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Memo

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From:	Sarah Portelance Tom Sharp	**Project No:**	1CT022.001.310
Cc:	Maritz Rykaart, SRK	**Date:**	April 11, 2014
Subject:	Hope Bay – Tailings Impoundment Area Water and Load Balance Model Update		

1 Introduction

Water and load balance models were prepared by SRK Consulting Inc. (SRK) to support the Environmental Impact Assessment submitted to the Nunavut Impact Review Board (SRK 2005), and the water licence application submitted to the Nunavut Water Board (SRK 2007). In 2011, the model was updated to support the assessment of revised water management scenarios as part of the proposed expansion of the underground mine to the Doris Central and Doris Connector deposits. The milling rate was 800 tonnes per day (tpd) and three groundwater scenarios were evaluated to provide a range of potential groundwater inflows to the mine. The water and load balance model accounted for the co-disposal of cyanide treated and flotation tailings and incorporated a year-round discharge from the Tailing Impoundment Area (TIA) during operations and a seasonal open water discharge after closure.

To support the additional proposed conditions described in the Project Proposal submitted by TMAC Resources Inc. (TMAC 2013), the water and load balance was updated to include:

- Milling rates of 800 tpd and 1,800 tpd;
- Additional load associated with the increased volume of waste rock stored above ground;
- Additional tailings deposition and a reduced depth of water cover at closure; and
- Change in total mine life and associated closure period.

This memorandum summarizes of the modifications included in the updated water balance and water quality predictions for the proposed project. Other inputs remained the same as previous iterations of the model. For further details on the inputs and source terms, refer to Appendix 10 of the Project Description Report (TMAC 2013).

2 Water Balance Approach

The primary objective of the water balance is to predict water quality during operations and at closure. The water quality model combines concentrations and flow rates to estimate loading and accounts for other processes to predict water quality in the discharge from the TIA over the mine life and at closure.

The simulation settings of the updated model were not modified from the existing water and load balance model presented in Appendix 10 of the Project Description (TMAC 2013). The model was run on a monthly time step for a period of 300 months (24 years). A Monte Carlo simulation was used to stochastically vary annual precipitation over the modeled time period for 100 iterations.

3 Model Set-Up

3.1 Model Inputs

The updated water balance model includes the following inputs:

- Upstream runoff and direct precipitation to the TIA;
- Runoff from mine waste rock stored above ground (1,200,000 tonnes);
- Runoff from ore stockpiled during milling operations;
- Mine site runoff from quarried rock used as fill, construction material, road base and other infrastructure construction fill;
- Treated mill tailings discharged to the TIA (for a milling rate of 800 tpd and 1,800 tpd);
- Treated sewage effluent discharge to the TIA for a camp of 360 people;
- Saline groundwater (total of three scenarios);
- Saline drilling fluids;
- Blasting residuals present in waste rock, quarried rock, ore and mine water (groundwater);
- Solute and suspended matter released to the TIA from shoreline erosion and re-suspension by wave action;
- Salinity release to the TIA due to thawing where permafrost is present along the shores of the TIA; and
- Degradation reactions.

3.2 Model Scenarios

A total of six scenarios were modelled to predict a range of possible outcomes based on the two proposed milling rates, of 800 tpd and 1,800 tpd, and various groundwater scenarios (Table 3.1). At an increased production rate, the mine life is reduced as the ore is processed at a faster rate.

Table 3.1: Summary of Modelling Scenarios

Scenario	1	2	3	4	5	6
Milling Rate (tpd)	800	800	800	1,800	1,800	1,800
Groundwater Scenario	Base Case	Low Flow	No Flow	Base Case	Low Flow	No Flow

The Base Case groundwater scenario estimates a groundwater inflow of 3,500 m^3/day during the first half of underground mining and increases to 7,000 m^3/day by end of mine life. In addition, the possibility of increased inflow from drillholes was also included in the base case scenario. This scenario illustrates the effect of large inflows during underground mining to ensure the TIA has adequate storage capacity.

Groundwater inflows are 1,000 m^3/day, for the Low Flow scenario, during the underground mining operations. In addition, no groundwater flow was included in the water and load model scenarios to assess the results of the water quality in the TIA due to the lack of potential dilution.

The No Flow groundwater scenario assumes no groundwater is intercepted by the underground workings. This scenario assesses the effect on TIA water quality of having no dilution by groundwater.

3.3 Water Management Strategy Components

Similar to the water and load balance provided in Appendix 10 (TMAC 2013), the following key components were applied to the water management strategy during operations and closure:

- Maximum discharge of 120 L/s during operations and closure;
- Maximum water elevation of 32.5 m when concentrations in the TIA are suitable for discharge and 33.5 m when concentrations exceed discharge limits;
- Discharge to the receiving environment begins at the start of the underground mining;
- Groundwater from underground dewatering is routed to the TIA until the end of underground mining plus six months;
- Continue seasonal (June to October) discharge during closure;
- A minimum water cover is 2.3 m above the surface of tailings during operations and closure to prevent re-suspension of sediments; and
- An interim period of 1 year was applied to allow for the drawdown of water levels in the TIA to 27.0 m (1 m cover above maximum tailing deposition elevation) prior to flushing the TIA with Doris Lake water during winter months (November to April) until water quality concentration meet closure guidelines.

Table 3.2 provides a summary of major dates incorporated into the water and load balance model. Mining operations end in Year 8 and Year 5 for a milling rate of 800 tpd and 1,800 tpd respectively.

Table 3.2: Timeline for Water and Load Balance Model

Mine Date Description	Milling Rate (tpd)	
	800 (Scenarios 1,2,3)	1,800 (Scenarios 4,5,6)
Start of mill load from Doris North	Year 3 (April)	Year 3 (April)
End Doris North Mining / Start of TIA Discharge	Year 5 (August)	Year 4 (April)
End of Underground Dewatering	Year 8 (June)	Year 5 (October)
Start of TIA Flushing	Year 9 (June)	Year 6 (October)

4 Results

4.1 Water Quality Predictions

To evaluate the discharge water quality for all six scenarios, the 90th percentiles of maximum concentrations during operations and at closure were assessed. The 90th percentile of concentrations represent the upper concentration limit in the TIA based on 100 realizations for a range of annual precipitation inputs.

Optimized discharge periods had to be applied to ensure the discharge met the water quality criteria in Water Licence for the Doris North Project (NWB No. 2AM-DOH1323) during operations and closure. Discharges from the TIA during operations needed to meet the water quality criteria specified in the Water Licence Part G, Clause 28 and the TIA marine end-of-pipe discharge targets (Rescan 2011). Water quality criteria in Part G, Clause 30 of the water licence govern TIA discharge during closure. These water quality criteria for operation and closure are presented in Table 4.1 and 4.2, respectively.

For all six scenarios, ammonia-N controlled discharge from the TIA into the receiving environment for operations. The concentration of ammonia-N within the TIA exceeds the discharge limit of 6 mg/l at the 90th percentile most frequently during the winter. Discharge periods were optimized to address this for each scenario to ensure the TIA discharge met water quality criteria. The optimized discharge periods and maximum concentrations for each scenario during operations are presented in Table 4.1. In the 800 tpd scenarios (Scenario 1, 2, and 3 pumping occurs during more months of the year than the 1,800 tpd scenarios (Scenario 4, 5, and 6).

Flushing the TIA with water from Doris Lake during the winter months and allowing discharge from the TIA to Roberts Bay in the summer months decreases concentrations in the TIA below closure water quality criteria. Table 4.2 provides a summary of the 90th percentile concentrations at closure for all six scenarios. Closure for the 1,800 tpd scenarios occurs sooner than the 800 tpd scenarios.

Due to the large inflow of saline groundwater in the base case groundwater scenarios, chloride levels in the TIA discharge determine the number of years required for flushing the TIA with Doris Lake water. For the low and no groundwater scenarios, copper levels define the onset of closure.

Table 4.1: Maximum Concentrations During Operations (90th Percentile). Units are mg/L.

Discharge Period			Scenarios					
			1 800 tpd Base Case	**2 800 tpd Low Flow**	**3 800 tpd No Flow**	**4 1,800 tpd Base Case**	**5 1,800 tpd Low Flow**	**6 1,800 tpd No Flow**
No Discharge Months			Dec	Feb - Mar	Jan-Mar	Jan-May	Jan-Apr	Feb-Jun
End of Operations			Year 8 (June)	Year 8 (June)	Year 8 (June)	Year 5 (October)	Year 5 (October)	Year 5 (October)
Parameter	**TIA Discharge Standard** (Part G, Sec 28)	**TIA Marine Discharge Target** (Rescan 2011						
TDS			48,938	4,600	1,691	24,527	4,439	1,779
Free_CN			0.001	0.001	0.001	0.001	0.001	0.001
Total_CN	1		0.006	0.014	0.012	0.006	0.007	0.010
WAD_CN			0.088	0.200	0.162	0.184	0.187	0.172
SCN			47	85	85	52	60	73
Sulphate			2,106	192	148	1,044	196	86
Chloride			21,284	3,323	3,492	11,095	3,573	2,620
Salinity		150	38.45	6.00	6.31	20.04	6.46	4.73
Ammonia_N	6		5.01	5.68	4.40	5.72	5.77	5.81
Nitrate_N			5.24	4.88	6.13	4.21	4.21	3.50
Nitirite_N		118	0.86	1.34	1.28	1.36	1.46	1.67
Alkalinity			174	179	179	145	145	173
Hardness			13,309	1,039	469	6,571	1,065	403
Aluminum			0.15	0.30	0.29	0.16	0.18	0.21
Antimony			0.07	0.12	0.13	0.05	0.07	0.07
Arsenic	0.5	0.381	0.004	0.005	0.005	0.004	0.004	0.004
Barium			0.200	0.051	0.048	0.103	0.037	0.028
Beryllium			0.002	0.002	0.003	0.001	0.001	0.001
Boron			3.33	0.28	0.17	1.65	0.29	0.13
Cadmium		0.0025	0.0002	0.0003	0.0003	0.0002	0.0002	0.0002
Calcium			5798	1556	1665	3069	1243	1187
Chromium		0.017	0.005	0.010	0.010	0.006	0.007	0.008
Cobalt			0.022	0.034	0.035	0.022	0.025	0.030
Copper	0.3		0.09	0.22	0.20	0.07	0.11	0.12
Iron			5.56	1.11	1.08	2.88	0.96	0.80
Lead	0.2		0.00	0.00	0.00	0.00	0.00	0.00
Manganese			2.14	0.17	0.06	1.05	0.15	0.03
Mercury		0.00037	0.000029	0.000043	0.000043	0.000030	0.000033	0.000040
Molybdenum			0.05	0.04	0.04	0.03	0.03	0.03
Nickel	0.5		0.05	0.05	0.05	0.04	0.05	0.06
Selenium			0.01	0.01	0.01	0.01	0.01	0.01

Silver			0.01	0.02	0.01	0.01	0.01	0.01
Thallium			0.0002	0.0001	0.0001	0.0001	0.0001	0.0001
Uranium			0.0003	0.0002	0.0002	0.0003	0.0003	0.0003
Vanadium			0.01	0.02	0.02	0.01	0.01	0.01
Zinc	0.5		0.24	0.21	0.22	0.16	0.15	0.18

Note: Salinity calculated from predicted chloride concentration (Salinity = 0.00180655 x [chloride]

Table 4.2: Maximum Concentrations at Closure (90th Percentile). Units are mg/L.

Parameter	**TIA Discharge Standard (Part G, Sec 30)**	**Scenarios and End of Closure**					
		1 800 tpd Base Case	**2 800 tpd Low Flow**	**3 800 tpd No Flow**	**4 1,800 tpd Base Case**	**5 1,800 tpd Low Flow**	**6 1,800 tpd No Flow**
		Year 19 (January)	Year 16 (October)	Year 16 (October)	Year 17 (November)	Year 15 (November)	Year 15 (November)
TDS		350	176	148	303	163	145
Free_CN	0.005	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
Total_CN	0.01	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
WAD_CN		0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
SCN		0.10	0.15	0.26	0.23	0.30	0.26
Sulphate		12.76	5.43	4.34	10.86	4.85	4.12
Chloride	150	146	87	80	127	76	67
Salinity		0.26	0.16	0.14	0.23	0.14	0.12
Ammonia_N	1.54	0.001	0.001	0.001	0.001	0.001	0.001
Nitrate_N	2.9	0.003	0.003	0.003	0.003	0.003	0.003
Nitirite_N	0.06	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Alkalinity		31.49	31.25	31.34	31.48	31.53	31.48
Hardness		98.34	50.29	42.82	85.94	47.60	42.96
Aluminum	0.1	0.07	0.10	0.10	0.06	0.07	0.07
Antimony		0.0003	0.0004	0.0006	0.0003	0.0004	0.0003
Arsenic	0.005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
Barium		0.004	0.003	0.003	0.004	0.003	0.003
Beryllium		0.00001	0.00001	0.00002	0.00001	0.00001	0.00001
Boron		0.04	0.03	0.03	0.03	0.02	0.02
Cadmium	0.000017	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
Calcium		31.78	14.47	13.55	28.24	14.11	11.81
Chromium	0.001	0.0003	0.0004	0.0004	0.0003	0.0004	0.0004
Cobalt		0.0001	0.0001	0.0002	0.0001	0.0002	0.0002
Copper	0.002	0.001	0.002	0.002	0.002	0.0018	0.002
Iron	0.3	0.16	0.17	0.16	0.14	0.14	0.14
Lead	0.001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Manganese		0.02	0.01	0.01	0.01	0.01	0.01
Mercury	0.000026	0.0000021	0.0000043	0.0000044	0.0000013	0.0000023	0.0000023
Molybdenum	0.073	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002

Nickel	0.025	0.0006	0.0007	0.0007	0.0007	0.0007	0.0007
Selenium	0.001	0.00077	0.00088	0.00089	0.00073	0.00079	0.00079
Silver	0.0001	0.00002	0.00003	0.00005	0.00003	0.00004	0.00004
Thallium	0.0008	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
Uranium		0.00003	0.00003	0.00003	0.00002	0.00003	0.00003
Vanadium		0.001	0.001	0.001	0.001	0.001	0.001
Zinc	0.03	0.004	0.004	0.004	0.004	0.004	0.004

Note: Salinity calculated from predicted chloride concentration (Salinity = 0.00180655 x [chloride]

5 Conclusion

A total of six scenarios were evaluated. These scenarios consisted of two milling rates and three groundwater discharge rates. The results indicate that for both milling scenarios (800 tpd and 1,800 tpd) discharge occurs intermittently generally in the open water season. The water and load balance model shows by optimizing the discharge periods the TIA water quality meets both TIA discharge limits and proposed marine discharge targets (Rescan 2011). Discharge periods are more constrained for the 1,800 tpd scenarios than the 800 tpd scenario but still meet discharge water quality criteria.

6 References

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