Th	Sr	Cd	Sb	Bi	V	Ca %	P %	La	Cr	Mg %	Ba	Ti %	B	Al %	Na %	K %	W	Hg	Sc	Tl	S %	Ga	Se	Te
BK625 Sludge	5.3	95.2	4663	4066	47.6	35.7	8.1	2125	2.58	118.4	8.4	1.3	5.3	227	57.6	19	1.5	13	12.74	0.043	6	53	0.39	102	0.003	<20	0.78	0.024	0.09	31.3	0.1	1.4	0.1	0.89	2	0.9	<0.2
QAQC																																					
Reference Material (1)																																					
STD OREAS45PA	1	632.6	18.5	120	0.3	310.7	113.1	1111	16.83	4.1	1.1	49	6.4	15	<0.1	0.1	0.2	233	0.25	0.035	17	867	0.12	193	0.145	<20	3.69	0.009	0.08	<0.1	0.03	46.6	<0.1	<0.05	18	0.5	<0.2
True Value STD OREAS45PA	0.9	600	19	119	0.3	281	104	1130	16.559	4.2	1.2	43	6	14	0.09	0.13	0.18	221	0.2411	0.034	16.2	873	0.095	187	0.124	-	3.34	0.011	0.0665	0.011	0.03	43	0.07	0.03	16.8	0.54	-
Percent Difference	11.1	5.4	-2.6	0.8	0	10.6	8.7	-1.7	1.6	-2.4	-8.3	14	6.7	7.1		-23.1	11.1	5.4	3.7	2.9	4.9	-0.7	26.3	3.2	16.9	-	10.5	-18.2	20.3	-	0	8.4	-	-	7.1	-7.4	-
Reference Material (2)																																					
STD DS7	19	105.6	61.9	382	0.8	55.5	9.8	603	2.31	51.9	4.3	49.6	3.7	68	5.9	4.4	4.4	80	0.91	0.074	11	189	1.04	390	0.122	36	0.99	0.09	0.46	2.9	0.21	2.3	3.6	0.19	4	3.6	0.9
True Value STD DS7	20.5	109	70.6	411	0.9	56	9.7	627	2.39	48.2	4.9	70	4.4	69	6.4	4.6	4.5	84	0.93	0.08	12	179	1.05	410	0.124	39	0.959	0.089	0.44	3.4	0.2	2.5	4.2	0.19	5	3.5	1.08
Percent Difference	-7.3	-3.1	-12.3	-7.1	-11.1	-0.9	1	-3.8	-3.3	7.7	-12.2	-29.1	-15.9	-1.4	-7.8	-4.3	-2.2	-4.8	-2.2	-7.5	-8.3	5.6	-1	-4.9	-1.6	-7.7	3.2	1.1	4.5	-14.7	5	-8	-14.3	0	-20	2.9	-16.7
Detection Limits	0.1	0.1	0.1	1	0.1	0.1	0.1	1	0.01	0.5	0.1	0.5	0.1	1	0.1	0.1	0.1	2	0.01	0.001	1	1	0.01	1	0.001	20	0.01	0.001	0.01	0.1	0.01	0.1	0.1	0.05	1	0.5	0.2
Acme Group No.	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX	1DX

TABLE 3. WHOLE ROCK ANALYSIS, BELLEKENO SLUDGE. (INCLUDES QA/QC INFORMATION.)

Sample ID	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	MgO %	Na_2O %	K_2O %	MnO %	TiO_2 %	P_2O_5 %	Cr_2O_3 %	Ba %	LOI %	Total %
BK625 Sludge	40.6	9.1	4.51	19.1	0.88	0.25	1.35	0.3	0.62	0.1	0.02	0.09	19.7	96.65
QA/QC														
Reference Materials-1														
STD: SY-4(D)	50	20.66	6.31	8.06	0.52	7.15	1.62	0.11	0.27	0.12	<0.001	0.04	4.56	99.39
True Value STD SY-4	49.9	20.69	6.21	8.05	0.54	7.1	1.66	0.11	0.29	0.13	0.03	4.56	-	-
Percent Difference	0.2	-0.1	1.6	0.1	-3.7	0.7	-2.4	0	-6.9	-7.7	17.6	0	-	-
Reference Materials-2														
STD SO-18	58.1	14	7.6	6.3	3.4	3.8	2.2	0.4	0.7	0.8	0.6	0.1	1.93	99.16
True Value STD SO-18	58.47	7.67	6.42	3.35	3.71	2.17	0.4	0.7	0.83	-	-	-	-	-
Percent Difference	-0.6	-1	-1.6	0.6	1.6	0	2.6	4.3	-2.4	-	-	-	-	-
Detection Limits	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.001	0.01	-	-
Method	4X	4X	4X	4X	4X	4X	4X	4X	4X	4X	4X	4X	4X	4X

Some of the general characteristics of the Bellekeno sludge are:

- After densification along the bottom of Pond 1, the sludge is approximately 84% water with the 16% solids being fine particulates from the mine operations, and lime-based metal hydroxide sludge principally comprised of excess lime and hydroxides of manganese, iron and zinc.
- The whole rock analysis shows that the major constituents are principally silicates and residual lime, low percentages of gangue minerals, and minor minerals associated with the vein materials (Table 3).
- The lead, zinc, and silver content are consistent with some minor amounts of broken fine grain vein material being suspended in the mine discharge, and being removed by settling and filtration processes in the treatment system.
- As of this writing, the only additive used (other than lime) is ferric chloride which promotes flocculent formation. The sludge is highly alkaline because of its significant makeup consisting of a hydroxide from the lime that is added. In the future, an additional polymer may be used to aid in settling.
- Because of the lime content, the sludge is highly net neutralizing with a Neutralization Potential of 310.4 kg $CaCO_3$/Tonne, a maximum potential acidity of 17.5 $CaCO_3$/Tonne, and a neutralization potential of 327.9 $CaCO_3$/Tonne. The ratio of approximately NP/AP = 18.7:1 shows a highly alkaline sludge with a strong excess of lime.

Acidification or low redox conditions generally could lead to particle breakdown. The circum-neutral drainage from Bellekeno indicates that there is no acid generating potential that would potentially destabilize and re-leach metals from the sludge, especially in light of the significant NP:AP ratio of the sludge and the amount of AP necessary to cause dissolution of the sludge. The general characteristics of the tailings are mildly net neutralizing conditions; the addition of lime-rich sludge will benefit the tailings if mixed into the DSTF with respect of net neutralization, pH, and physical characteristics (the lime enhances cementation reactions). If the sludge is closed in the valley tailings area, the sludge composition is such that the sludge should be expected to remain stable under the conditions found in the valley tailings storage pond area.

3.3. SLUDGE DISPOSAL

Sludge collected in the vacuum truck will be transported either to the separate Bellekeno storage pond in the Valley Tailings Facility or to the Keno Hill District Mill and deposited in the low pyrite thickener where it will be mixed with filtered and dry stacked tailings. Both of these locations are suitable long term storage locations and the sludge characteristics presented demonstrate the sludge will be stable in either area. The separate sludge storage location for Bellekeno sludge at the VTF is shown in Figure 5.

FIGURE 5. BELLEKENO 625 SLUDGE DEPOSIT LOCATION IN VALLEY TAILINGS AREA.

3.4. PROPOSED CLOSURE

In the approved water license, the Water Board agreed that the use of a bioreactor to treat closure water discharged from the Bellekeno 625 underground mine workings is a feasible technology for long term treatment of waters generated from the mine. In addition, AKHM plans to implement various passive measures if required, such as potentially in situ treatment of the mine pool, in conjunction with the bioreactor to maximize performance of the system.

AKHM plans to build the bioreactor in the existing settling ponds and that effort would be undertaken during closure when the Bellekeno mine is flooding. The ponds will be drained and completely desludged at that time, and then the empty ponds would be converted into bioreactors. That would allow the discharge from the mine to be controlled as necessary through active pumping thereby giving the bioreactor time to become established. The Board also requested additional information such as details required to design and operate such a bioreactor and further evaluation of the performance from the Galkeno 900 bioreactor system. That information will be provided as requested in the approved Water License.

3.5. MONITORING AND MITIGATION

The following measures will be implemented during the duration of water treatment and sludge generation at Bellekeno:

- Sludge volumes will be recorded in the Operator's Log Book for each load of sludge pulled from the Water Treatment retention ponds
- The above information will be included in the Company's Monthly Report to the Yukon Water Board as well as summarized in the Annual Report

The template used for the Operator's Log Book is included for reference in this document's Appendix.

4.0 **APPENDIX**

Sludge/Water Tracking Log **Week:**

Sludge Removal

Removed From	Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		**Comment**
	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	
SK 100															
GK 300 Desludge Pond															
GK 900															
BK 625															
Other:															
Other:															

Sludge Deposit

Deposited At	Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		**Comment**
	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	
Sime Pit															
Valley															
Mill/DSTF															
Other:															
Operator:															

Water Removal

Removed From	Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		**Comment**
	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	
Flat Creek															
SK 100															
GK 300 Old Pond															
GK 900															
Other:															

Lime Deposit

Deposited At	Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		**Comment**
	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	gal	loads	
SK 100															
GK 300															
GK 900															
BK 625															
Mill															
Other:															
Operator:															