TECHNICAL MEMORANDUM

Schlumberger WATER SERVICES

1875 LAWRENCE STREET, SUITE 500
DENVER, COLORADO 80202, USA

TELEPHONE: (303) 297 9005
TELEFAX: (303) 297 9007
www.water.slb.com

To: Delbert Parr, Linda Schmoll, Mark Huffington
Company: Fairbanks Gold Mining, Inc.
Project No.: 052631
From: Drummond Earley, Liane George
Date: February 11, 2013

Subject: Fort Knox pit lake evaluation 2012 update

1 INTRODUCTION

This document presents an update to the Fort Knox pit lake evaluation technical memoranda (WMC, December 2006, February 2008, February 2009 and SWS, March 2010, and March 2011/Sept, 2011b, April 2012) completed in support of the Reclamation and Closure Plan for the Fort Knox Mine. This update reflects the revised closure strategy in support of the proposed mine expansion, which includes an enlarged pit and a modified centerline tailing dam raise. A site-wide water balance and chemical mixing and equilibrium model has been prepared in support of site closure analysis. Water balance and water quality results from these models are used along with updated water quality data to complete the pit lake evaluation. The pit lake study was prepared to evaluate the short- and long-term pit lake quality following the solution management approach proposed for the Fort Knox Mine.

The Fort Knox Mine is located approximately 15 miles northeast of Fairbanks, Alaska. The site includes several sections in T2N, R2E and T2N, R3E, Fairbanks Meridian near the headwaters of the Fish Creek drainage. The site is located on land owned by the State of Alaska, the Alaska Mental Health Trust, and private parties.

1.1 Purpose

The proposed Reclamation and Closure Plan for the Fort Knox Mine incorporates pumping decant and seepage water from the Tailing Storage Facility (TSF) to the pit once mining/milling activity has been completed. In addition to tailing decant and seepage water, groundwater and runoff will be allowed to accumulate in the pit as existing dewatering operations will also be decommissioned. A mixing model is used to evaluate long-term water quality of the pit lake at the time discharge is predicted to occur. The results of this analysis indicate, using conservative assumptions, whether or not water quality criteria will be met at the time discharge from the pit lake occurs.

The purpose of the evaluation presented in this document is to provide an estimate of pit lake water quality during the recovery period and determine the effectiveness of the proposed solution management and treatment approach in achieving compliance. This update incorporates recent water balance/flow data for the pit lake, revised water quality estimates, and the most recent dewatering well chemistry data (2012 sampling data) as input to the pit lake model.

1.2 Objectives

The objectives of this update are to:

- present the revised water balance/flow data for the pit lake filling period
- present revised estimates of tailings decant and heap leach water quality
- present the updated groundwater quality data
- predict short and long-term, post-closure, pit lake water quality using the recent dataset
- determine the effectiveness of the current reclamation approach from a water quality perspective

2 PROJECT BACKGROUND

The December 2006 technical memo provides a description of the site climate, topography, hydrology and hydrogeology.

The following is a summary of the relevant elements of the Fort Knox Mine Reclamation and Closure Plan (SWS, 2010b) and TSF Closure Management Plan (SWS, 2011) as they relate to the pit lake, including details of the site-wide water balance and mixing model prepared in support of closure.

The pit volume is based on the Phase 8 mine plan expansion, and a spill point elevation of 1,470 ft amsl. The site-wide water balance and chemistry mixing model were developed based on the actions listed below.

The post closure operation plan allows optional discharge of draindown and rinse water from the heap leach facility to the pit or to the TSF decant pond. This integrated water balance and geochemical model update presents predicted pit lake water quality with draindown/rinse water from the heap leach facility directed to the pit.

Once mining/milling is completed, the following closure activities will be initiated:

- TSF decant water will be pumped to the pit.
- Seepage collected from the interception system will be pumped back to the TSF and to the pit for a period of approximately five years (or as long as necessary to meet discharge quality standards).
- TSF decant water will be diluted over the pump-back period by the inflow of upgradient surface water.
- The operation of the heap leach will continue with remaining stockpiled ore and continued leaching estimated through 2028 post-mining/milling. The initial draindown after leaching is ceased will be transferred to the pit, and rinsing of the heap leach will commence.
- TSF decant water will be pumped to the pit to maintain freeboard elevation in TSF.
- Based on the mine plan and water balance model, TSF decant water will be periodically pumped to the pit at least through the end of 2027, post-mining.

3 MODELING APPROACH AND UPDATED DATA

The site-wide water balance model provides the magnitude and relative proportions of inflows to the pit during the recovery period. The initial transfer of water from the TSF is estimated from the operation water balance, and is 6,150 ac-ft diluted by 6,850 ac-ft of runoff and precipitation from the period after milling ceases in 2018 to 2020 when the closure water balance begins. Time steps of 2, 5, 15, 35, 47, 75 and 100 years are used to evaluate water quality over time. According to the closure water balance model, the pit lake will reach the spill point at approximately year 47, post-mining. The calculated inflow/outflows are presented in Table 3.1.

Table 3.1 Inflow volumes to pit lake

Time period		AVERAGE INFLOWS TO PIT LAKE (gpm)						AVERAGE OUTFLOWS FROM PIT LAKE (gpm)	
Years	Duration	Direct precipitation to lake	Pit wall runoff	Surface water runoff to lake	TSF decant/ seepage pumped water	Heap leach draindown/ rinse	Groundwater Inflow	Evaporation	Overflow
0-2	2	98	339	4	1,019	0	1,669	62	0
2-5	3	147	338	4	2,919	0	1,633	87	0
5-15	10	198	303	4	282	31	1,422	117	0
15-47	32	275	251	4	0	0	1111	167	4
47-75	28	312	218	5	0	0	756	184	1,107
75-100	25	315	221	4	0	0	758	188	1,111

The site-wide water balance model also includes mixing calculations to estimate chemical concentrations over time for: the TSF decant pond, TSF seepage, heap leach draindown, and the pit lake based on observed water quality data, and accounting for direct precipitation, surface water runon, and evaporation based on site climate data. The mixing model is conservative in that it does not account for mass removal reactions over time.

Input water quality data for the TSF decant water over the selected timesteps have been calculated based on the results of the mixing model. These data are presented in Table 3.2. The initial water quality in the TSF is based on the measured values from 2012. It is likely that the actual concentrations will be more dilute because active tailings deposition will stop in 2018, and runoff/direct precipitation will be the only inflows until initial closure conditions ensue. During years 0 through 2, the decant pond water quality is dominated by the most recent water quality data (measured) from the decant pond; during model years 2 to 5, the decant pond water reflects a mixture of initial pond chemistry, pumped seepage water, upgradient surface water runon, and direct precipitation; and during years 5 through 15, the decant pond chemistry is dominated by surface water runon and direct precipitation. The WAD-cyanide values for the pit wall runoff have been updated based on the most recent MWMP lab data collected in 2011 and 2012 and replace the previous estimates based on old data. These results were scaled to better represent the reduced pit wall surface area reactivity as compared to the crushed MWMP test sample reactivity.

Table 3.2 Input chemistry data used in 2012 pit lake modeling update

	Precipitation	Groundwater	Surface Water	Pit Wall Runoff	Pit Wall Runoff	Tailings Decant Pond				Heap Leach Draindown
Parameter	Pure water equilibrated with atmospheric CO_2 and O_2	Average 2011 dewatering well samples	Upper Barnes Creek, average background data	Average 2011/2012 MWMP "composite waste dump" samples Unscaled	Average 2011/2012 MWMP "composite waste dump" samples Scaled	Initial TSF chemistry from 2011-2012 data WAD CN only for Summer/Fall	Average chemistry (Water Balance) years 0-2	Average chemistry (Water Balance) years 2-5	Average chemistry (Water Balance) years 5-15	Initial Chemistry of Heap Leach Draindown (Pregnant Solution 2012 data)
pH (su)	5.6	8.0	7.0	8.5	8.5	8.1	8.1	8.1	8.1	10.2
Alkalinity as CaCO3	0.0	74	15	67	4	63	72	65	6	225
Ammonia	0.0	0.000	0.010	0.95	0.06	3.06	2.0	1.0	0.012	13.21
Antimony	0.0	0.0032	0.0025	0.007	0.000	0.026	0.017	0.008	0.00006	0.0034
Arsenic	0.0	0.0247	0.0030	0.012	0.001	0.035	0.0233	0.0116	0.0013	0.0167
Barium	0.0	0.0014	0.0050	0.005	0.000	0.031	0.022	0.012	0.002	0.0150
Cadmium	0.0	0	0.00010	0.000050	0.000003	0.000065	0.000054	0.000041	0.000040	0.00710
Calcium	0.0	40.0	4.4	15.90	0.95	54.20	44	29	2	182.4
Chloride	0.0	0.3	0.70	5	0	39	26	12	0.38	170.4
Chromium	0.0	0.0000	0.0020	0.00085	0.00005	0.00000	0.00022	0.00042	0.00078	0.00570
Copper	0.0	0.0000	0	0.006	0.000	0.11	0.065	0.025	0.0003	0.2000
WAD-cyanide	0.0	0	0	0.026	0.0	0.029	0.018	0.008	0.00007	0.15
Fluoride	0.0	0.36	0.060	1.08	0.06	0.66	0.45	0.24	0.025	0.710
Iron	0.0	0.028	0.22	0.07	0	0.43	0.46	0.40	0.088	0.45
Lead	0.0	0.00026	0.0040	0.00035	0.00002	0.00062	0.0009	0.0010	0.0016	0.0002
Magnesium	0.0	5.4	1.6	2.40	0.14	5.40	4.5	3.1	0.7	0.3
Manganese	0.0	0.014	0	0.006	0.000	0.090	0.11	0.10	0.00032	0.003
Mercury	0.0	0.00000	0.00030	0.0	0.0	0.0	0.000033	0.000063	0.000118	0.00400
Nitrate, as N	0.0	0.54	0.25	0.460	0.028	14.100	9.27	4.47	0.14	52.710
Nitrite, as N	0.0	0.063	0.010	0.1500	0.0090	1.5100	1.0	0.5	0.0	2.31
Phosphorus	0.0	0.001	0.080	0.1250	0.0075	0.0260	0.030	0.031	0.031	0.015
Potassium	0.0	0.99	0.50	8.5	0.5	10.4	7.1	3.6	0.2	6.02
Selenium	0.0	0.00095	0.0020	0.00035	0.00002	0.00370	0.0026	0.0016	0.0008	0.0130
Silver	0.0	0.0000	0.0010	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sodium	0.0	16.1	2.0	25.8	1.5	81.7	57	30	1	87.2
Sulfate	0.0	78.2	6.7	0.03	0.0018	161	107	53	3	57
Zinc	0.0	0.013	0.003	0	0	0.00860	0.0068	0.0046	0.0013	0.9300

All units are in mg/L, unless otherwise noted
Precipitation chemistry derived in geochemical model (PhreeqC) by atmospheric equilibration with pure water
Groundwater and surface water data are based on analytical sample data from site
Pit wall runoff chemistry based on meteoric water mobility procedure (MWMP) test data on site waste rock samples, 2011\2012 data
Tailings decant pond chemistry averages calculated using site water balance mixing model, it is a mixture of recent pond water quality data, upgradient surface water, and seepage chemistry
Heap leach draindown chemistry based on pregnant solution with cyanide reduced to 0.15 mg/L

The cyanide concentrations from the decant pond shown in Table 3.2 were decreased by 60 percent from what is calculated by the mixing model to adjust the raw mixing results for estimated losses due to volatilization and degradation during transfer from one facility to another. There is not expected to be any significant cyanide in the pit wall runoff or in groundwater. The cyanide concentrations in the draindown solutions from the heap leach facility is assumed to be reduced to 0.15 mg/L from cyanide destruct and/or rinsing prior to transfer to the pit.

For this update, dewatering well data from 2012 were used to estimate the quality of groundwater inflow to the pit.

Updated groundwater chemistry was calculated based on the mean composition of water quality from each dewatering well pumped during 2012. For major ion chemistry, arithmetic averages were used, as these data are typically normally distributed. For trace metal chemistry, geometric mean data were used because these datasets are often skewed and a log-normal distribution best describes the data. By convention, if all analyses for a constituent in a well were non-detect, the concentration for that well was set to zero for calculating arithmetic and geometric means. If only some analyses were non-detect, the mean concentration for that well was calculated by substituting all non-detect values with one-half of the method detection limit for the analysis. Wells were weighted by flow to calculate the groundwater inflow chemistry. The data used to represent groundwater chemistry for the revised modeling are presented in Table 3.2. In Table 3.3, the values are presented with the April 2012 and March 2011 estimates for comparison. It is noted that the arsenic and antimony levels in the current estimate are significantly elevated as compared to the estimate made in April, 2012, which affects the predicted water quality in the pit lake with respect to water quality standards.

Table 3.3 Comparison of 2011 to 2012 groundwater quality model inputs

Parameter	January 2013 Modeling Groundwater Average/geomean data from dewatering wells (2012 data)	April 2012 Modeling Groundwater Average/geomean data from dewatering wells (2011 data)	March 2011 Modeling Groundwater Average/geomean data from dewatering wells (2008-2010 data)
pH (su)	8.0	8.3	8.35
Alkalinity as $CaCO_3$	74	85	85.5
Ammonia	ND	0.026	0.035
Antimony	0.0032	0.0008	0.0022
Arsenic	0.0247	0.0040	0.0072
Barium	0.0014	0.0010	0.0028
Cadmium	ND	0.000084	0.00007
Calcium	40.0	38.6	48
Chloride	0.3	0.7	1.2
Chromium	ND	0.0039	0.0052
Copper	ND	0.0037	0.0055
WAD-cyanide	ND	ND	0.003
Fluoride	0.36	0.28	0.26
Iron	0.028	0.076	0.041
Lead	0.00026	0.00046	0.0003
Magnesium	5.4	6.1	6.4
Manganese	0.014	0.008	0.014
Mercury	ND	0.00008	0.0001
Nitrate, as N	0.54	0.14	0.68
Nitrite, as N	0.063	0.008	0.023
Phosphorus	0.001	0.006	0.011
Potassium	0.99	0.90	0.96
Selenium	0.00095	0.00025	0.0005
Silver	ND	0.0039	0.0054
Sodium	16.1	14.1	12
Sulfate	78.2	63.3	39.3
Zinc	0.013	0.006	0.02

All data is in mg/L, unless otherwise noted.

If all analytical data for a constituent were reported below detection limits (non-detect), that value was set to zero for modeling.

4 PIT LAKE MODELING

The updated geochemical model was used to simulate solution mixing and chemical reactions to predict the pit lake composition at each selected time step. The modeling process is detailed in the SWS March 2010 pit lake update memo. In addition, the model has been modified to reflect the heap leach draindown transfer to the pit after going through CN destruct and TSF water treatment with ferrous sulfate per the Fort Knox Reclamation plan (WMC, 2006).

Results of the revised modeling are summarized in Table 4.1, and compared to reference water quality standards. End notes appended to Tables 4.1 describing sources of the cited numeric water quality standards, and other errata.

Pit lake water quality results were predicted for simulation years 2, 5, 15, 47, 75, and 100 corresponding with distinct intervals of water management operations or pit lake development events. Standards for cadmium, chromium, copper, lead, silver, and zinc represent hardness-based aquatic standards, which were calculated using a hardness value of 103.7 mg/L as $CaCO_3$.

Hardness was calculated based on the average calcium and magnesium concentrations in the lower wetland surface water samples collected between February 2000 and November 2005. Any surface water discharges from the TSF will report to this drainage. For comparison, the average hardness of the pit lake is predicted to be 69 to 80 mg/L as $CaCO_3$ at the time of first discharge.

The predicted pH of the pit lake water remains at 7.5 to 7.6 su throughout filling and once discharge is estimated to begin. The alkalinity values were predicted to hover around 75 mg/L as $CaCO_3$, indicating excess buffering capacity of the pit lake water. Model results indicate during time periods 1, 2, and 3 the concentrations of antimony, and WAD-cyanide are predicted to be elevated compared to standards. The main source of these constituents is the heap leach draindown and tailings decant and seepage water that are pumped to the pit lake during the first two years. The geochemical simulations indicate that cyanide destruct and rinsing of the heap leach draindown and TSF water treatment is effective in reducing WAD-cyanide and arsenic before the pit water level reaches the discharge stage. Natural and enhanced attenuation of cyanide (i.e. volatilization etc.) over time within the pit were not included in the modeling which implies a conservative prediction for WAD-cyanide concentrations in Table 4.1.

Table 4.1 2012 Update prediction of pit lake composition through time after closure.

Predicted exceedances of the reference standards are highlighted in bold.

Parameter/ Analyte	Reference standards*	Timestep 1	Timestep 2	Timestep 3	Timestep 4**	Timestep 5	Timestep 6
		Year 2	Year 5	Year 15	Year 47	Year 75	Year 100
pH, std units	**6.5 - 8.5**	7.5	7.6	7.6	7.6	7.6	7.6
Alkalinity, as $CaCO_3$	NS	59	74	75	75	75	75
Chloride	NS	14.9	11.9	9.2	7.7	7.3	7.3
Fluoride	NS	0.35	0.31	0.29	0.28	0.27	0.27
Nitrate, as N	**10**	7.2	5.8	4.4	3.8	3.6	3.6
Nitrite, as N	**1**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ammonia	**2.43-6.67**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sulfate, as $SO4^{2-}$	**250**	82	69	63	61	60	60
WAD-cyanide	**0.0052****	**0.010**	**0.008**	**0.006**	0.0051	0.0049	0.0049
Antimony	**0.006**	**0.011**	**0.0089**	**0.0068**	0.0060	0.0058	0.0058
Arsenic	**0.01**	**0.0010**	0.0035	0.0067	0.0081	0.0083	0.0083
Barium	**2**	0.014	0.011	0.0083	0.0070	0.0067	0.0067
Cadmium	**0.0003**	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Calcium	NS	31	29	28	27	26	26
Chromium	**0.01**	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Copper	**0.009**	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Iron	**1**	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Lead	**0.0025**	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Magnesium	NS	3.9	3.7	3.6	3.5	3.5	3.5
Manganese	**0.05**	0.043	**0.054**	0.041	0.035	0.034	0.034
Mercury	**0.00077**	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Phosphorus	NS	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Potassium	NS	4.3	3.6	2.7	2.4	2.3	2.3
Selenium	**0.005**	0.0022	0.0018	0.0015	0.0013	0.0013	0.0013
Silver	**0.003**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sodium	NS	30	25	21	19	19	19
Zinc	**0.12**	<0.005	0.005	0.010	0.009	0.009	0.009
Hardness (Ca, Mg)	NS	92	89	84	81	80	80

* Alaska Water Quality Criteria Manual for Toxic and other Deleterious Organic and Inorganic Substances, December 12, 2008.
** Discharge from the pit occurs at Year 47, post filling.
< Analyte concentration result is below typical analytical detection limits. Value shown is the detection limit.
NS = No standard

5 CONCLUSIONS

The results of the updated pit lake modeling indicate the following:

- With the exception of some variations in the concentrations of arsenic and other trace constituents, the most recent groundwater chemistry data from pit dewatering wells is largely consistent with that used in the previous analyses.
- Over the short-term mine closeout period, the pit will act as a hydraulic sink after closure with continued but diminishing hydraulic gradients that maintain groundwater flow toward the pit lake; over the long term after mine closure, the pit lake water will be treated (if necessary) so it complies with water quality standards.
- Antimony, arsenic and WAD-cyanide are below their respective reference standards when pit filling levels reach the outflow condition due to selective treatment of inflows and the addition of ferrous sulfate to the pit. Other constituents can be managed with now active treatment.
- The current modeling results suggest that both heap leach source WAD-cyanide and in pit treatment systems for antimony and arsenic may be required to attain water quality standards in the pit lake waterbody by the time outflow occurs at approximately 47 years after mine closure.
- The pit lake model will be updated as needed to reflect any changes in the Fort Knox mine post closure and reclamation plan and water management system. In addition, ongoing monitoring and testing data will be used to revise the model input parameters accordingly.

REFERENCES

Alaska Water Quality Criteria Manual for Toxic and other Deleterious Organic and Inorganic Subtances, December 12, 2008.

Water Management Consultants, Inc. (WMC). Fort Knox Pit Lake Evaluation, Technical Memorandum, December 28, 2006.

WMC, Fort Knox Mine Closure Management Plan for the Proposed Heap Leach, 2006b.

WMC, Revised Fort Knox Pit Lake Evaluation, Technical Memorandum, January 10, 2007

WMC, Fort Knox Pit Lake Evaluation, Technical Memorandum, Updated 2007 groundwater analytical data, February 27, 2008.

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Schlumberger Water Services (SWS), Fort Knox Pit Lake Evaluation, Technical Memorandum, Updated using 2009 groundwater chemistry data, March, 2010.

SWS, Fort Knox Mine Reclamation and Closure Plan, 2010b.

SWS, Tailings Facility Closure Management Plan, March 2011.

SWS, Fort Knox Pit Lake Evaluation, Technical Memorandum, Updated using 2010 groundwater chemistry data, March, 2011, updated Sept 2011b.

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