APPENDIX A-1

CONCEPTUAL STUDY
WATER TREATMENT PROCESS
For
Wolverine Underground Test Mine

May 2004

1.0 Introduction

A conceptual water treatment process was developed for the treatment of mine water and Waste rock dump seepage for the proposed underground test mine at Wolverine Mine. Chemistry data from the "Humidity cell waste water characterization test work" was used to develop a process flow sheet, mass balance, preliminary equipment sizing, capital cost projection and operating cost with an accuracy of +/- 30%. The estimated budget assumes that the site preparation is minimal and does not require a significant effort to prepare the site for installation. The following process design, capital and operating cost is for neutralization to pH 9.3-9.5 using sodium hydroxide to meet MMER requirements. Process design basis/criteria figures and sizes are preliminary for budgetary considerations only. The capital cost of this treatment system is estimated at $20,000. It was assumed that the treatment process will be operational from May to December of each year. Based on eight months of operation a year, the reagent cost is estimated to be $ 12,000 ($1500/month) and the labour cost is estimated at $25/hour to be $32,000 annually ($4,000/month). The treatment process will not require a full time operator; however, for the purpose of costing a provision for a full time operator was allowed. The capital cost does not include the cost for the settling pond. The following sections contain further details of quantities and costs. The chemistry modeling data is provided in the Appendix A -1 – Tables A-1 and A-2.

The water treatment process was designed using theoretical values obtained from the chemistry model, mainly based on data from the humidity cells. It is highly recommended to conduct a pilot plant testing or at least a bench scale testing to obtain reliable data and process validation.

2 Process Description

A conceptual process flow sheet for the treatment process is provided for this study.

2.1 Water Feed System

The primary sources for the plant will be underground mine water with a feed rate of 100 m^3/day (69.4 L/min.) and seepage from waste rock dumps at the rate of 4.3 m^3/day (3.0 L/min.). Based on the chemistry provided, underground mine water is expected to have high total suspended solids (TSS), approximately 100 mg/L. Both of the drainages will be mixed in existing seepage collection/testing sump and will be pumped directly to the neutralization reactor.

2.2 Caustic System

Sodium hydroxide was selected as a neutralizing agent instead of lime or hydrated lime. Specialized equipment is required to prepare lime or hydrated lime for usage. This would increase the capital and operating costs; therefore, sodium hydroxide was selected for neutralization.

Based on the chemistry modeling, sodium hydroxide requirement was estimated to be 0.08g per litre of feed. Sodium hydroxide solution will be obtained in 300 kg containers at a concentration of 50% (w/w) and pumped, using a metering pump, directly to the reactor. The pumping rate will be regulated, using a pH control meter, to maintain a set pH in the reactor. Approximately 6 tonnes (50% w/w) of sodium hydroxide would be required annually based on an average flow of 104.3 m^3/day for 365 days/year; a total of 20 containers will be required each year. The flow may decrease or stop over the winter month in which case treatment will not be required, and caustic requirement would be significantly reduced. For shipping cost estimates, it was assumed that 4 containers will be delivered on site at a time.

2.3 Neutralization

Underground mine water and dump seepage feed will be neutralized using sodium hydroxide. The treatment pH should be 9.0-9.5. Sodium hydroxide is a relatively fast reacting reagent; therefore, 10-15 minutes of reaction time has been allowed in the reactor. Reactor (1.0 m D X 1.5 m H) will be air agitated. Air will be sparged into the Reactor by a compressor. Air also provides oxygen that is required for oxidization of some metals. Neutralization with sodium hydroxide should remove most of the metals from the feed. Reactor slurry will be gravity feed to the Settling Pond.

2.4 Coagulants and Flocculants Addition

Coagulant and flocculant solutions will be added directly to the settling pond feed. Coagulation will neutralize the charge on the suspended solids, such that flocculation is more effective. Coagulant will be directly added in line and followed by flocculant addition. Flocculant will be diluted with process water at 1:1 dilution using an in-line static mixer. Flocculation will increase the particle settling velocity to settle metal precipitates and the suspended solids within the first two compartments of the settling pond. Coagulant and flocculant will be delivered to the site in 1m^3 containers and will be pumped from the original containers. The feed rate will be controlled with ratio controller; the expected feed rate for coagulant and flocculant should be 3-5 mg per litre of effluent. It is expected that only one container (1m^3) will be required annually for coagulant and flocculant.

2.5 Settling Pond

The proposed settling Pond will be 15m L by 7m W and 3m D, and it should be divided into 5 equal compartments. Solution will overflow from one section to another. The rectangular shape of the settling pond provides high surface area required for settling. It is expected that 80-85% of the solids will settle in the first compartment. To remove sludge from the first compartment, provision has been allowed to bypass the first compartment and directly feed the second compartment. The clarifier overflow is expected to have less than 10 mg/L of total suspended solids. Sludge can be removed from the pond using portable pumps following isolation of a compartment.

2.6 Notes on Material Balance

Feed chemistry was used to predict sodium hydroxide consumptions, and sludge characteristics. It is highly recommended to conduct a pilot plant testing, or at least a bench scale testing to obtain more accurate data.

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CAPITAL COSTS Wolverine Mine - Water Treatment Process	
Description	**Price ($)**
Reactor Tank with Sparger (1.0m Dia x 1.5m H)	$ 5,000
Air Compressor System (10 hp)	$ 5,000
Caustic Pump (0.5 hp)	$ 1,500
Coagulant Pump (0.5 hp)	$ 1,500
Flocculant Pump (0.5 hp)	$ 1,500
Flocculant Static In Line Mixer	$ 1,500
Fresh Water Tank	$ 2,500
Fresh Water Pump (1.5 hp)	$ 1,500
TOTAL COSTS[1]	**$ 20,000**

[1] Total costs are approximately ±30%.

Operating Cost Estimate

Wolverine Mine
Water Treatment Process

Reagent	Dose Rate (mg/L plant feed)	Annual Average Plant Flow Rate (L/min)	Annual Reagent Consumption (tonnes/year)	Reagent Unit Cost ($/tonne)	Annual Reagent Cost ($/year)
NaOH	80	72	3	1460	4,428
Shipping for NaOH (includes duties for hazardous material)					3,087
Coagullant			1	5000	5,000
Flocculant			1	5000	5,000
Shipping for Coagullant/Flocculant					957
				Sub-total:	**$18,472**
			Sub Total for Operations during May to Decemeber		**$12,315**

Item	Annual Consumption	Unit Cost ($)	Annual Cost ($/year)
O & M Capital	10 % of capital cost	20000	2,000
O & M Manpower	8 man-hours per day	25	48,667
		Sub-total:	**$50,667**
		TOTAL (EST.)	**$62,981**

Shipping costs are estimated 5 deliveries per year. Shipping costs were obtained from Bandstra Shipping.
Operating cost are estimated for 8 labour hours per day for 8 months a year.

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TABLE A-1

Water Quality and Sludge Generation Prediction

Water Treatment Process
Wolverine
April 12,2004

Ion	Ion Wt. (g/mol)	Hydroxide Formula	Hydroxide Weight (g/mol)	Mass of Ion Present (mg/L)	Mass of OH^- (mg/L)	Mass of Precip. (mg/L)
Al	26.98	$Al(OH)_3$	78.01	0.11	0.21	0.32
Ag	107.87	AgOH	124.88	0.00	0.00	0.00
As	74.92	$As(OH)_3$	125.95	0.00	0.00	0.00
Bi	208.98	$Bi(OH)_3$	260.01	0.00	0.00	0.00
Ca	40.08	$Ca(OH)_2$	74.1	32.99	28.00	60.99
Cd	112.41	$Cd(OH)_2$	146.43	0.02	0.01	0.02
Cu	63.55	$Cu(OH)_2$	97.57	0.04	0.02	0.06
Fe	55.85	$Fe(OH)_3$	106.88	0.00	0.00	0.00
Pb	207.2	$Pb(OH)_2$	241.22	0.00	0.00	0.00
Mg	24.31	$Mg(OH)_2$	58.33	6.90	2.90	4.97
Mn	54.94	MnO_2	86.94	0.51	0.00	0.81
Ni	58.71	$Ni(OH)_2$	92.73	0.02	0.01	0.03
S*	32.06	$CaSO_4.2H_2O$	172.18	0.00	0.00	0.00
Sb	121.75	$Sb(OH)_3$	172.78	0.00	0.00	0.00
Se	78.96	$Se(OH)_4$	147	0.07	0.06	0.13
Si	28.09	$Si(OH)_2$	62.11	0.25	0.30	0.55
Zn	65.38	$Zn(OH)_2$	99.4	1.29	0.67	1.96
SO_4^{2-}*	96.06	$CaSO_4.2H_2O$	172.18	95.00	0.00	0.00
CO_3^{2-}	59.98	$CaCO_3$	100.06	0.00	0.00	0.00
TSS	n/a	n/a	n/a	100	n/a	90.00
Total					**32.18**	**159.85**

Available NaOH = 95.0 %

Lime use = 0.074 g $Ca(OH)_2$/L
Lime use = 0.062 g lime (CaO)/L
NaOH Use = 0.080 g NaOH/L

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TABLE A-2

Sludge Quality Prediction

HDS Process Design
Wolverine
April 12,2004

Ion	Mass of Ion Present (mg/L)	Mass of OH^- (mg/L)	Mass of Precip. (mg/L)	Mass of Metal (mg/L)	Sludge Composition (%)
Al	0.11	0.21	0.32	0.11	0.20
Ag	0.00	0.00	0.00	0.00	0.00
As	0.00	0.00	0.00	0.00	0.00
Bi	0.00	0.00	0.00	0.00	0.00
Ca	32.99	28.00	60.99	32.99	38.16
Cd	0.02	0.01	0.02	0.02	0.01
Cu	0.04	0.02	0.06	0.04	0.04
Fe	0.00	0.00	0.00	0.00	0.00
	0.00				
Pb	0.00	0.00	0.00	0.00	0.00
Mg	6.90	2.90	4.97	6.90	3.11
Mn	0.51	0.00	0.81	0.51	0.51
Ni	0.02	0.01	0.03	0.02	0.02
Sb	0.00	0.00	0.00	0.00	0.00
Se	0.07	0.06	0.13	0.07	0.08
Si	0.25	0.30	0.55	0.25	0.35
Zn	1.29	0.67	1.96	1.29	1.23
$CaCO_3$	0.00	0.00	0.00	0.00	0.00
TSS	100.00	n/a	90.00	100.00	56.30
Total		**32.18**	**159.85**	**142.20**	**100.00**

Solids generation = 0.160 g/L