6.3 Water Quality Results

6.3.1 Tailings Impoundment Area

Water quality predictions in the TIA were made from operations through post-closure. The parameters presented are those with an associated CCME water quality guideline for the long-term protection of freshwater aquatic life (CCME 2015), with the exception of free cyanide, mercury and selenium. Free cyanide is excluded due to lack of data for developing source terms. Mercury and selenium have been excluded due to high detection limits in the mill effluent water quality dataset, which could result in artificially elevated predictions. Although chromium concentrations are provided, they have not been compared to the CCME guideline as the predictions represent total chromium, whereas the CCME guideline applies to chromium VI.

Predictions are provided for dissolved and total concentrations. The total concentrations were calculated assuming the total solids in the TIA are comprised of tailings solids from the tailings beach and based on the maximum background TSS of 5.9 mg/L. Predicted concentrations after the TIA refills were compared to the CCME guidelines for reference purposes only.

The predicted average monthly concentrations in the TIA are shown through operations to post-closure in Appendix B. A summary of the predicted mean and maximum monthly concentrations in the TIA during operations, prior to the end of dewatering, and after closure, subsequent to refilling is provided in Table 6-2.

Discharge from the TIA to Doris Creek will continue during the 2015/2016 open water season. As shown in the figures in Appendix B, concentrations of parameters in the TIA increase during operations. When milling begins in 2017, the water from the TIA will be mixed with groundwater during the open water season and discharged to Roberts Bay. At closure, the TIA will be dewatered by pumping year-round to Roberts Bay until the target elevation is met. The water quality predictions for discharge to Roberts Bay during operations and post-closure are discussed in Section 6.3.2.

Concentrations are predicted to peak during the winter due to “cryoconcentration”. When ice forms in the pond, the ice freezes as pure water and all the contaminants are concentrated in the free water column. During the dewatering period, over the winter, when the pond volume has been reduced and there is only a small volume of water remaining, the free water volume decreases in some cases to zero due to the simulation of ice formation. To avoid discontinuities in the model where loads are divided by a small (or zero) water volume, the frozen volume was restricted to 50% of the total TIA volume during the refilling period. Water in the TIA during this period would not be discharged. Discharge would only occur when the water level is above 28.3 m and the applicable water quality objectives are met.

Table 6-2: Predicted Water Quality in the TIA

Parameter	Predicted Monthly Concentrations (mg/L)								Background Max (mg/L)		CCME Guideline (mg/L)
	Operational Mean		Operational Max[1]		Post Closure Mean		Post Closure Max[1]		Mean	Max	
Chloride	98		220		78		130		62	64	120
Ammonia_N	0.21		3.5		0.0014		0.0020		0.010	0.014	1.54
Nitrate_N	0.51		1.9		0.29		0.48		0.0054	0.0059	13
Nitrite_N	0.25		0.83		0.021		0.034		0.0015	0.0016	0.060
Metals	***Diss.***	***Total***	***Diss.***	***Total***	***Diss.***	***Total***	***Diss.***	***Total***	***Total***	***Total***	***Total***
Aluminum	0.098	0.14	0.22	0.30	0.12	0.20	0.19	0.27	0.078	0.130	0.100
Arsenic	0.0022	0.0022	0.0092	0.0093	0.0041	0.0041	0.0067	0.0067	0.0043	0.0005	0.0050
Boron	0.070	0.070	0.25	0.25	0.036	0.036	0.059	0.059	0.070	0.070	1.5
Cadmium	0.000099	0.000099	0.00049	0.00049	0.000018	0.000019	0.000030	0.000031	0.0000040	0.000010	0.00007
Chromium	0.0023	0.0027	0.010	0.011	0.00058	0.0014	0.00095	0.0018	0.00036	0.00042	Cr VI
Copper	0.016	0.016	0.077	0.078	0.0046	0.0047	0.0075	0.0077	0.0014	0.0014	0.002
Iron	1.100	1.200	4.300	4.500	0.170	0.380	0.270	0.480	0.130	0.180	0.300
Lead	0.00055	0.00057	0.0026	0.0027	0.00013	0.00016	0.00021	0.00024	0.000063	0.00010	0.001
Molybdenum	0.023	0.023	0.12	0.12	0.0011	0.0011	0.0018	0.0018	0.00014	0.00015	0.073
Nickel	0.0031	0.0032	0.013	0.014	0.0011	0.0013	0.0018	0.0020	0.00049	0.00050	0.025
Silver	0.0027	0.0027	0.014	0.014	0.000022	0.000024	0.000035	0.000037	0.0000045	0.000018	0.0001
Thallium	0.00010	0.00010	0.00045	0.00045	0.000054	0.000055	0.000087	0.000089	0.000030	0.000073	0.0008
Uranium	0.00013	0.00013	0.00045	0.00045	0.00011	0.00011	0.00018	0.00018	0.00013	0.00013	0.015
Zinc	0.013	0.013	0.049	0.050	0.0050	0.0054	0.0081	0.0085	0.0027	0.0039	0.030

Source: \\Van-svr0\projects\01_SITES\Hope.Bay\1CT022.002_2015_Hope Bay Ongoing Support\200_Type_A_ Water_License\700_Site_Wide_WQ_Model\Deliverables\Tables\TIA WQ Results.xlsx

Notes:
1. Although the peak concentrations are presented here for reference, they occur consistently in the winter due to simulated cryoconcentration, during which time there would be no discharge, and the limits would not apply.
2. CCME Guideline: Water quality guideline for the long-term protection of freshwater aquatic life

The results of the simulated cryoconcentration were not be validated. There are a number of factors that affect the water quality predictions in ice conditions, including ice cover, ice thickness, and the solubility of the contaminants. Solubility limits have not been invoked in the model. For some parameters, precipitates would form and the simulated spikes in concentrations would not occur. Predicted concentrations without cryoconcentration are roughly equivalent to the lower concentrations predicted during the ice-free months, with no spikes in the winter. As these predicted peaks only occur in the winter when discharge to Doris Creek would not occur, they do not have a material effect on the outcome.

Once the TIA is refilled, provided the water quality meets the applicable guidelines and/or license limits, water from the TIA will be discharged to the Tail Lake Outflow channel. The predicted concentrations during this time were compared to the CCME water quality guidelines for the long-term protection of freshwater aquatic life (CCME 2015) in Table 6-2 for reference only. The CCME guidelines apply to aquatic habit, while the TIA is a designated tailings disposal area. The results indicate that the predicted mean concentrations in the TIA are below the CCME guidelines once the TIA refills for most parameters, with the exception of total aluminum, copper and iron.

The following summarizes the comparison of the predicted post-closure mean concentrations in the TIA once it refills and CCME water quality guidelines for freshwater aquatic life:

- The majority of predicted concentrations in the TIA are below the CCME guidelines.
- Aluminum – The monthly median background concentration in August exceeds the guideline. Predicted mean dissolved and total concentrations in the TIA are above the guideline; the predicted mean total concentration is 2 times the guideline, and 2.6 times the mean background concentration.
- Copper – Predicted mean total and dissolved concentrations are above the guideline; the mean total concentration is 2.4 times the guideline and 3.4 times the mean background concentration.
- Iron – Predicted mean dissolved concentrations are below the guideline. Predicted mean total concentrations are 1.3 times the guideline and 2.9 times the mean background concentration.

The parameters where the predicted mean concentrations are above the CCME guidelines in the TIA are primarily driven by loadings from the tailings beach. The tailings beach will be covered at closure with a 0.3 m layer of quarry rock. It is assumed the cover will be fully applied by the end of calendar year 2021. At that time, the loading on the tailings beach will be based on the cover source term. This source term was conservatively derived as the maximum of the surface infrastructure area and tailings beach concentrations. Consequently, there is no benefit accounted for in the model for the cover application.

6.3.2 Roberts Bay Outfall

Water quality predictions were made under average hydrological conditions for the effluent discharging to Roberts Bay from the Marine Outfall Mixing Box. Once milling begins, water from the TIA will be mixed with saline groundwater from the underground mine and discharged to Roberts Bay. At closure, the TIA will be dewatered to Roberts Bay.

Groundwater modeling was carried out in a separate model (SRK 2015b). For the purposes of the water and load balance model, concentrations at the Mixing Box were predicted assuming a baseline flow of groundwater of 3,000 m^3/day year-round. The groundwater concentration is based on a mixture of talik, bedrock and fresh water intercepted during underground development (SRK 2015b).

Three sets of predictions are provided to represent different timeframes during the mine life and dewatering of the TIA:

1. **Groundwater + TIA Effluent** – During the open water season, effluent from the TIA will be pumped to the Mixing Box and combined with groundwater prior to discharge to Roberts Bay.
2. **Groundwater Only** – During the winter, groundwater will be pumped to the Mixing Box and discharged to Roberts Bay when the underground sump capacity is reached.
3. **TIA Effluent Only** – After mining ceases and groundwater is no longer collected, the TIA will be dewatered to Roberts Bay by year-round pumping to the Mixing Box.

The parameters presented in this section are the marine water quality guidelines shown previously in Table 5-2 (Page 30). Results for pH, percent change in salinity and radium are not presented as they were not modeled. Mercury has been excluded from predictions of mixed water and TIA effluent due to high detection limits in the mill effluent water quality dataset, which could result in artificially elevated predictions. Predicted chromium concentrations provided represent total chromium, while the water quality guidelines represent the sum of the guideline values for chromium III and chromium VI.

Predictions are provided for dissolved and total concentrations for the mixed concentration and TIA effluent. The total concentrations were calculated assuming the total solids in the TIA are comprised of tailings solids from the tailings beach and based on the maximum background TSS of 5.9 mg/L.

The predicted monthly mean and maximum concentrations at the Marine Outfall Mixing Box for the three scenarios noted above are provided in Table 6-3, along with the marine water quality guidelines. Concentrations of cadmium and mercury in the Marine Outfall Mixing Box effluent are predicted to exceed the marine water quality guidelines at different timeframes during operations and post-closure dewatering.

Table 6-3: Predicted Concentrations at Marine Outfall Mixing Box

Parameter	Predicted Monthly Concentrations (mg/L)									Marine Guideline (mg/l)
	Groundwater + TIA Effluent Mean		Groundwater + TIA Effluent Max		GW Only	TIA Effluent Only Mean		TIA Effluent Only Max		
Nitrate_N	0.65		0.80		0.93	0.19		0.40		16
Total Cyanide	0.0043		0.0053		0.0036	0.0041		0.086		1
Metals	***Diss.***	***Total***	***Diss.***	***Total***	***Diss.***		***Total***	***Diss.***	***Total***	***Total***

Parameter	Predicted Monthly Concentrations (mg/L)									Marine Guideline (mg/)
	Groundwater + TIA Effluent Mean		Groundwater + TIA Effluent Max		GW Only	TIA Effluent Only Mean		TIA Effluent Only Max		
Arsenic	0.0025	0.0026	0.0034	0.0035	0.0024	0.0040	0.0041	0.0092	0.0092	0.0125
Cadmium	0.00013	0.00013	0.00018	0.00018	0.00012	0.00019	0.00019	0.00046	0.00046	0.00012
Chromium	0.0020	0.0029	0.0031	0.0039	0.00086	0.0039	0.0047	0.0095	0.010	0.0575
Copper	0.013	0.013	0.021	0.021	0.0012	0.030	0.030	0.074	0.074	0.3
Lead	0.00054	0.00058	0.00083	0.00087	0.00029	0.0010	0.0010	0.0025	0.0025	0.2
Mercury					0.000049					0.000016
Nickel	0.0030	0.0032	0.0044	0.0046	0.0018	0.0053	0.0055	0.013	0.013	0.5
Zinc	0.074	0.074	0.080	0.080	0.15	0.020	0.020	0.047	0.048	0.5

Source: \\Van-svr0\projects\01_SITES\Hope.Bay\1CT022.002_2015_Hope Bay Ongoing Support\200_Type_A_
Water_License\700_Site_Wide_WQ_Model\Deliverables\Tables\ TIA WQ Results.xlsx

Notes:
1. Mercury for mixed concentrations and TIA are not reported due to high detection limits in Mill effluent source term (shaded in grey).
2. Groundwater reported as dissolved metals only.

7 Conclusions

The water and load balance model was run from 2010 to 2035. The key dates and phases in the model are:

- 2010 to 2014 – Model calibration period
- April 2015 – Doris Mine operations restart
- January 2017 – Mill operations and discharge to Roberts Bay begin (TIA effluent discharged during open water season only)
- April 2021 – Closure and TIA dewatering begin
- December 2021 – Site reclamation completed

The TIA water balance was calibrated using measured climate data, along with measured inflows from mine site collection ponds and discharge to Doris Creek. Hydrological parameters were adjusted to optimize the agreement between measured and predicted elevations, and the model was able to adequately predict measured elevations in the TIA.

Precipitation-driven inflows to the TIA are on average 500,000 m^3/year. During operations, the total inflow to the TIA increases to approximately 1.5 million m^3/year, with mean total discharge to Roberts Bay of 500,000 m^3/year. TIA effluent will be combined with groundwater and discharged to Roberts Bay via the Mixing Box. Groundwater will be pumped at a rate of 3,000 m^3/day when the sump capacity is met. Water from the TIA will be pumped at a rate of 4,000 m^3/day. This rate was selected to provide a gradual increase in the TIA volume to ensure adequate supply of mill demands and depth for operating reclaim pumps, particularly in the winter under frozen conditions.

At closure, the TIA will be dewatered to Roberts Bay by year-round pumping at 4,000 m^3/day to accelerate improved water quality. Based on the mean results of the water balance, the TIA will be dewatered to an elevation of 23 m in 2023 and will refill to an elevation of 28.3 in 2028. The projected dewatering rate is just under 1.5 million m^3/year, with a mean total dewatering volume of 3.1 million m^3.

The impact of water demands during operations on Doris Lake was evaluated. During operations, freshwater for the mill, water for industrial use and groundwater recharge are expected to cause a drawdown in Doris Lake. On average, these withdrawals constitute less than 10% of baseline discharge from Doris Lake. The predicted drawdown during operations is less than 0.20 m. The maximum withdrawal is expected to occur in 2019 (Year 3) when the groundwater recharge and freshwater demand peak.

Water quality predictions were generated for the TIA, groundwater and Marine Outfall Mixing Box effluent (for discharge to Roberts Bay). The predicted water quality in the TIA after it refills was compared to the CCME water quality guidelines for the long-term protection of freshwater aquatic life. The comparison is for reference purposes only as the CCME guidelines apply to natural watercourses, whereas the TIA is a designated tailings impoundment facility. The majority of predicted concentrations in the TIA are expected to be below the CCME guidelines once the TIA refills with the exception of aluminum, copper and iron:

- Aluminum – The monthly median background concentration in August exceeds the guideline. Predicted mean dissolved and total concentrations in the TIA are above the guideline; the mean total concentration is 2 times the guideline, and 2.6 times the mean background concentration.
- Copper – Predicted mean total and dissolved concentrations are above the guideline; the mean total concentration is 2.4 times the guideline and 3.4 times the mean background concentration.
- Iron – Predicted mean dissolved concentrations are below the guideline. Predicted mean total concentrations are 1.3 times the guideline and 2.9 times the mean background concentration.

Water quality predictions were made for discharge to Roberts Bay under three scenarios: 1) groundwater plus TIA effluent; 2) groundwater only; and 3) TIA effluent only (during post-closure dewatering). The predicted monthly mean and maximum concentrations at the Marine Outfall Mixing Box during the three scenarios were compared to the CMME marine water quality guidelines MMER. Concentrations of cadmium and mercury in the Mixing Box effluent are predicted to be above the marine water quality guidelines at different timeframes during operations and post-closure dewatering.

Total metals concentrations are calculated with an assumed TSS concentration based on the composition of tailings solids. TSS concentrations will vary and the configuration of the TIA will allow for solids to settle out. Consequently, the predicted total metals may not fully materialize and the total metals concentrations are likely conservative.

This report, Doris North Project – Water and Load Balance, was prepared by SRK Consulting (Canada) Inc.

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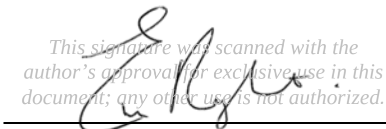
and reviewed by



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All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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Appendix A – Water Quality Inputs

Table A- 1: Background Water Quality at TL-1

Parameter	Median Monthly Concentration (mg/L)				
	June	July	August	September	October
TDS	110	80	90	110	110
TSS	1.4	1.7	2.1	2.0	2.0
Free_CN	N/A	N/A	N/A	N/A	N/A
Total_CN	0.0012	0.0013	0.0014	0.0015	0.0015
WAD_CN	N/A	N/A	N/A	N/A	N/A
CNO	N/A	N/A	N/A	N/A	N/A
SCN	N/A	N/A	N/A	N/A	N/A
Sulphate	4.0	2.9	3.3	4.2	4.2
Chloride	33	32	49	57	57
Ammonia_N	0.027	0.012	0.0080	0.011	0.011
Nitrate_N	0.0052	0.0061	0.0053	0.010	0.010
Nitrite_N	0.0012	0.0014	0.0013	0.0018	0.0018
Alkalinity	29	30	31	27	27
Ortho_P	0.0020	0.0020	0.0020	0.0020	0.0020
Phosphate_P	0.0078	0.0086	0.011	0.0088	0.0088
TOC	5.7	5.3	5.2	4.8	4.8
Hardness	36	35	50	52	52
Aluminum	0.018	0.015	0.022	0.023	0.023
Antimony	0.000034	0.000061	0.00010	0.00014	0.00014
Arsenic	0.00024	0.00026	0.00041	0.00037	0.00037
Barium	0.0021	0.0022	0.0038	0.0039	0.0039
Beryllium	0.000044	0.000060	0.0000030	0.0000042	0.0000042
Bismuth	0.0000068	0.000011	0.0000025	0.0000013	0.0000013
Boron	0.015	0.015	0.015	0.013	0.013
Cadmium	0.000012	0.000017	0.0000022	0.0000020	0.0000020
Calcium	6.5	6.2	9.5	9.6	9.6
Chromium	0.00032	0.00024	0.00029	0.00029	0.00029
Cobalt	0.000035	0.000057	0.000091	0.000095	0.000095
Copper	0.00093	0.00076	0.00070	0.00071	0.00071
Iron	0.054	0.13	0.41	0.41	0.41
Lead	0.000041	0.000052	0.000069	0.000023	0.000023
Lithium	N/A	N/A	N/A	N/A	N/A
Magnesium	5.1	4.7	6.7	6.7	6.7
Manganese	0.0013	0.0028	0.011	0.014	0.014
Mercury	0.00000060	0.00000060	0.00000060	0.00000060	0.00000060
Molybdenum	0.000091	0.000081	0.000068	0.000074	0.000074
Nickel	0.00051	0.00055	0.00052	0.00044	0.00044
Phosphorus	0.0078	0.0086	0.011	0.0088	N/A

Parameter	Median Monthly Concentration (mg/L)				
	June	July	August	September	October
Potassium	1.7	1.4	1.6	1.9	1.9
Selenium	0.00042	0.00038	0.00086	0.00092	0.00092
Silicon	N/A	N/A	N/A	N/A	N/A
Silver	0.000021	0.000030	0.00000090	0.0000014	0.0000014
Sodium	17	16	23	25	25
Strontium	0.027	0.027	0.043	0.045	0.045
Tellerium	N/A	N/A	N/A	N/A	N/A
Thallium	0.000034	0.000017	0.0000053	0.0000043	0.0000043
Thorium	N/A	N/A	N/A	N/A	N/A
Tin	0.000044	0.000082	0.000049	0.000034	0.000034
Titanium	N/A	N/A	N/A	N/A	N/A
Uranium	0.000019	0.000022	0.0000094	0.000014	0.000014
Vanadium	0.00036	0.00014	0.000093	0.000056	0.000056
Zinc	0.0046	0.0042	0.0037	0.0034	0.0034
Zirconium	N/A	N/A	N/A	N/A	N/A

Source: \\VAN-SVR0\Projects\01_SITES\Hope.Bay\1CT022.001_2014 Hope Bay Ongoing Support\410_Prep of Submission\Water Quality Prediction\Water Quality Data\WaterQuality_1CT022-001_Rev06_MCN.xlsx>

Table A- 2: Background Water Quality at TL-2

Parameter	Median Monthly Concentration (mg/L)				
	June	July	August	September	October
TDS	140	120	130	150	150
TSS	3	4.3	5.9	3.6	3.6
Free_CN	N/A	N/A	N/A	N/A	N/A
Total_CN	0.0013	0.0014	0.0013	0.0013	0.0013
WAD_CN	N/A	N/A	N/A	N/A	N/A
CNO	N/A	N/A	N/A	N/A	N/A
SCN	N/A	N/A	N/A	N/A	N/A
Sulphate	4.1	3.1	3.2	3.4	3.4
Chloride	57	63	62	64	64
Ammonia_N	0.0083	0.014	0.013	0.0081	0.0081
Nitrate_N	0.0054	0.0059	0.0053	0.0053	0.0053
Nitrite_N	0.0013	0.0016	0.0013	0.0016	0.0016
Alkalinity	26	27	27	28	28
Ortho_P	0.00075	0.00075	0.00075	0.00075	0.00075
Phosphate_P	0.019	0.024	0.033	0.031	0.031
TOC	5.1	5.2	5.6	5	5
Hardness	40	41	44	44	44
Aluminum	0.077	0.058	0.13	0.062	0.062
Antimony	0.00012	0.0002	0.0004	0.000097	0.000097
Arsenic	0.00038	0.00039	0.00045	0.00047	0.00047

Parameter	Median Monthly Concentration (mg/L)				
	June	July	August	September	October
Barium	0.0032	0.0031	0.0038	0.0032	0.0032
Beryllium	0.000037	0.0000037	0.0000049	0.000004	0.000004
Bismuth	0.000023	0.000063	0.000017	0.0000037	0.0000037
Boron	0.022	0.021	0.023	0.022	0.022
Cadmium	0.00001	0.0000032	0.0000025	0.0000021	0.0000021
Calcium	6.6	7.1	7.3	7.6	7.6
Chromium	0.00042	0.0002	0.0004	0.00039	0.00039
Cobalt	0.000058	0.000052	0.00018	0.000065	0.000065
Copper	0.0012	0.0013	0.0014	0.0014	0.0014
Iron	0.11	0.11	0.18	0.12	0.12
Lead	0.000069	0.000067	0.0001	0.000038	0.000038
Lithium	N/A	N/A	N/A	N/A	N/A
Magnesium	5.5	5.9	6.2	6.3	6.3
Manganese	0.011	0.015	0.017	0.021	0.021
Mercury	0.0000009	0.0000009	0.0000009	0.0000009	0.0000009
Molybdenum	0.00012	0.00015	0.00015	0.00014	0.00014
Nickel	0.00049	0.0005	0.00049	0.00049	0.00049
Phosphorus	N/A	N/A	N/A	N/A	N/A
Potassium	2.2	2.3	2.3	2.3	2.3
Selenium	0.00074	0.00078	0.00093	0.001	0.001
Silicon	N/A	N/A	N/A	N/A	N/A
Silver	0.000018	0.0000014	0.0000012	0.000001	0.000001
Sodium	28	30	32	32	32
Strontium	0.036	0.038	0.039	0.041	0.041
Tellerium	N/A	N/A	N/A	N/A	N/A
Thallium	0.000045	0.000073	0.00002	0.0000072	0.0000072
Thorium	N/A	N/A	N/A	N/A	N/A
Tin	0.0001	0.00021	0.000095	0.000038	0.000038
Titanium	N/A	N/A	N/A	N/A	N/A
Uranium	0.000033	0.000029	0.000037	0.000033	0.000033
Vanadium	0.0005	0.00016	0.00032	0.00018	0.00018
Zinc	0.0034	0.0027	0.0039	0.0017	0.0017
Zirconium	N/A	N/A	N/A	N/A	N/A

Source: \\VAN-SVR0\Projects\01_SITES\Hope.Bay\1CT022.001_2014 Hope Bay Ongoing Support\410_Prep of Submission\Water Quality Prediction\Water Quality Data\WaterQuality_1CT022-001_Rev06_MCN.xlsx>

Table A- 3: Solute Release Rates (mg/kg/week) from Humidity Cell Tests on Doris Flotation Tailings Samples (SRK 2015a)

HC#	HC-57	HC-1	HC-66
Doris Deposit	Connector	Central	North
Alk	25	13	35
SO4	1	5	4.8
Ca	6.1	3.1	8
Mg	2.7	2.3	4
Ag	3.1E-06	0.000024	3.1E-06
Al	0.016	0.0064	0.028
As	0.0027	0.00048	0.016
Cd	5.4E-06	0.000024	3.1E-06
Co	0.000031	0.00074	0.000062
Cr	0.00007	0.00024	0.00006
Cu	0.005	0.0009	0.00019
Fe	0.0043	0.0095	0.0053
Hg	1.9E-06	0.0024	1.2E-06
Mn	0.016	0.009	0.021
Mo	0.00041	0.0029	0.00068
Ni	1.6E-07	0.00022	4.1E-07
Pb	0.000028	0.00054	0.000015
Sb	0.00014	0.000048	0.00011
Se	0.000031	0.0003	0.00013
U	0.000005	0.00001	0.00002
Zn	0.00033	0.001	0.00029

Source: \\VAN-SVR0\Projects\01_SITES\Hope.Bay\1CT022.002_2015_Hope Bay Ongoing Support\200_Type_A_Water_License\700_Site_Wide_WQ_Model\Model\HB_Tailings_WQ_Pred_REV01_kss.xlsx>

Table A- 4: Source Concentrations at ST-2

Parameter	Median Monthly Concentration (mg/L)				
	June	July	August	September	October
TDS	N/A	N/A	N/A	N/A	N/A
TSS	4.0	7.0	6.1	9.0	15
Free_CN	0.0070	0.0060	0.0060	0.0050	0.0060
Total_CN	0.058	0.012	0.0088	0.019	0.041
WAD_CN	N/A	N/A	N/A	N/A	N/A
CNO	N/A	N/A	N/A	N/A	N/A
SCN	N/A	N/A	N/A	N/A	N/A
Sulphate	61	140	200	180	120
Chloride	1100	1600	1700	1900	2100
Ammonia_N	27	30	22	30	40
Nitrate_N	45	87	87	87	87
Nitrite_N	0.63	0.50	0.50	0.50	0.50
Alkalinity	97	91	130	130	160
Ortho_P	N/A	N/A	N/A	N/A	N/A
Phosphate_P	N/A	N/A	N/A	N/A	N/A
TOC	4.4	4.4	4.4	4.4	4.4
Hardness	760	1500	1300	2400	1500
Aluminum	0.12	0.10	0.079	0.080	0.13
Antimony	0.00050	0.00050	0.00080	0.00050	0.00050
Arsenic	0.00072	0.0013	0.00050	0.00088	0.00063
Barium	0.091	0.11	0.096	0.25	0.20
Beryllium	0.0010	0.0010	0.0010	0.0010	0.0010
Bismuth	N/A	N/A	N/A	N/A	N/A
Boron	0.20	0.34	0.46	0.29	0.23
Cadmium	0.000074	0.00014	0.00012	0.00018	0.00014
Calcium	410	470	430	810	740
Chromium	0.0050	0.0040	0.0020	0.0038	0.0050
Cobalt	0.0036	0.0040	0.0042	0.0083	0.0075
Copper	0.0091	0.0072	0.0077	0.0076	0.0060
Iron	0.23	0.30	0.40	0.60	0.85
Lead	0.00027	0.00027	0.00050	0.00029	0.00035
Lithium	0.11	0.072	0.056	0.30	0.26
Magnesium	39	61	69	80	71
Manganese	0.37	0.84	0.87	1.2	2.0
Mercury	0.00010	0.000020	0.000020	0.00010	0.00010
Molybdenum	0.0050	0.0050	0.0081	0.0053	0.0083
Nickel	0.0024	0.0038	0.0066	0.0067	0.0054
Phosphorus	N/A	N/A	N/A	N/A	N/A
Potassium	21	26	30	34	30
Selenium	0.00086	0.0025	0.0038	0.0024	0.0017

Parameter	Median Monthly Concentration (mg/L)				
	June	July	August	September	October
Silicon	N/A	N/A	N/A	N/A	N/A
Silver	0.000020	0.000020	0.000020	0.000020	0.000020
Sodium	200	400	460	480	420
Strontium	N/A	N/A	N/A	N/A	N/A
Tellerium	N/A	N/A	N/A	N/A	N/A
Thallium	0.00020	0.00012	0.00020	0.00020	0.00020
Thorium	N/A	N/A	N/A	N/A	N/A
Tin	0.050	0.050	0.050	0.050	0.050
Titanium	0.0056	0.0029	0.011	0.0053	0.0040
Uranium	0.00053	0.0011	0.0020	0.0016	0.0012
Vanadium	0.0010	0.0010	0.0020	0.0010	0.0019
Zinc	0.011	0.016	0.060	0.17	0.11
Zirconium	N/A	N/A	N/A	N/A	N/A

Source: \\VAN-SVR0\Projects\01_SITES\Hope.Bay\1CT022.001_2014 Hope Bay Ongoing Support\410_Prep of Submission\Water Quality Prediction\Water Quality Data\WaterQuality_1CT022-001_Rev06_MCN.xlsx>

Appendix B – Water Quality Figures

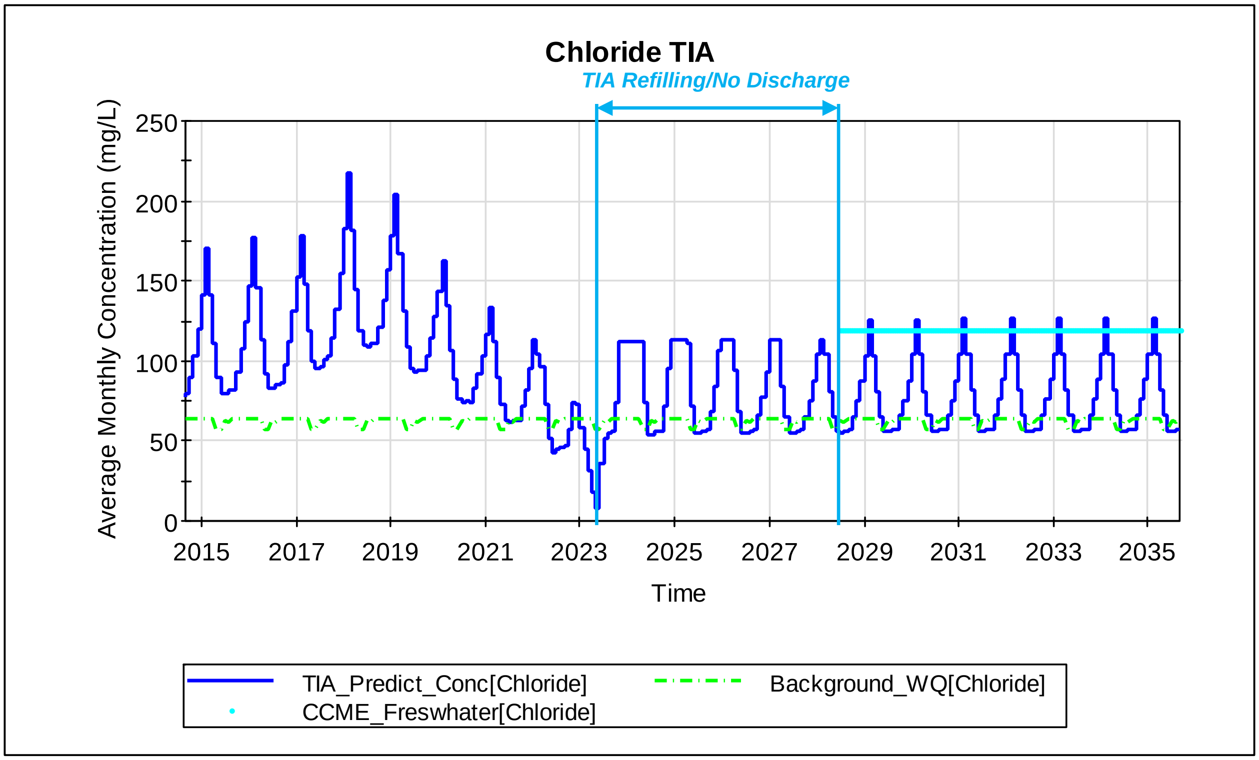

Figure B- 1: Predicted Water Quality in TIA – Chloride

Source: \\Van-svr0\projects\01_SITES\Hope.Bay\1CT022.002_2015_Hope Bay Ongoing Support\200_Type_A_Water_License\700_Site_Wide_WQ_Model\Model\HopeBay_WLBalance_TypeA_Rev19_SPB_KPW.gsm

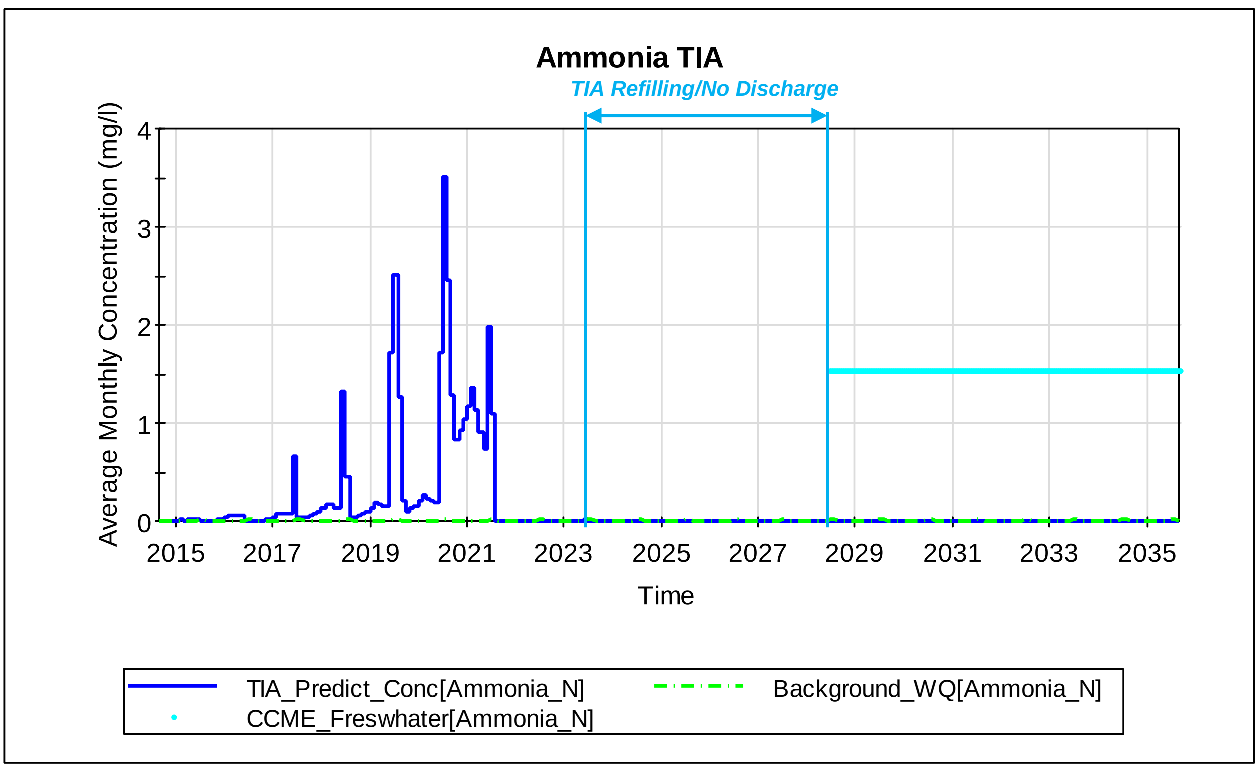

Figure B- 2: Predicted Water Quality in TIA – Total Ammonia

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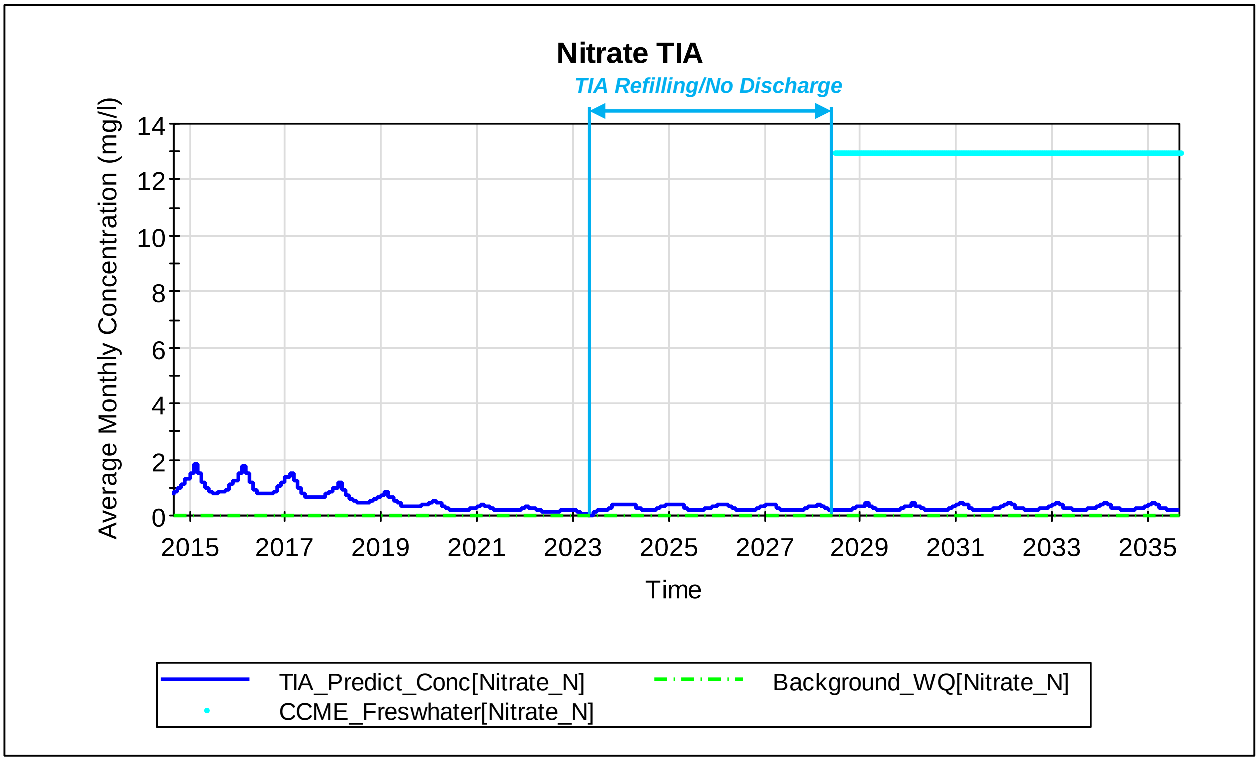

Figure B- 3: Predicted Water Quality in TIA – Nitrate as N

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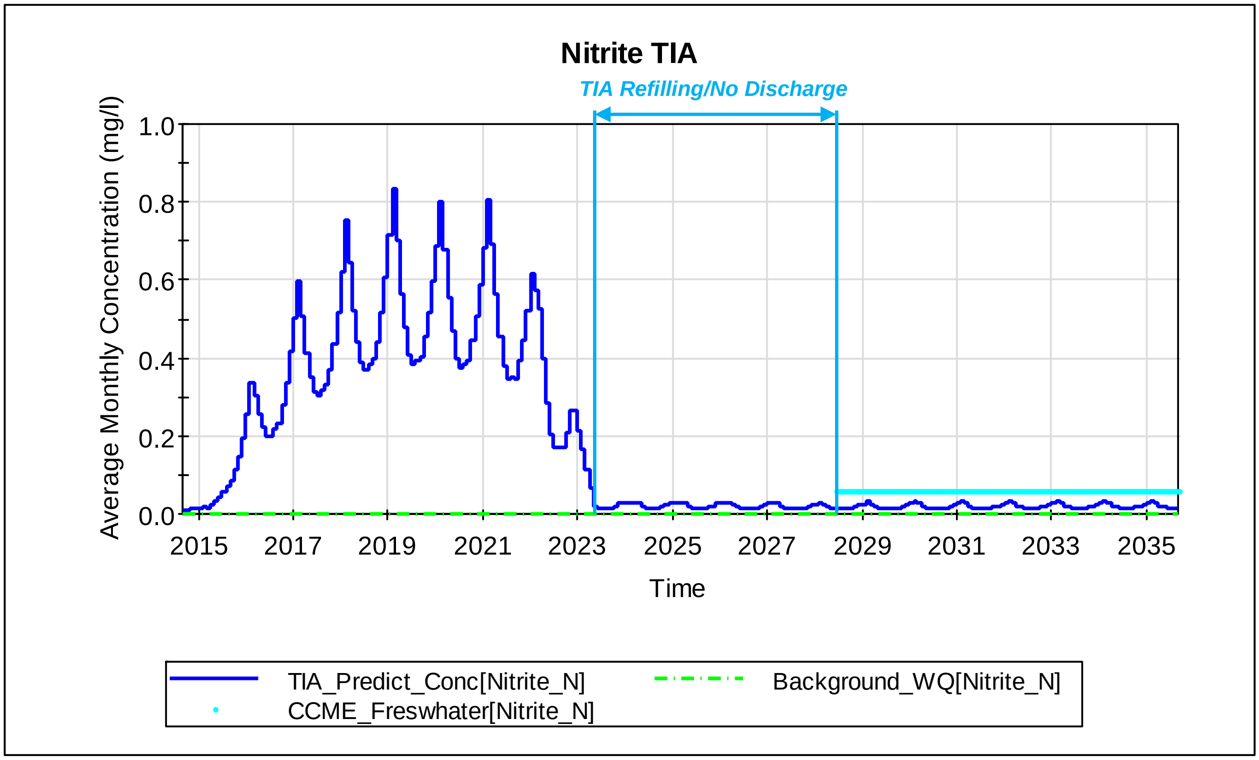

Figure B- 4: Predicted Water Quality in TIA – Nitrite as N

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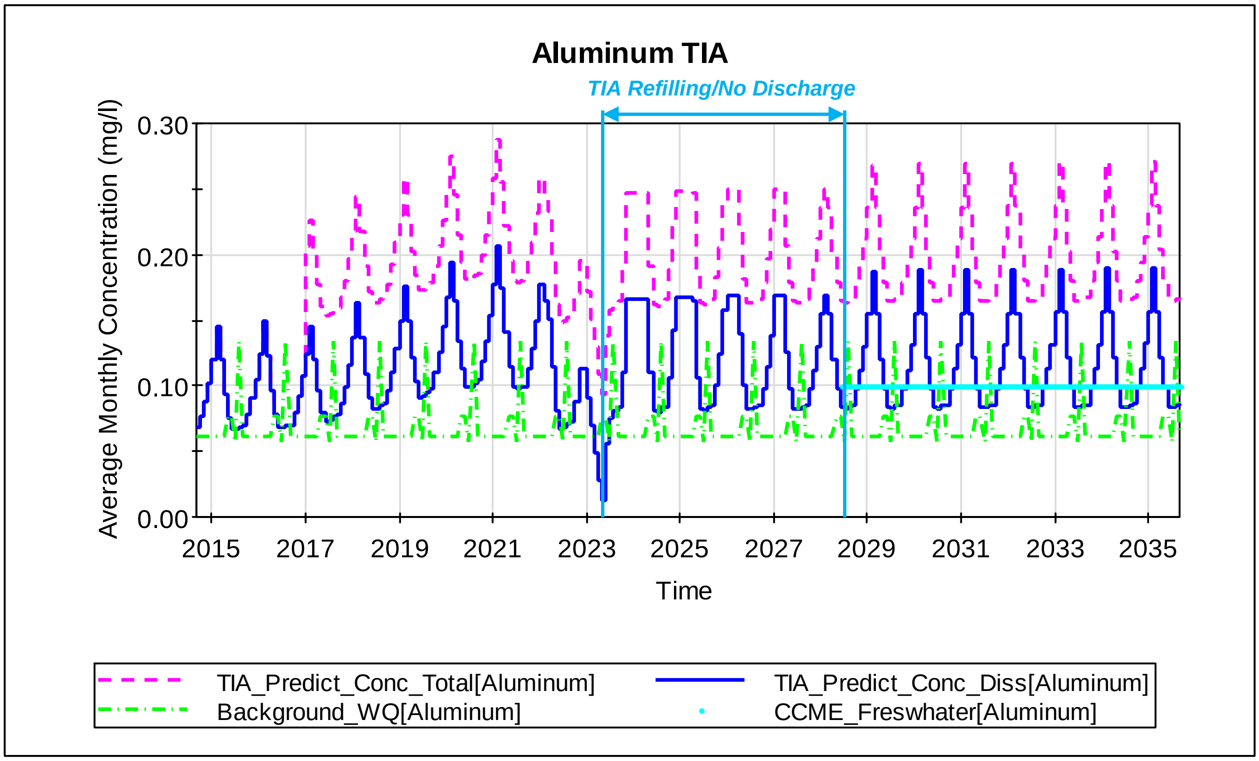

Figure B- 5: Predicted Water Quality in TIA – Aluminum

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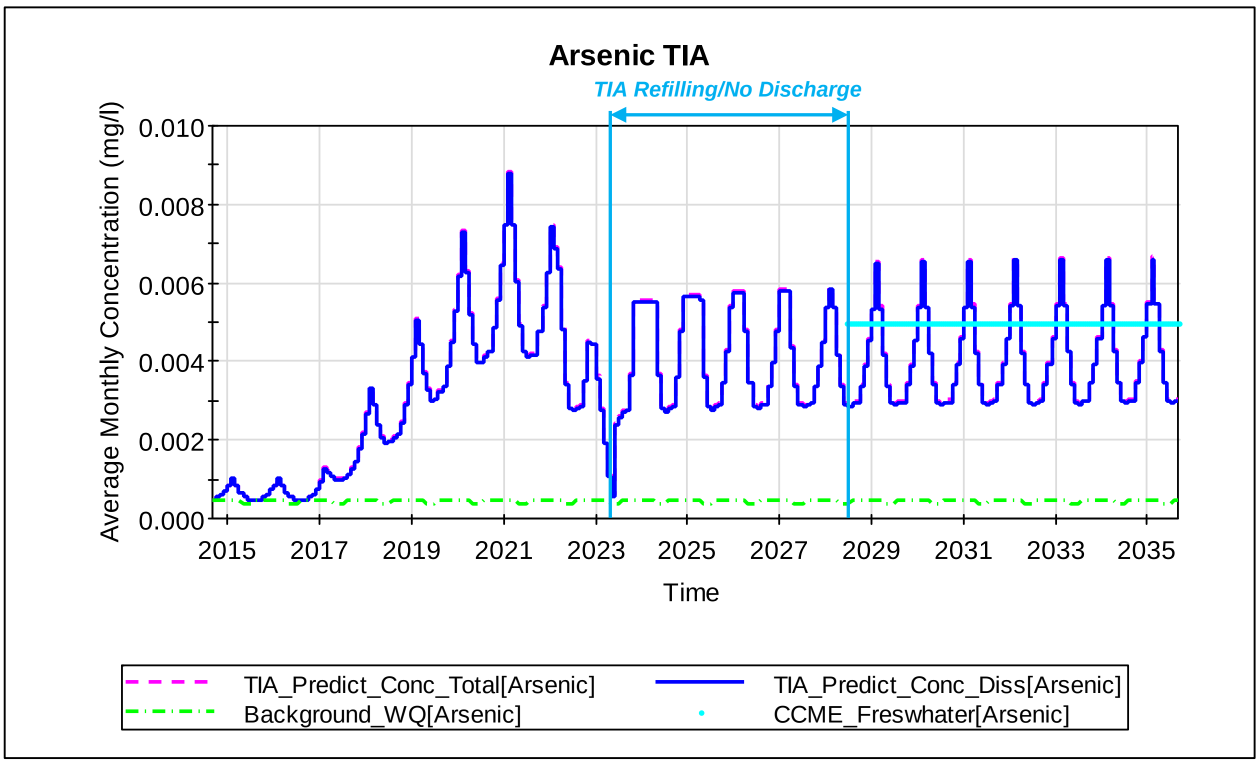

Figure B- 6: Predicted Water Quality in TIA – Arsenic

Source: Source: \\Van-svr0\projects\01_SITES\Hope.Bay\1CT022.002_2015_Hope Bay Ongoing Support\200_Type_A_Water_License\700_Site_Wide_WQ_Model\Model\HopeBay_WLBalance_TypeA_Rev19_SPB_KPW.gsm

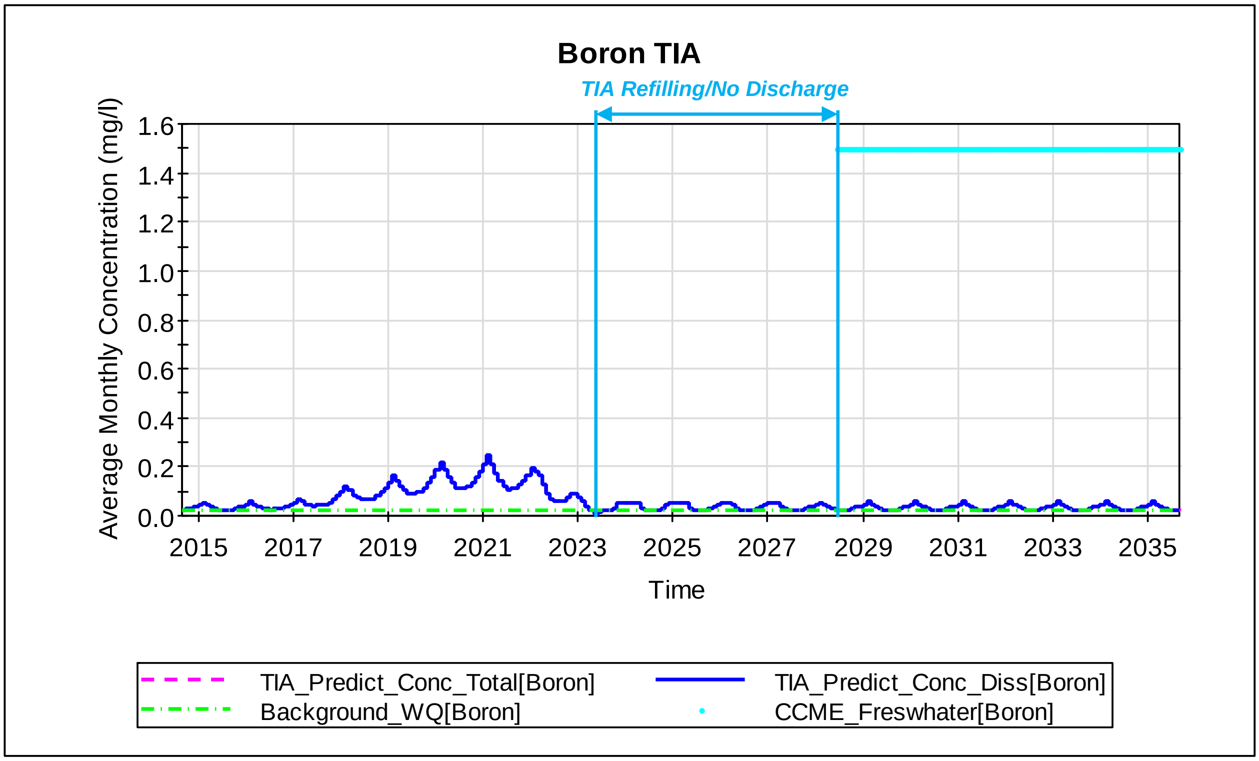

Figure B- 7: Predicted Water Quality in TIA – Boron

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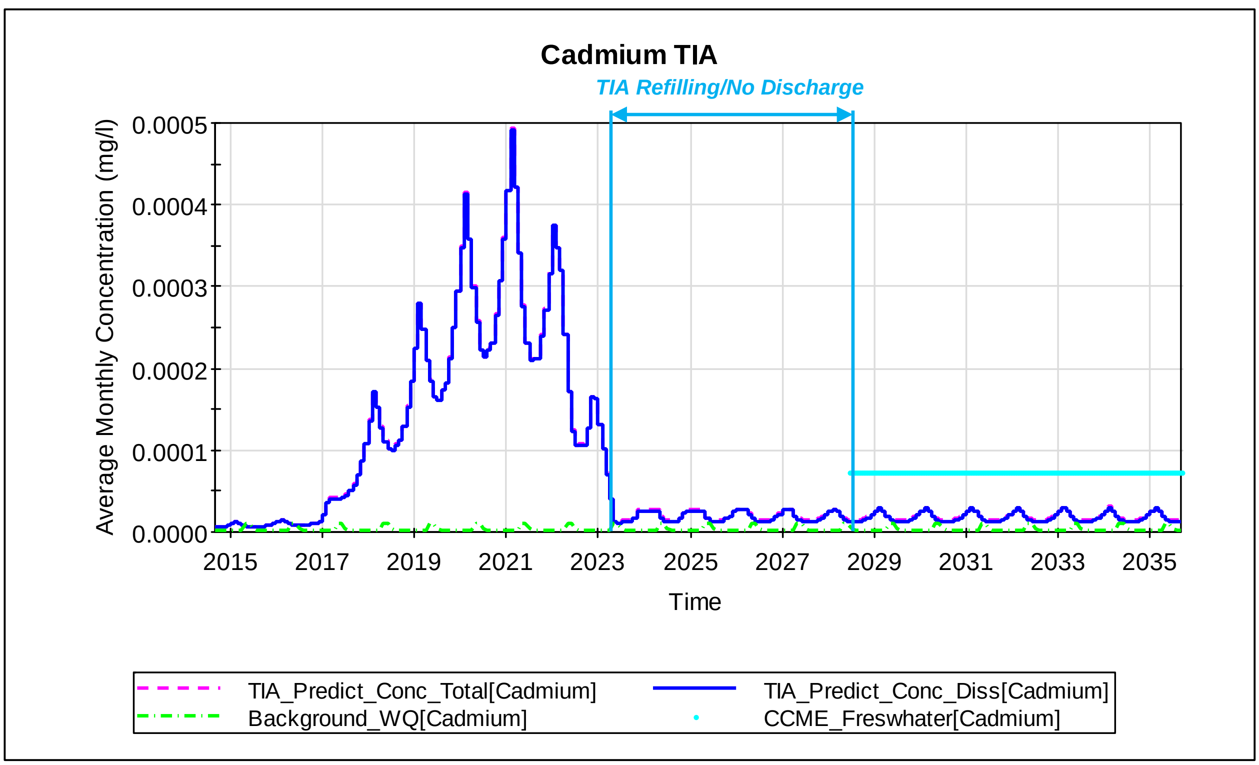

Figure B- 8: Predicted Water Quality in TIA – Cadmium

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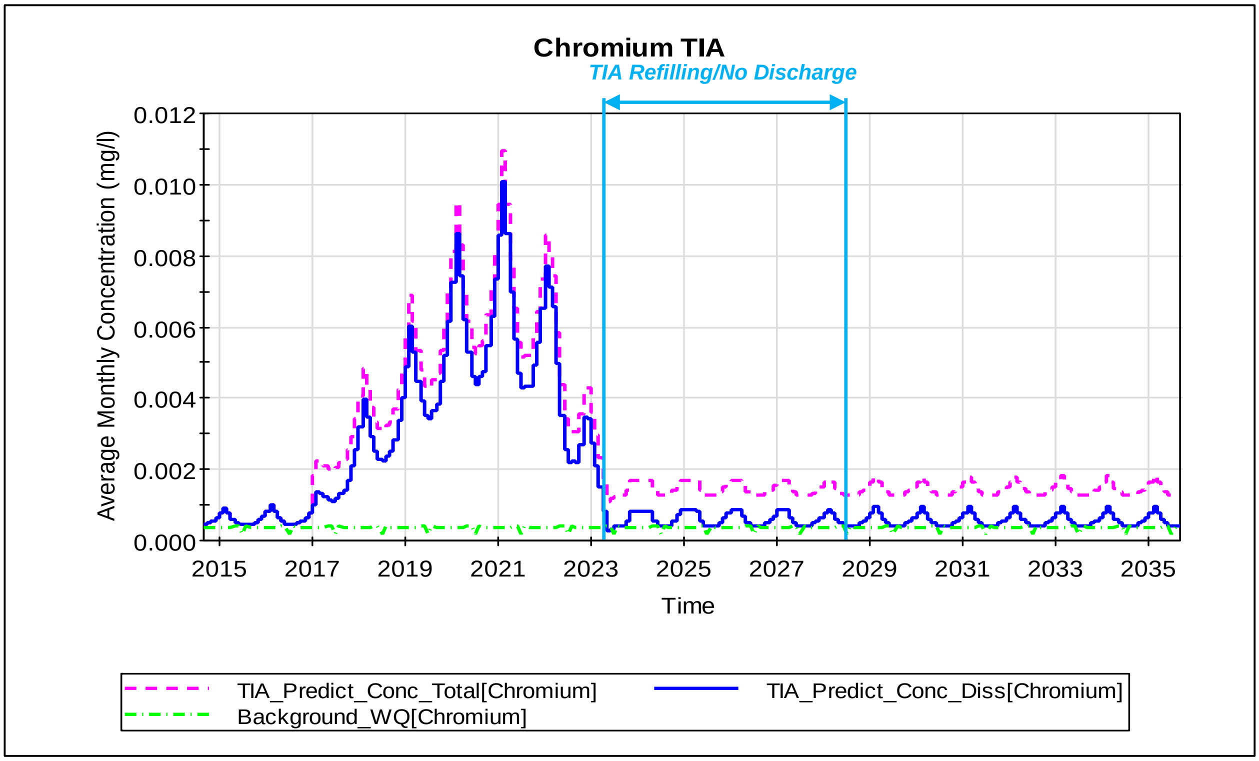

Figure B- 9: Predicted Water Quality in TIA – Chromium

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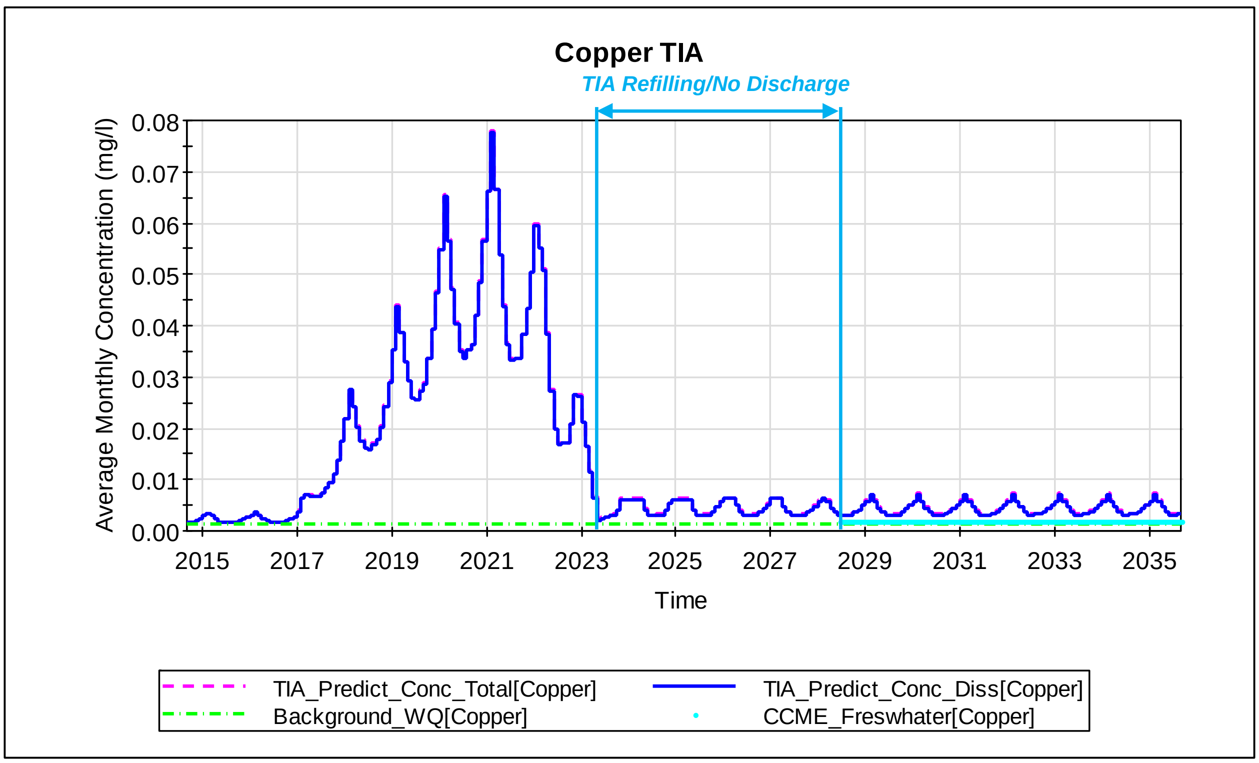

Figure B- 10: Predicted Water Quality in TIA – Copper

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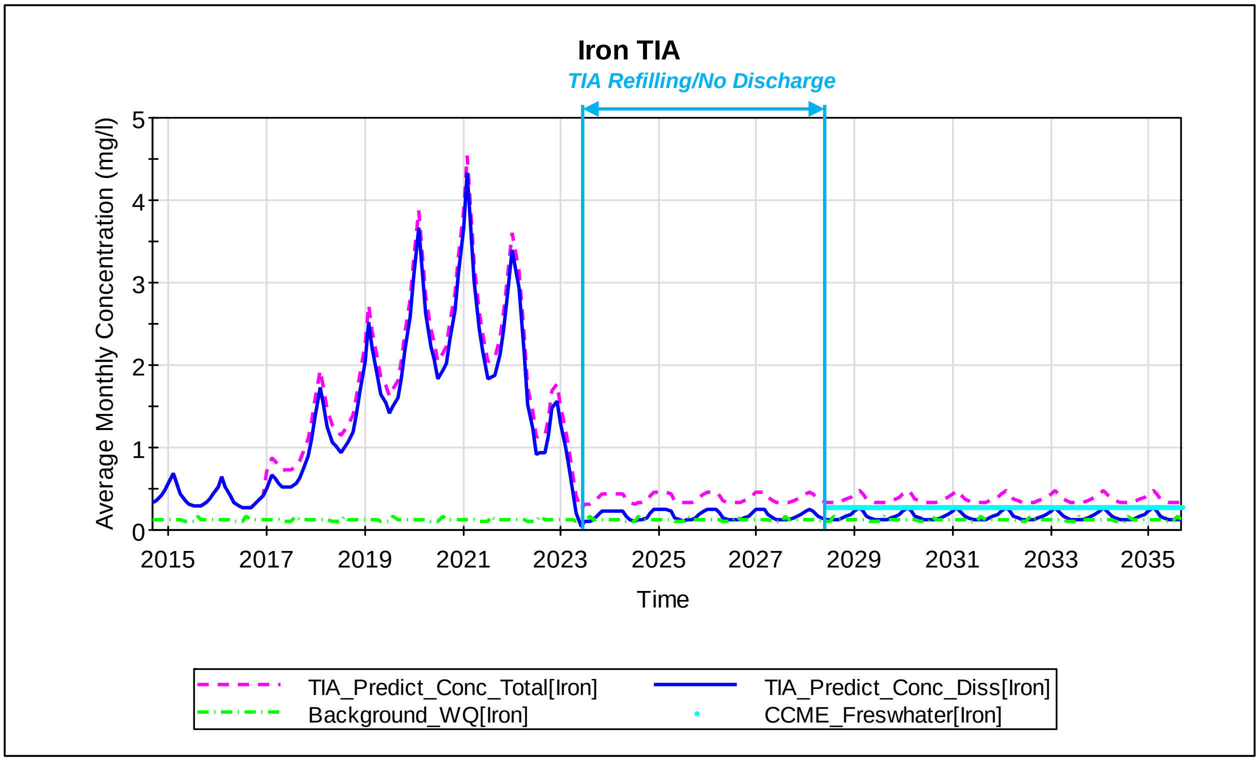

Figure B- 11: Predicted Water Quality in TIA – Iron

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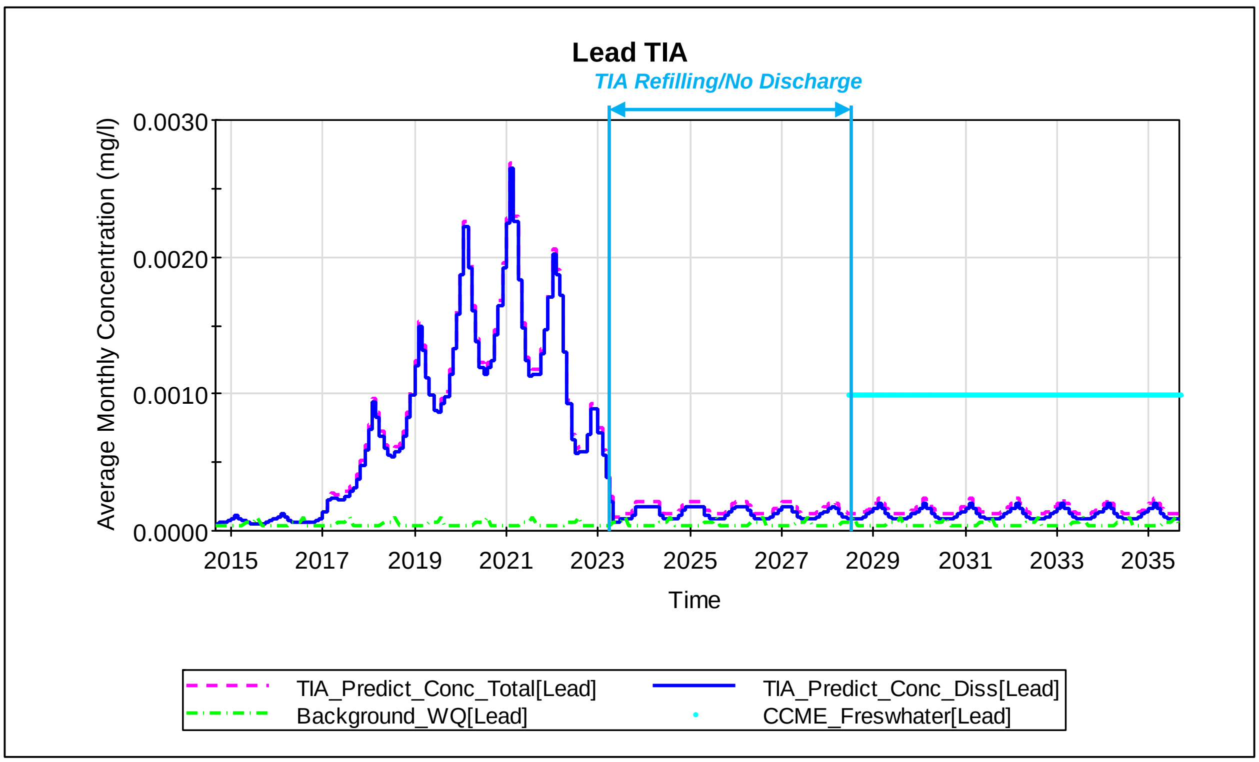

Figure B- 12: Predicted Water Quality in TIA – Lead

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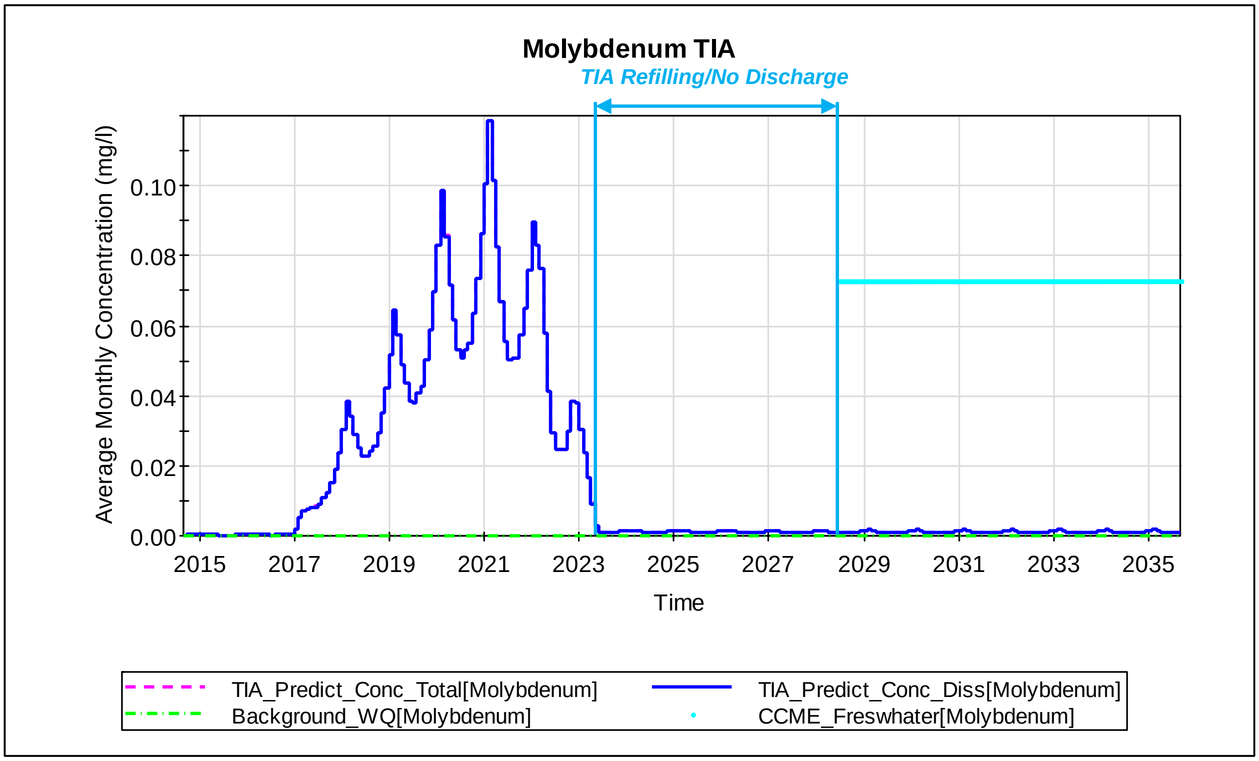

Figure B- 13: Predicted Water Quality in TIA – Molybdenum

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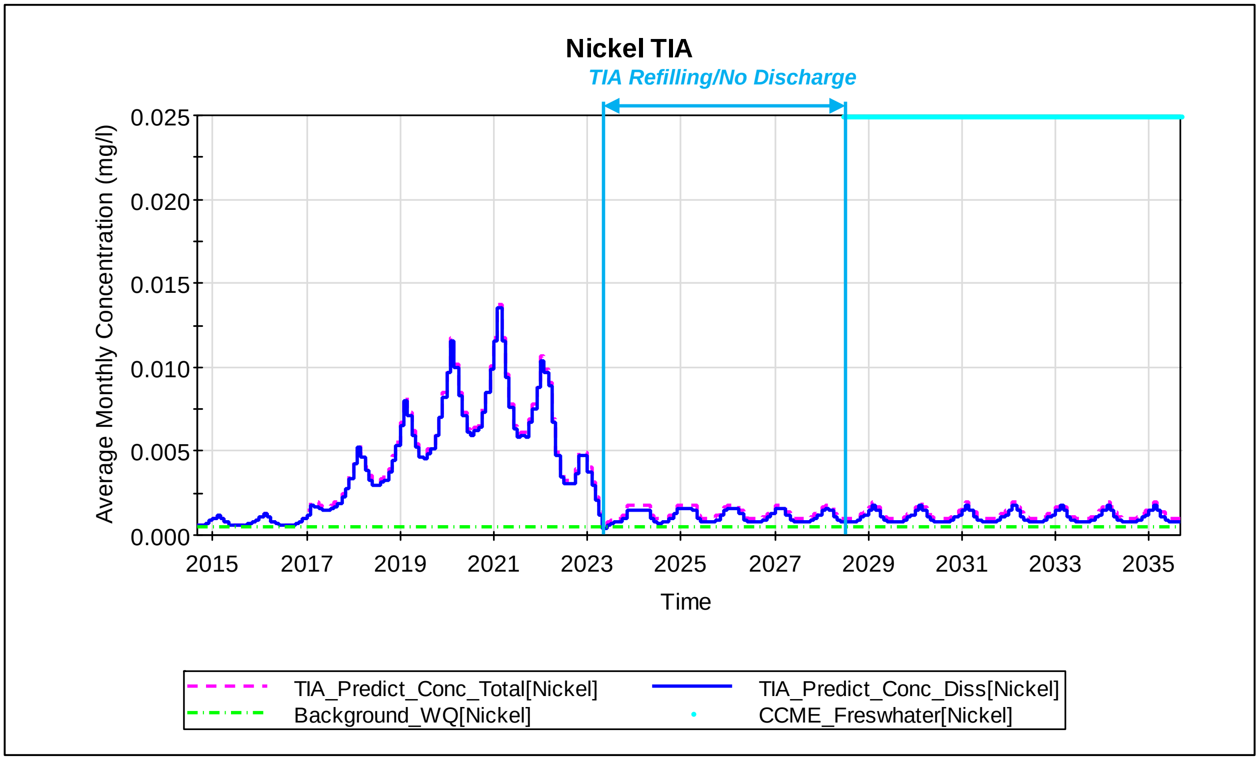

Figure B- 14: Predicted Water Quality in TIA – Nickel

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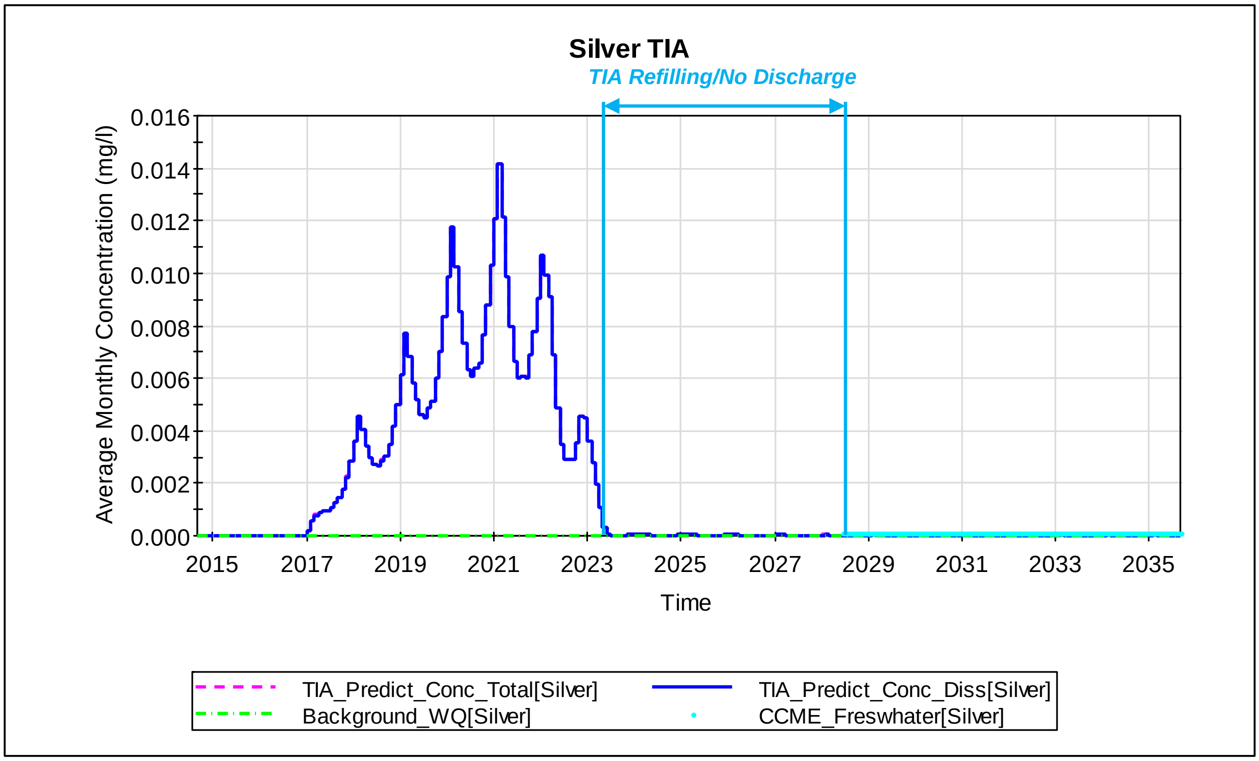

Figure B- 15: Predicted Water Quality in TIA – Silver

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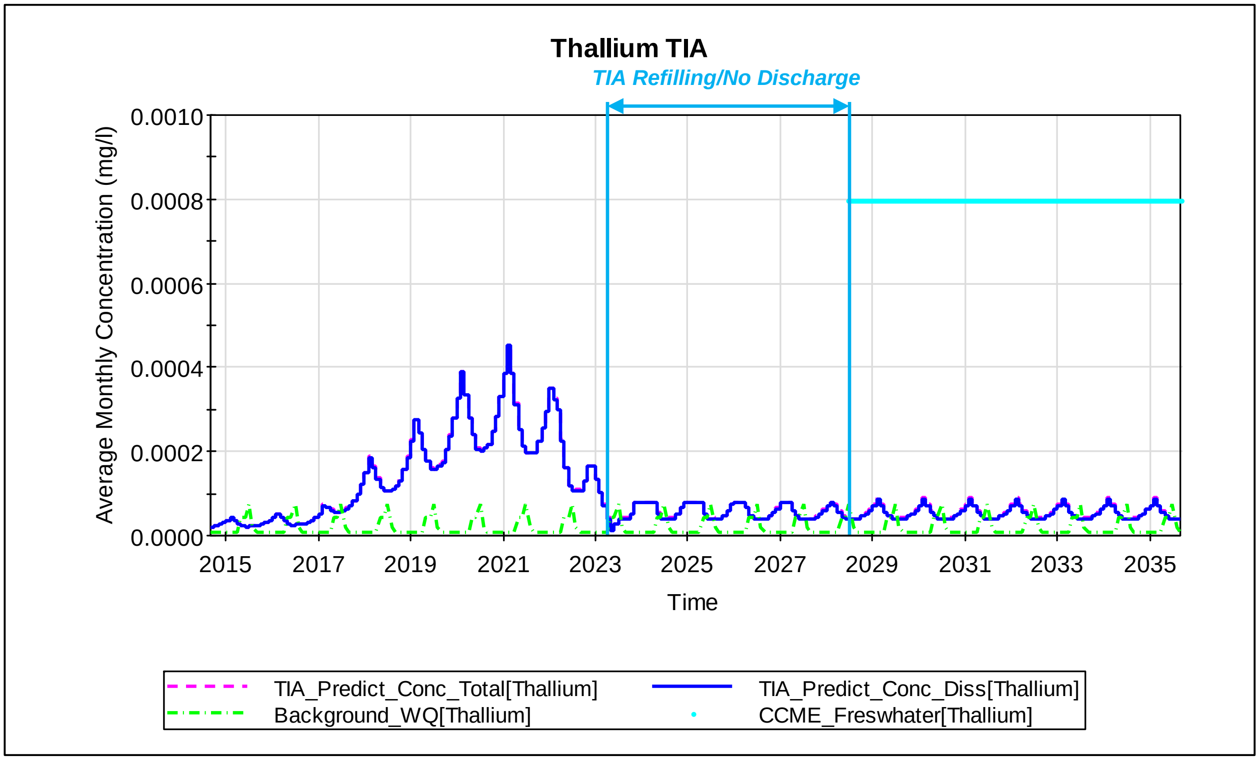

Figure B- 16: Predicted Water Quality in TIA – Thallium

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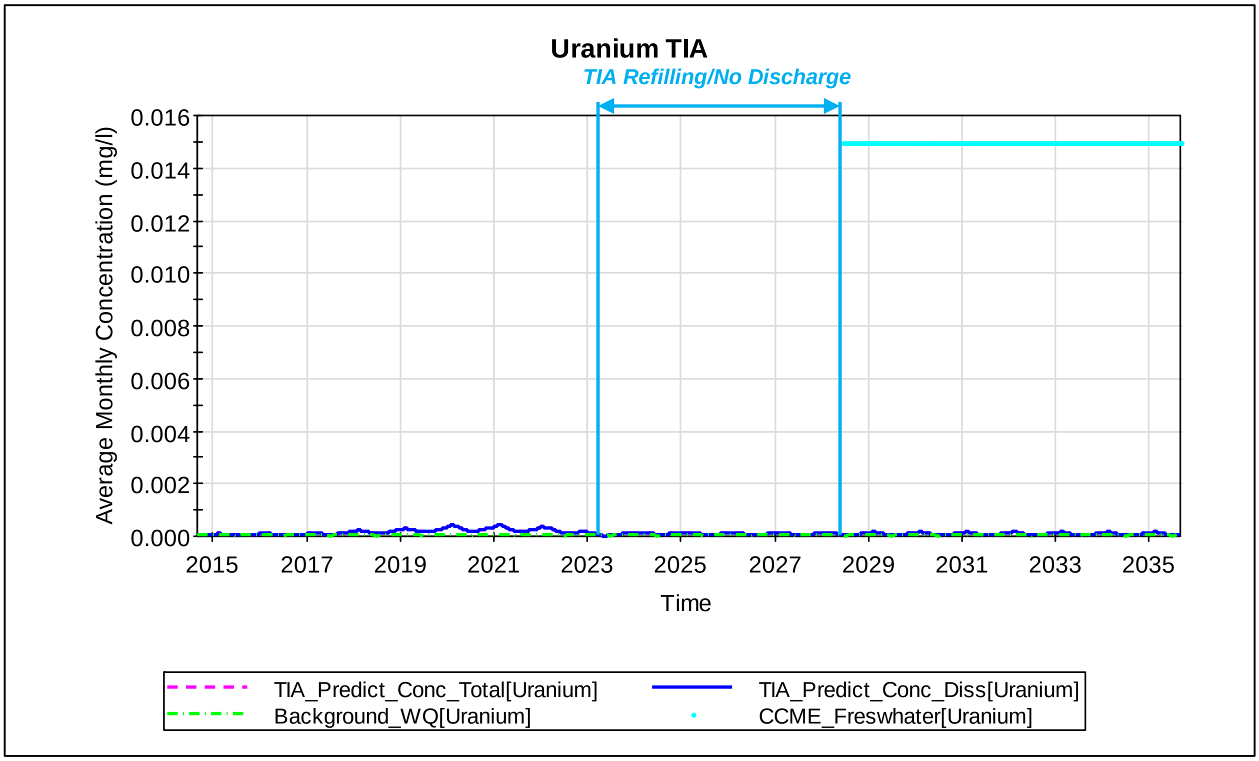

Figure B- 17: Predicted Water Quality in TIA – Uranium

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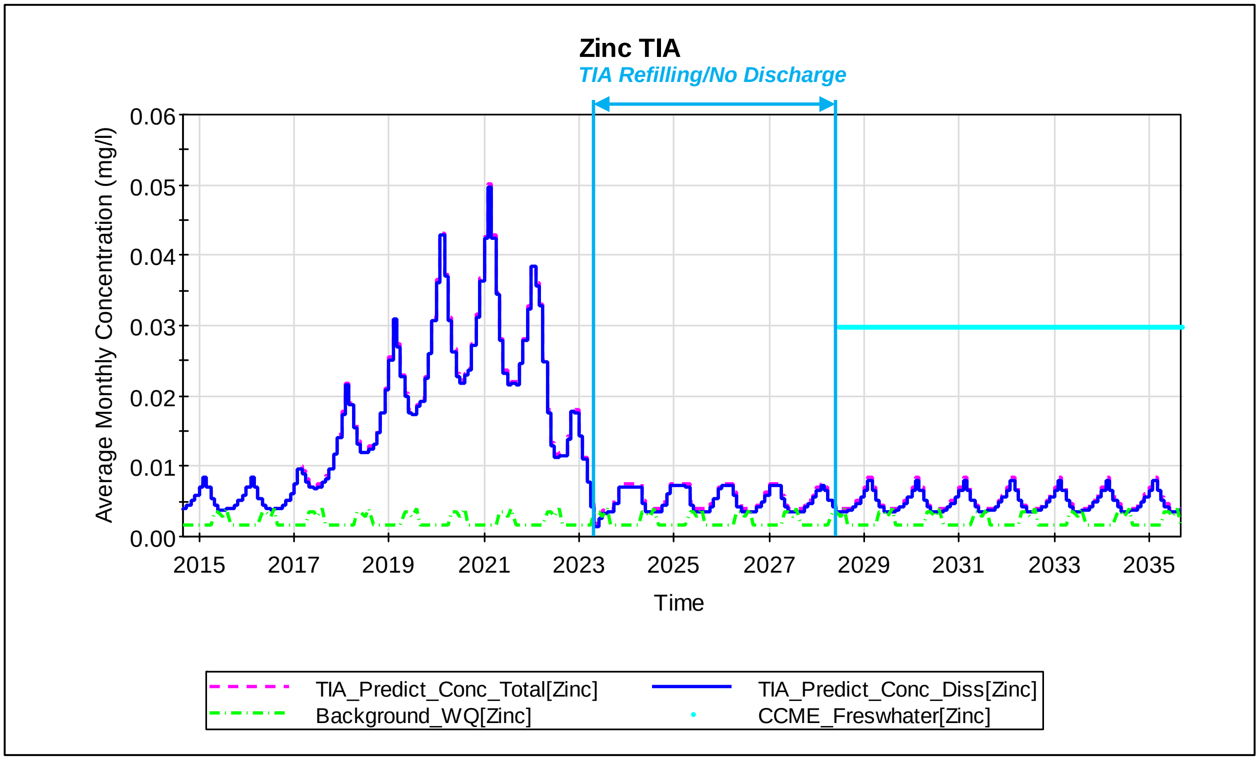

Figure B- 18: Predicted Water Quality in TIA – Zinc

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Water_License\700_Site_Wide_WQ_Model\Model\HopeBay_WLBalance_TypeA_Rev19_SPB_KPW.gsm

Package 6
Engineering and Design Documents

P6-11 Storage Pad U

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vancouver@srk.com
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Memo

To:	John Roberts	**Client:**	TMAC Resources
From:	Lowell Wade	**Project No:**	1CT022.002.200.1400
Cc:	Maritz Rykaart, SRK	**Date:**	May 29, 2015
Subject:	Doris North Project: Expanded Laydown Area (Pad U)		

1 Introduction

TMAC Resources is currently in the process of reviewing the laydown and storage requirements for the Doris North Project (the Project) in the Kitikmeot Region of Nunavut, Canada. The expanded mine life, from four to six years, will require additional laydown and storage, to support underground operations.

The expanded laydown area (Pad U) will provide the additional laydown and storage to support underground operations as well as temporary ore storage resulting from the expanded scope of the underground program, if required. The expanded laydown area (Pad U) would be initially constructed as a tiered general purpose pad and could be modified to accommodate up to 552,200 tonnes (306,800 m^3) of ore, as needed.

Contact water from the expanded laydown area (Pad U) will be collected in a new Sedimentation/Pollution Control Pond constructed immediately downstream of Pad U, to ensure proper water management.

This memo provides details of the pad and pond design, and should be read in conjunction with the attached set of Issued for Discussion (IFD) engineering drawings (Attachment 1).

2 Design Concept

The expanded laydown area (Pad U) will be initially constructed as a three tier general purpose pad, with the possibility of converting this area into a temporary ore stockpile if and when required. Initially the new Sedimentation/Pollution Control Pond will function as a Sedimentation Pond, only, with a non-woven geofabric lined containment berm. The design of the Sedimentation Control Pond allows it to be converted into a Pollution Control Pond, if ore is stockpiled on Pad U by the addition of a geomembrane liner. Drawing DN-WRE-01 of Attachment 1 shows the outlines of the proposed expanded laydown area (Pad U), while Drawing DN-WRE-02 shows the plan of the largest possible ore stockpile that could be built over the same footprint.

The ore stockpile design includes a ramp for haul truck access via the Secondary Road.

Two options for the potential ore stockpile are shown on Drawing DN-WRE-03. The three tiered Pad U could be left in place for a 442,000 tonne (245,000 m^3) ore stockpile or, alternatively, the expanded laydown (Pad U) could be regraded to a 1 m thick Run-of Quarry (ROQ) pad for a 552,000 tonne (306,000 m^3) ore stockpile.

3 Expanded Laydown and Storage Alternatives

TMAC considered three surface infrastructure alternatives for the expanded laydown area (Pad U) at the Project location:

- South Expanded Laydown Area / Waste Rock Pile: Construction of a large 1 m thick layer of geochemically acceptable material in the low lying area south of the existing Float Plane Dock Access Road. This 67,700 m^2 laydown area, with sufficient area for a 1 M tonne waste rock pile, would cover the wet swampy ground with several surface water drainage channels that have been identified as potential fish habitat. *This option was not selected because of the wet ground conditions and the potential fish habitat.*
- East Expanded Laydown Area / Waste Rock Pile: Construction of a large 1 m thick layer of geochemically acceptable material to the east of the Secondary Road and north of the Float Plane Dock Access Road (SRK, 2013). This 57,300 m^2 laydown area, with sufficient area for a 0.9 M tonne waste rock pile was considered when a permanent waste rock storage requirement was needed. *This option was not selected as all waste rock will now expected to be temporarily placed on Pad T and will be returned underground at the end of mining activities.*
- East Expanded Laydown Area / Ore Stockpile: A re-examination of surface infrastructure and material handling requirements resulted in the re-evaluation for the use of the East Expanded Laydown Area. This option would see the construction of a smaller tiered pad in the sloped area to the east of the Secondary Road and north of the Float Plane Dock Access Road. This area is in proximity to the underground operations, as well, the watershed is favourable in ensuring any runoff will be routed towards the new Sedimentation/Pollution Control Pond located directly downstream along the north side of the Float Plane Dock Access Road. This 31,300 m^2 laydown area could be utilized for general purpose laydown and/or accommodate up to 0.6 M tonnes of ore to be temporarily stockpiled. *This option is the preferred option.*

4 System Design

4.1 Expanded Laydown Area (Pad U)

4.1.1 Design Criteria

The design criteria for the tiered expanded laydown area are as follows:

- No cut is allowed, except in designated rock quarries;
- Minimum 1 m fill thickness must be maintained;
- Maximum fill thickness should be less than 6 m when possible;
- Safety barricades (oversize ROQ boulders larger than 1 m diameter, Jersey Barriers, or berms) are to be placed along the crest where fill thicknesses are greater than 3 m.
- 1.5H:1.0V slopes are utilized with fill thickness less than 2 m;
- 2.0H:1.0V slopes are utilized with fill thickness greater than 2 m;
- Ramp grades shall not exceed 10%;
- Ramps shall have a minimum width of 8 m and a turning radius of 12 m;
- The maximum particle size for ROQ is 500 mm for fill thickness of 850 mm, and 900 mm for fill thickness exceeding 850 mm. All material shall be free from organic matter, soil, snow and ice; and
- Each tier shall be constructed with a general drainage gradient of 0.5% directed towards the Sedimentation/Pollution Control Pond.

4.1.2 Design

The ROQ fill for the pad will be placed and shaped such that three benches, comprising the tiered pad, will be created at the following elevations: 34.0, 39.0, and 43.5 m above sea level. Access to the benches will be created by ramps from the Secondary Road onto the pads at the appropriate elevation. Alternatively, the Expanded Laydown Area (Pad U) could be regraded to a 1 m thick ROQ pad that follows the original topography. The Expanded Laydown Area (Pad U) has a base area of 31,300 m^2.

4.2 Temporary Ore Stockpile

4.2.1 Design Criteria

The design criteria for the ore stockpile are as follows:

- Ramp grades shall not exceed 7%.
- Ramps shall have a minimum width of 8 m and turning radius of 12 m.

- The overall slopes of the ore stockpile should not exceed 2.5H:1V for long-term storage.
- Contact water will be directed to the Sedimentation/Pollution Control Pond.
- A minimum 1 m wide buffer zone will be maintained around the ore stockpile through appropriate offsets and through construction of access roads and berms (if necessary) around the extents of the ore stockpile.

4.2.2 Design

The conceptual ore stockpile design includes construction of a 5 m high intermediate benches for an overall slope angle of 2.5H:1V. Intermediate bench side slopes are at angle of repose.

Ramps have been designed to take advantage of the sloping topography and connect to the Secondary Road. Around the stockpile a 1m offset has been designed. This 1 m offset assists in routing contact water towards the Sedimentation/Pollution Control Pond and also serves as a buffer zone.

A stability analysis was carried out using the maximum amount of ore which could be stockpiled on Pad U and is provided in Attachment 2. If ore is temporarily stored on Pad U, TMAC should implement measures to ensure a 2 m minimum setback distance, from the operating crest of the ore stockpile, is maintained for the haul trucks.

4.3 Sedimentation/Pollution Control Pond

4.3.1 Design Criteria

The Sedimentation/Pollution Control Pond has the capacity to contain contact water from the overall drainage area and 25% of annual snow coverage combined with a 100-year, 24-hour storm event which all together is the equivalent of 2,700 m^3 of water.

4.3.2 Design

This new water management structure will be constructed downstream of the expanded laydown area (Pad U) and will function as a Sedimentation Control Pond, while Pad U is utilized for general purpose laydown. The Sedimentation Control Pond can be converted into a Pollution Control Pond, if the need arises to stockpile ore on Pad U. The new Sedimentation/Pollution Control Pond will capture contact water from the tiered rock fill pads and the area upstream of Pad U. The final height of the Sedimentation/Pollution Control Pond will be 2 meters above the existing elevation of the Water Supply Line Intake Pad (at the East end of the Float Plane Dock Access Road) near Doris Lake. To facilitate this berm construction, a portion of the Float Plane Dock Access Road will have to be raised.

The Sedimentation Control Pond containment berm will be constructed of ROQ and the upstream slope will be lined with non-woven geofabric. If converted to a Pollution Control Pond, the upstream slope of the containment berm will have an additional geomembrane liner keyed into the original ground by a small 1 m deep key trench. The geomembrane liner will be placed on a levelling course of 20 mm minus (3/4 inch) crushed rock, and will be protected against mechanical puncture by a non-woven geotextile and by a 0.3 m thick layer of 20 mm minus (3/4 inch) crushed rock.

Two 250 mm diameter corrugated steel culverts will be installed through the Float Plane Dock Access Road with the invert elevation set at the Sedimentation/Pollution Control Pond's full supply level of 28.7 m. The purpose of the Spillway Culverts is to prevent water, retained by the Sedimentation/Pollution Control Pond from over-topping the Float Plane Dock Access Road in the event of an emergency were water within the Sedimentation/Pollution Control Pond cannot be managed. A Rip Rap Apron is located at the outlet of the Spillway Culverts, to prevent erosion of the tundra, should any water be discharged through the culverts. Any water discharged through the Spillway Culverts will flow towards Doris Lake. The Spillway Culverts are approximately 71 m from the end of the Float Plane Dock Access Road at Doris Lake.

A geomembrane liner will only be install on the upstream face of the Float Plane Dock Access Road if the Sedimentation Control Pond is converted to a Pollution Control Pond. The bottom surface of the Sedimentation/Pollution Control Pond will be unlined.

4.4 Survey Data

The design of Expanded Laydown Area (Pad U) is based on topographic contour maps produced from 2008 aerial photography supplied by Hope Bay Mining Limited (HBML). No detailed ground surveys have been completed.

4.5 Foundation Conditions

Comprehensive geotechnical investigations have been carried out at the Hope Bay Site (SRK 2009). This information confirms that the area lies within the zone of continuous permafrost, with the permafrost being up to 550 m deep. Permafrost temperature at the surface is about -8ºC and the active layer is generally less than 1 m thick. Laboratory and in-situ tests on disturbed and undisturbed samples indicate that the overburden soils are predominantly comprised of marine silts and clays, and the pore-water in these soils has high salinity, depressing the freezing point to -2ºC. The ice-rich overburden soils are typically between 5 and 20 m deep, before encountering competent bedrock, predominantly basalt. Bedrock is frequently exposed, rising columnar 5 to 100 m above the surrounding landscape.

Thermal modelling has determined that a 1 m minimum of rock fill cover would be required over the tundra to preserve the permafrost under the infrastructure pads (SRK 2006). Since all pads are designed to have a flat surface with minor grading for drainage, the ROQ fill thickness reaches up to 7 m at places due to underlying topography.

The geotechnical design parameters for Hope Bay have been summarized in SRK (2011a).

5 Construction Methodology

The expanded laydown area (Pad U) will be constructed with ROQ material excavated from the permitted and approved Quarry #2. SRK (2007) discusses the complete details pertaining to geochemical characterization of these rock quarries confirming their suitability for use in construction. The management and monitoring of quarry development for the construction of the infrastructure pads and access roads is discussed in SRK (2014).

Surface grade material for the expanded laydown area (Pad U) will be from Quarry #2 and the crusher located in Quarry #2. Complete material quantities are included in Attachment 1.

The Expanded Laydown Area (Pad U) and temporary ore stockpile will be constructed in accordance to SRK's Technical Specifications (SRK 2011b).

6 References

SRK Consulting (Canada) Inc., 2006. Doris North Project – Thermal modeling to support design thickness for granular pads. Technical Memorandum, Prepared for Miramar Hope Bay Limited, Project Number: 1CM014.008, August 20, 2006.

SRK Consulting (Canada) Inc., 2007. Geochemical Characterization of Quarry Materials, Doris North Project. Hope Bay, Nunavut, Canada (Revised March 2007). Report Prepared for Miramar Hope Bay Limited, Project Number 1CM014.008.241. March 2007.

SRK Consulting (Canada) Inc., 2009. Hope Bay Gold Project: Stage 2 Overburden Characterization Report, Prepared for Hope Bay Mining Limited, Project Number: 1CH008.002, September 2009.

SRK Consulting (Canada) Inc., 2011a. Hope Bay Project – Geotechnical Design Parameters. Revision 0. Report Prepared for Hope Bay Mining Limited. Project Number: 1CH008.033.216. October 2011.

SRK Consulting (Canada) Inc., 2011b. Technical Specifications Earthworks and Geotechnical Engineering. Hope Bay Project, Nunavut, Canada. Revision G – Issued for Construction. Report Prepared for Hope Bay Mining Ltd. Project Number: 1CH008.027. March 2011.

SRK Consulting (Canada) Inc., 2013. Design Brief: Doris North Project Expanded Waste Rock Storage Pad (Pad U). Technical Memorandum prepared for TMAC Resources Inc. Project Number: 1CT022.000. November 2013.

SRK Consulting (Canada) Inc., 2014. Hope Bay Project Quarry Management and Monitoring Plan – Revision 02. Report prepared for TMAC Resources Inc. Project Number: 1CT022.001. December 2014.

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Attachment 1

Engineering Drawings for the Expanded Laydown Area (Pad U)

Engineering Drawings for the Pad U Expanded Laydown Area Doris North Project, Nunavut, Canada

ACTIVE DRAWING STATUS

DWG NUMBER	DRAWING TITLE	REVISION	DATE	STATUS
DN-WRE-00	Engineering Drawings for the Pad U Expanded Laydown Area, Doris North Project, Nunavut, Canada	A	May 29, 2015	Issued for Discussion
DN-WRE-01	Pad U - General Arrangement	A	May 29, 2015	Issued for Discussion
DN-WRE-02	Temporary Ore Stockpile - General Arrangement	A	May 29, 2015	Issued for Discussion
DN-WRE-03	Sections and Details 1of 2	A	May 29, 2015	Issued for Discussion
DN-WRE-04	Sections and Details 2 of 2	A	May 29, 2015	Issued for Discussion

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PROJECT NO: 1CT022.002.200.1400
Revision A
May 29, 2015
Drawing DN-WRE-00

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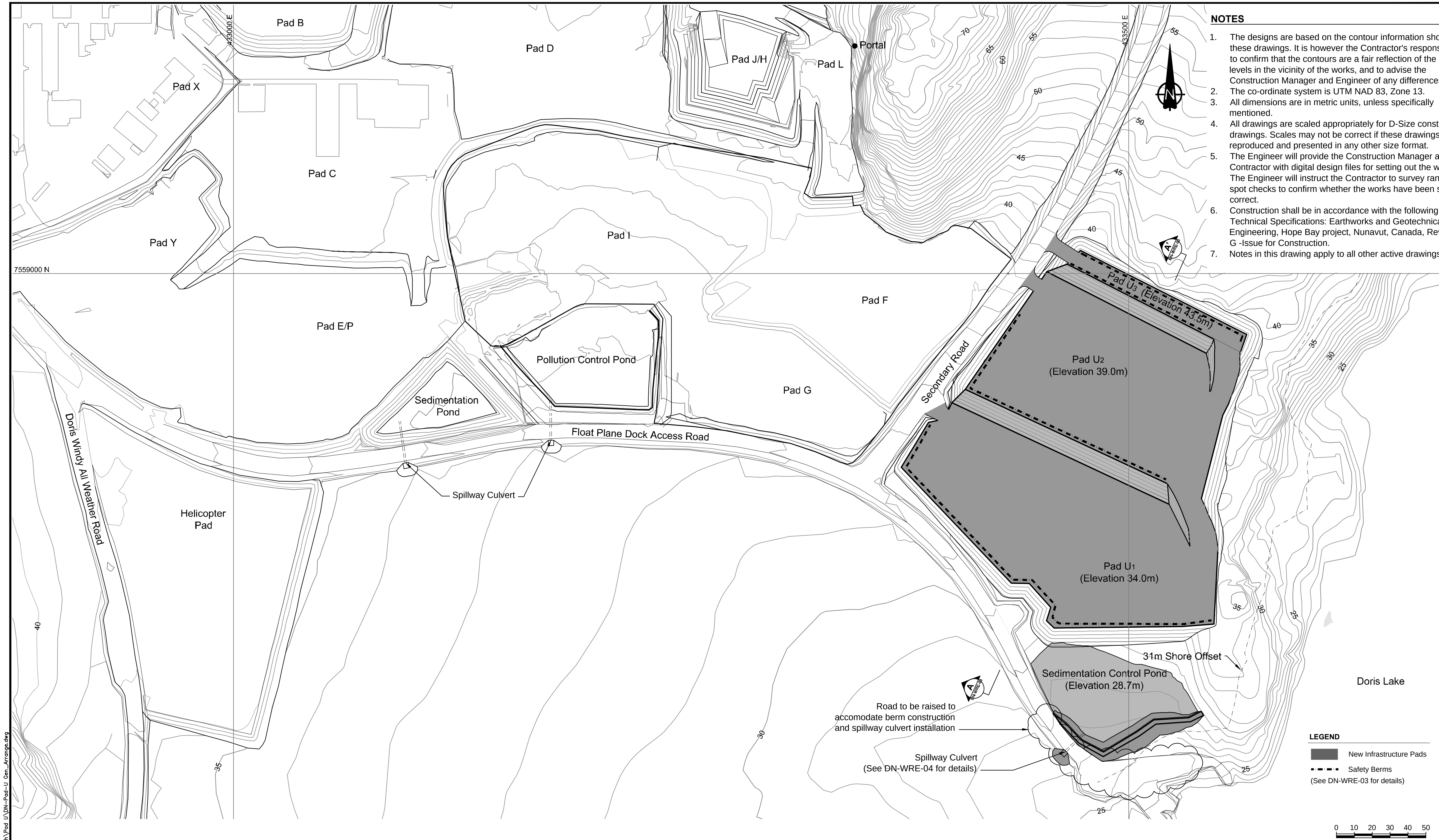

NOTES

1. The designs are based on the contour information shown on these drawings. It is however the Contractor's responsibility to confirm that the contours are a fair reflection of the ground levels in the vicinity of the works, and to advise the Construction Manager and Engineer of any differences.
2. The co-ordinate system is UTM NAD 83, Zone 13.
3. All dimensions are in metric units, unless specifically mentioned.
4. All drawings are scaled appropriately for D-Size construction drawings. Scales may not be correct if these drawings are reproduced and presented in any other size format.
5. The Engineer will provide the Construction Manager and Contractor with digital design files for setting out the works. The Engineer will instruct the Contractor to survey random spot checks to confirm whether the works have been set out correct.
6. Construction shall be in accordance with the following Technical Specifications: Earthworks and Geotechnical Engineering, Hope Bay project, Nunavut, Canada, Revision G -Issue for Construction.
7. Notes in this drawing apply to all other active drawings.

LEGEND

- New Infrastructure Pads
- Safety Berms

(See DN-WRE-03 for details)

DRAWING NO.	DRAWING TITLE	DRAWING NO.	DRAWING TITLE	NO.	DESCRIPTION	CHK'D	APP'D	DATE
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				A	ISSUED FOR DISCUSSION	JBK	EMR	29May15
REFERENCE DRAWINGS				REVISIONS				

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DESIGN: IM/JBK	DRAWN: BFM/LR	REVIEWED: LW
CHECKED: JBK	APPROVED: EMR	DATE: May 29, 2015

FILE NAME: DN–Pad–U Gen_Arrange.dwg

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HOPE BAY PROJECT

SRK JOB NO.: 1CH022.002.200.1400

Doris North

DRAWING TITLE:

Pad U
General Arrangement

DRAWING NO.	SHEET	REVISION NO.
DN-WRE-01	2 OF 5	A

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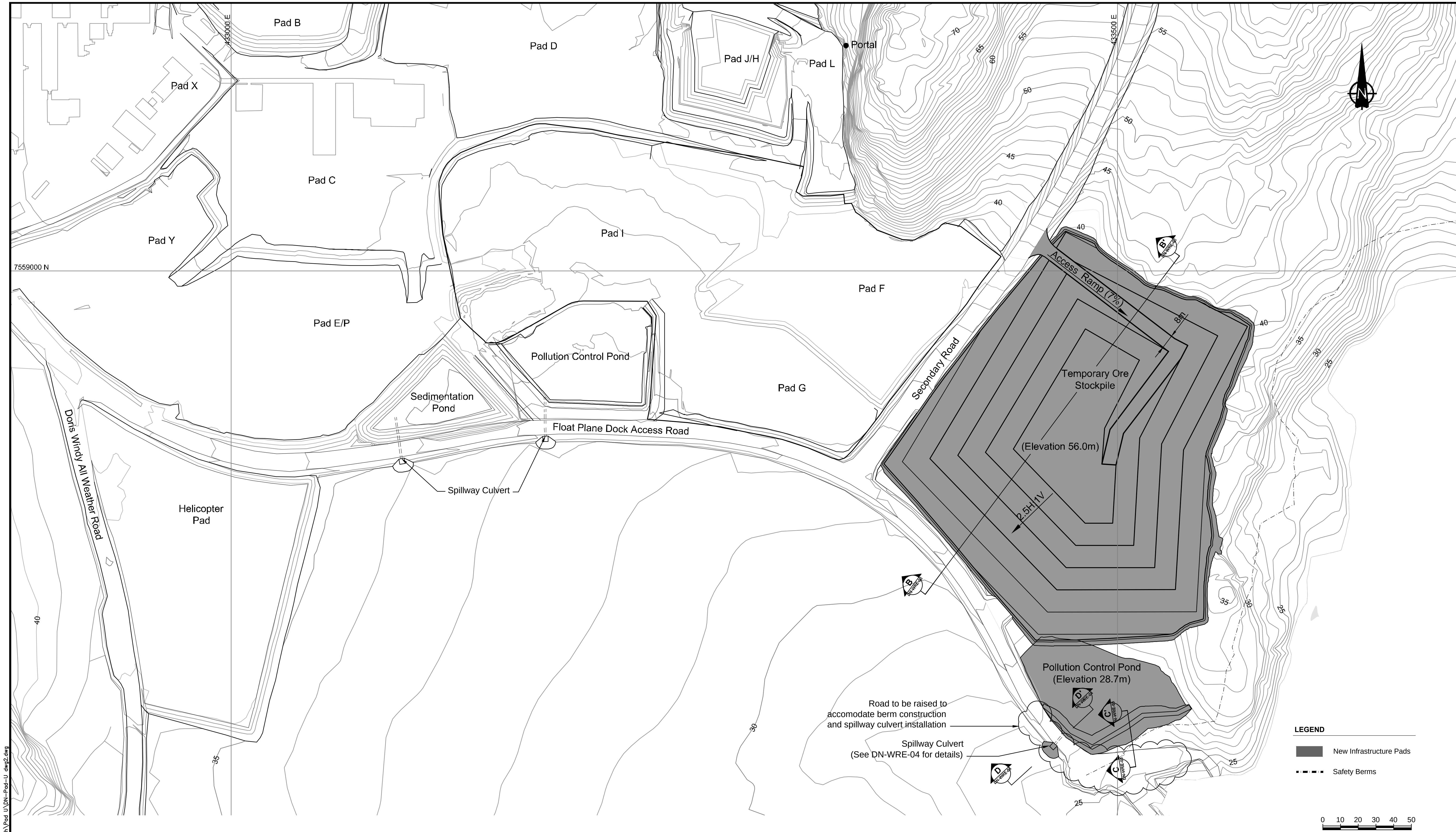

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				A	ISSUED FOR DISCUSSION	JBK	EMR	29May15
REFERENCE DRAWINGS				REVISIONS				

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CHECKED: JBK	APPROVED: EMR	DATE: May 29, 2015
FILE NAME: DN–Pad–U dwg2.dwg		

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HOPE BAY PROJECT

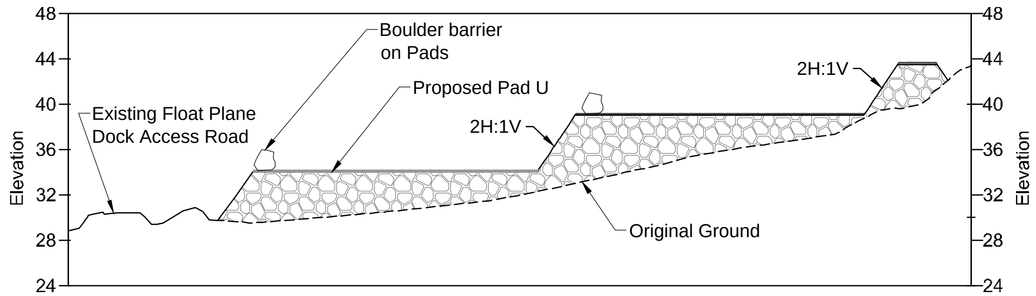
SRK JOB NO.: 1CH022.002.200.1400

Doris North

DRAWING TITLE:

Temporary Ore Stockpile
General Arrangement

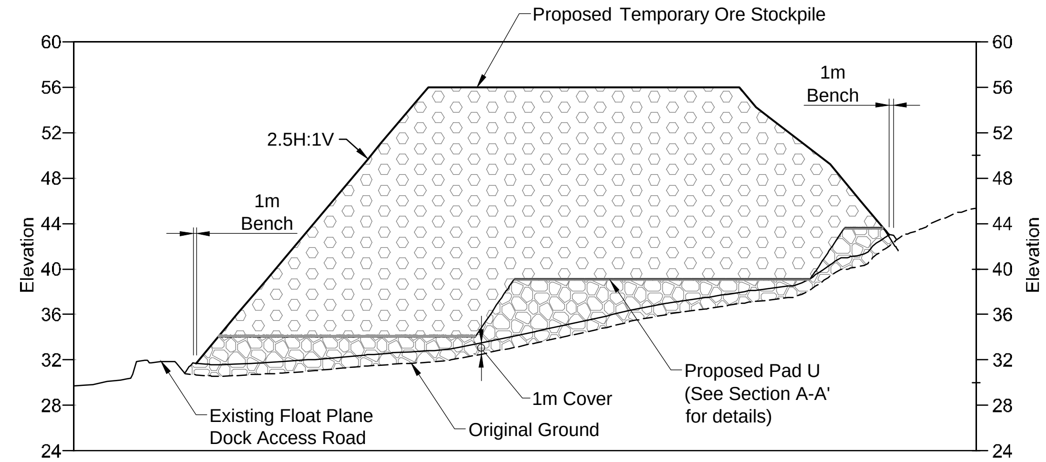
DRAWING NO.	SHEET	REVISION NO.
DN-WRE-02	3 OF 5	A



A DN-WRE-01 **SECTION A - A'**

Horizontal Scale in Meters (0, 10, 20, 30, 40, 50)

3X Vertical Exaggeration Scale in Meters (0, 3.33, 6.67, 10, 13.33, 16.67)



B1 DN-WRE-02 **OPTION 1 - LEAVE PAD U IN PLACE**
SECTION B1 - B1'

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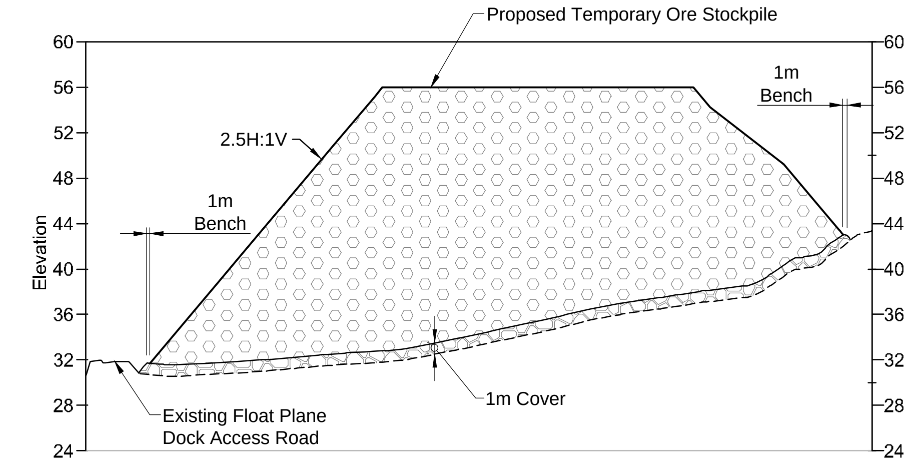

B2 DN-WRE-02 **OPTION 2 - REGRADE PAD U**
SECTION B - B'

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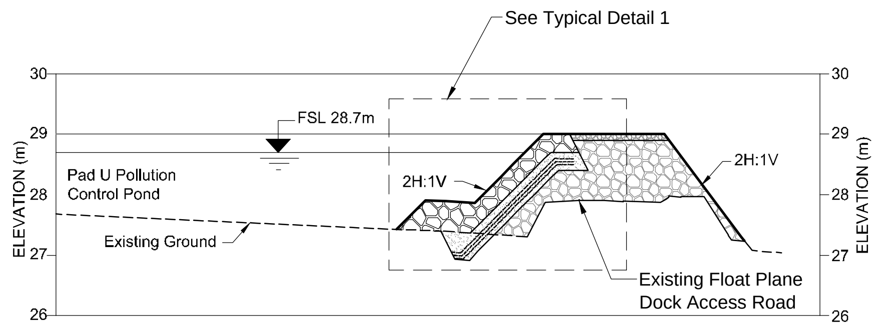


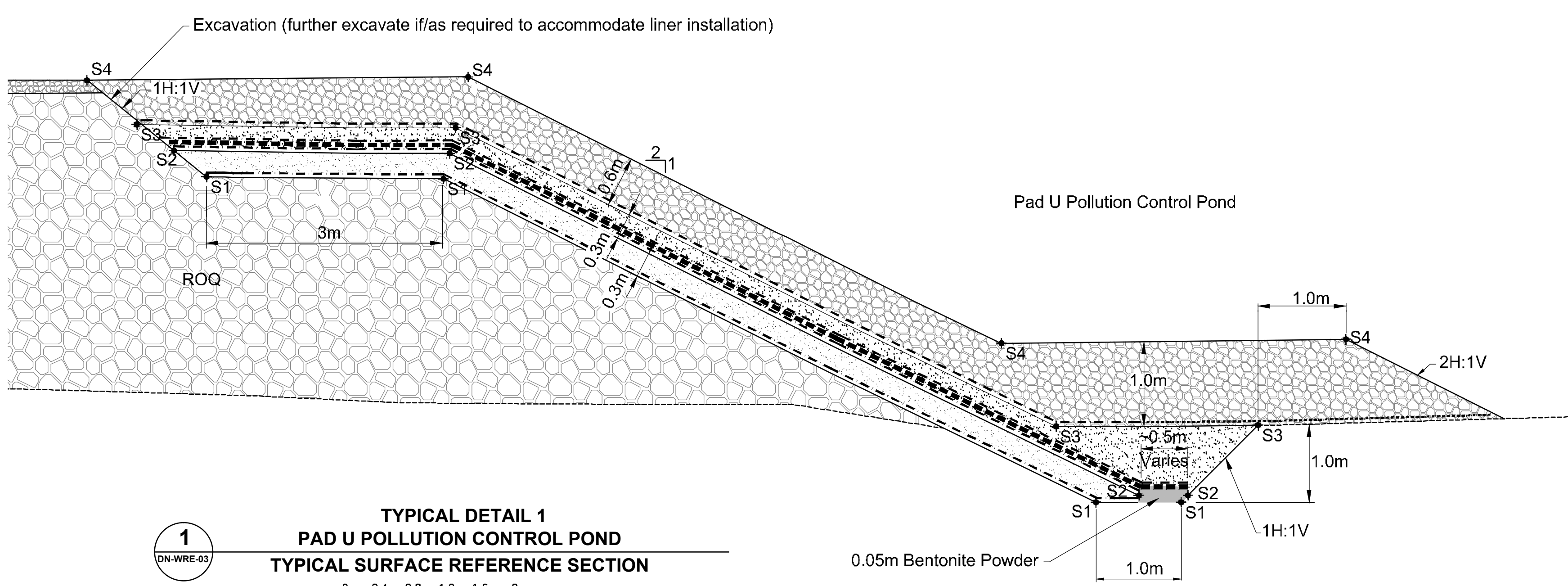
C DN-WRE-02 **SECTION C - C'**

Horizontal Scale in Meters (0, 2.5, 5, 7.5, 10, 12.5)

4X Vertical Exaggeration Scale in Meters (0, 0.625, 1.25, 1.875, 2.5, 3.125)

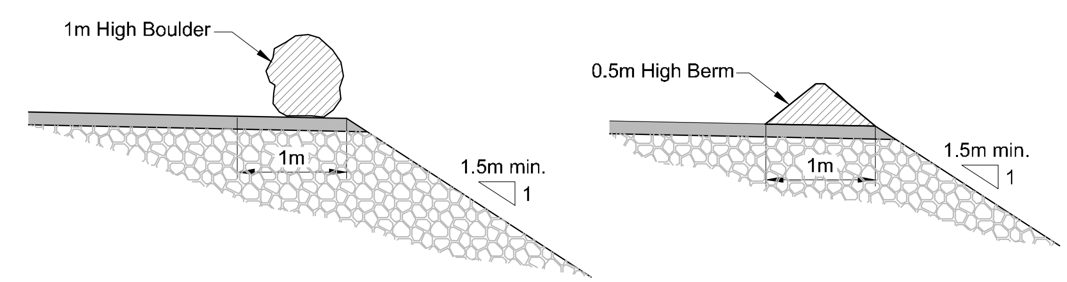
Materials and Quantities

Item	Quantity / Area / Volume		Description
Run of Quarry	Pad U (1m cover over OG) Pad U (above 1m cover) Pollution Pond (to 29m crest elevation) Total	31,300 m³ 57,400 m³ 1,250 m³ 89,950 m³	Approximate in-place neat-line volumes (no allowance has been made for losses and/or tundra embedment) Volumes for ROQ and Surfacing Material derived by Civil 3D (2011)
Surfacing Material	Pad U Total	3,650 m³ 3,650 m³	Side slopes 2H:1V Unless otherwise noted. Lined system / road raise volumes not included (modeling to completed).
Temporary Ore Stockpile	Option 1 (Pad U left as is) Option 2 (Pad U Regraded)	~ 245,750 m³ ~ 306,800 m³	Ore storage estimates based on Gemcom gems, volumes, hard calculations and Civil 3D volumes.



1 DN-WRE-03 **TYPICAL DETAIL 1**
PAD U POLLUTION CONTROL POND
TYPICAL SURFACE REFERENCE SECTION

Scale in Meters (0, 0.4, 0.8, 1.2, 1.6, 2)



2 DN-WRE-01 **DETAIL 2**
TYPICAL BERM BARRIER OPTIONS
NOT TO SCALE

LEGEND

- ¾" Crushed Material
- 1 ¼" Crushed Material
- Run of Quarry Material
- Rip Rap
- Existing ground surface
- Textured 60 mil HDPE Liner
- 12 oz. Non-woven Geotextile

DRAWING NO.	DRAWING TITLE	DRAWING NO.	DRAWING TITLE	NO.	DESCRIPTION	CHK'D	APP'D	DATE
				A	ISSUED FOR DISCUSSION	JBK	EMR	29May15
REFERENCE DRAWINGS				REVISIONS				

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DESIGN: JBK | DRAWN: BFM/LR | REVIEWED: LW
CHECKED: JBK | APPROVED: EMR | DATE: May 29, 2015
FILE NAME: DN-Pad-U Section-Details.dwg

TMAC RESOURCES

HOPE BAY PROJECT

SRK JOB NO.: 1CH022.002.200.1400

Doris North

DRAWING TITLE: Sections and Details 1 of 2

DRAWING NO.: DN-WRE-03 | SHEET 4 OF 5 | REVISION NO. A

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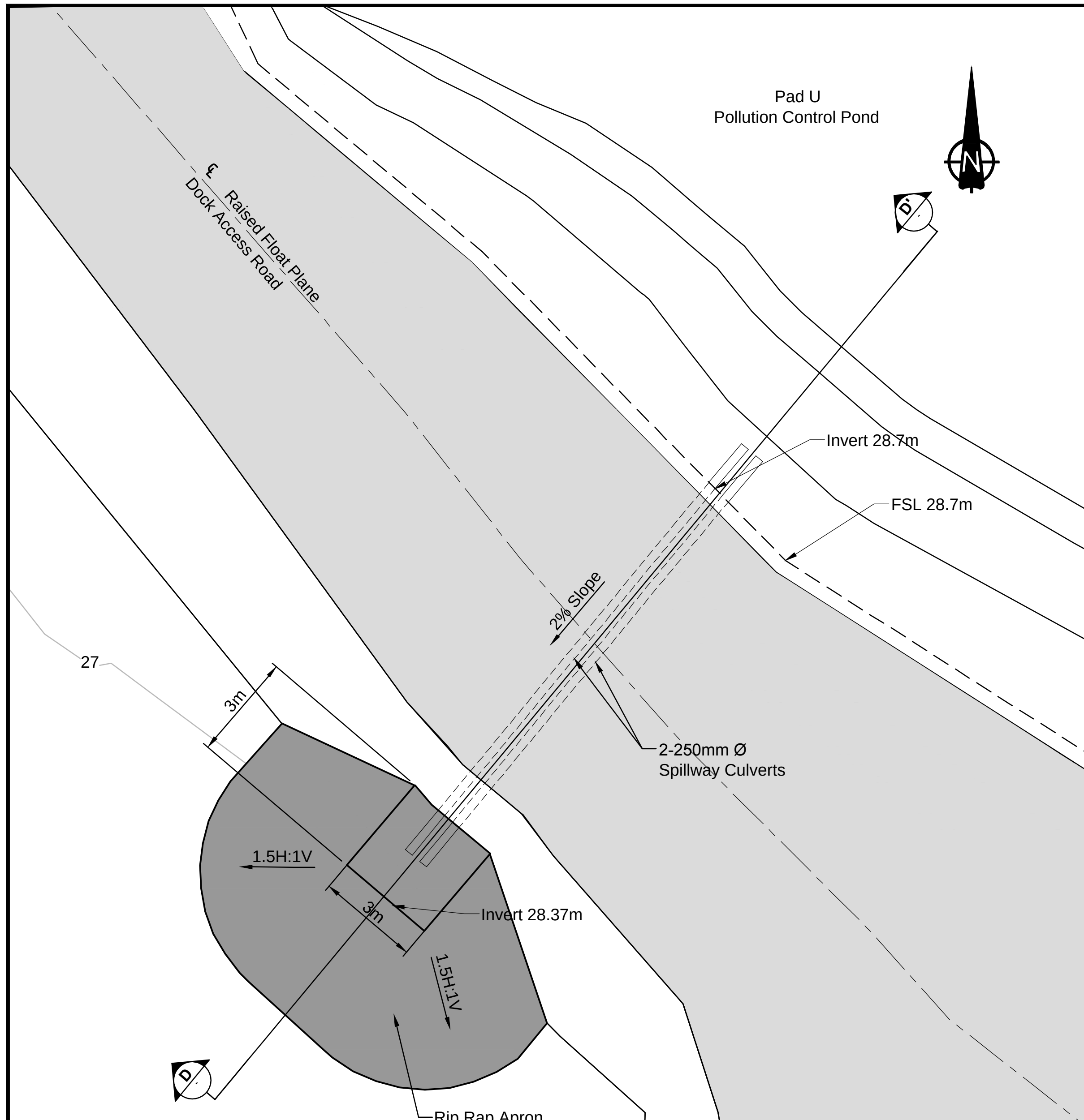
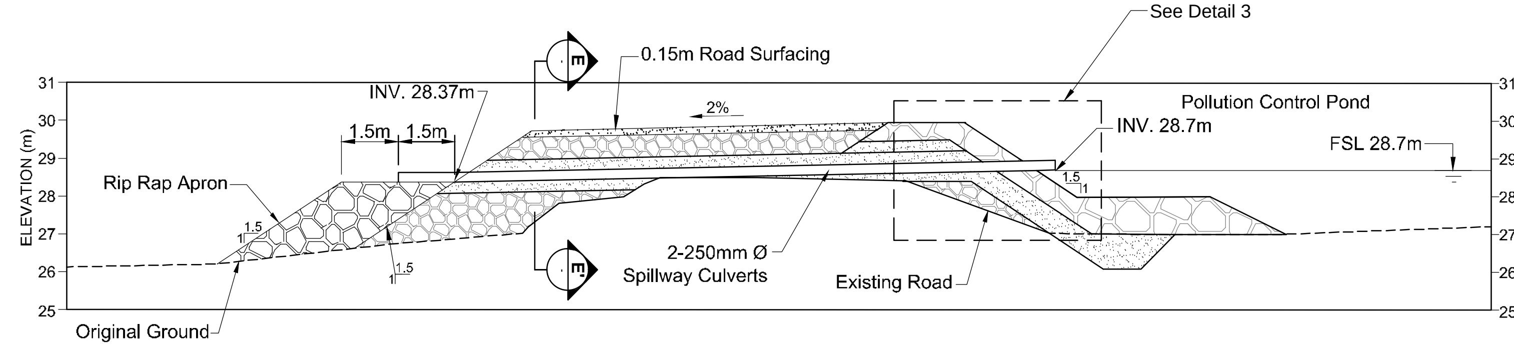
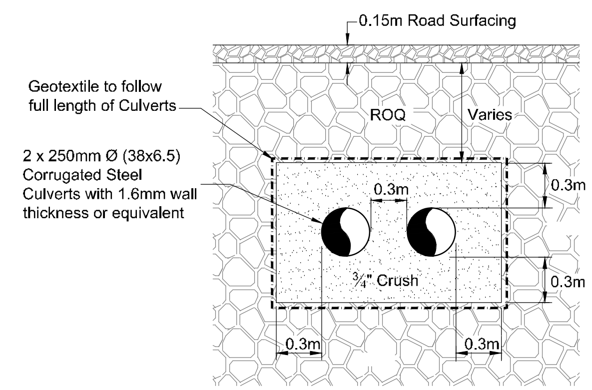


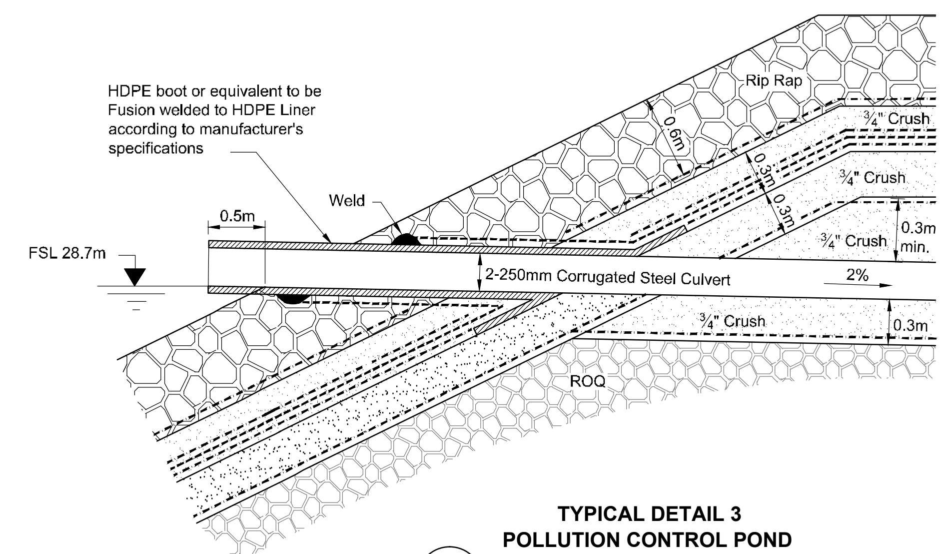
3 (DN-WRE-02)
DETAIL 3 - POLLUTION CONTROL POND SPILLWAY CULVERT
NOT TO SCALE



D (DN-WRE-02)
SECTION D - D'
0 1 2 3 4 5
Scale in Meters



E
SECTION E-E'
SPILLWAY CULVERT SECTION
NOT TO SCALE



3
TYPICAL DETAIL 3
POLLUTION CONTROL POND
PIPE PENETRATION
NOT TO SCALE

LEGEND

¾" Crushed Material	Existing ground surface
1 ¼" Crushed Material	Textured 60 mil HDPE Liner
Run of Quarry Material	12 oz. Non-woven Geotextile
Rip Rap	

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REVISIONS

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CHECKED: JBK	APPROVED: EMR	DATE: May 29, 2015

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TMAC RESOURCES

HOPE BAY PROJECT

SRK JOB NO.: 1CH022.002.200.1400

Doris North

DRAWING TITLE: Sections and Details 2 of 2

DRAWING NO.: DN-WRE-04 | SHEET 5 OF 5 | REVISION NO. A

Attachment 2

Doris North Pad U Ore Stockpile Stability Analysis

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vancouver@srk.com
www.srk.com

Memo

To:	Project File	**Client:**	TMAC Resources Inc.
From:	Murray McGregor, Lowell Wade	**Project No:**	1CT022.002.200.1400
Cc:		**Date:**	May 29, 2015
Subject:	Doris North Pad U Ore Stockpile Stability Analysis		

1 Introduction

This memo presents the results of a slope stability analyses for a temporary ore stockpile on top of Pad U in Doris Camp. The stability analysis was carried out using the Morgenstern-Price method as applied in SLOPE/W. The model is set up using three materials: marine silt and clay, run of quarry (ROQ) foundation pad, and run of mine rock. The typical active layer thickness for uncovered marine silt and clay is about 1 m. It will be assumed the ROQ foundation pad protects the permafrost of the silts and clays that it sits atop. The ROQ foundation pad is assumed to be unfrozen since it is the thickness of the active layer. The temporary ore stockpile is assumed to be unfrozen because the rate it will be dumped will likely surpass the freezeback of the stockpile.

Table 1 summarizes the material properties used in the analysis taken from the previous Doris Creek Bridge Abutments stability analysis (SRK, 2010).

Table 1: Material Properties

		ROQ Foundation Pad	Run of Mine Rock	Marine Silt and Clay Foundation
Saturated Unit Weight (kN/m^3)		20	20	18.5
Degree of Saturation		30%	30%	85%
Porosity		0.3	0.3	0.52
Volumetric Water Content		0.09	0.09	0.442
Unfrozen	Apparent Cohesion c' (kPa)	0	0	0
	Friction angle, φ^0	40	39	30
Frozen	Apparent Cohesion c' (kPa)	5	n/a	112
	Friction angle, φ^0	40	n/a	26

2 Method

The analysis is carried out using a critical cross-section of the temporary ore stockpile, taking into consideration the foundation slope and ultimate pile height. This typical section, complete with assigned material zones, is presented in Figure 1.

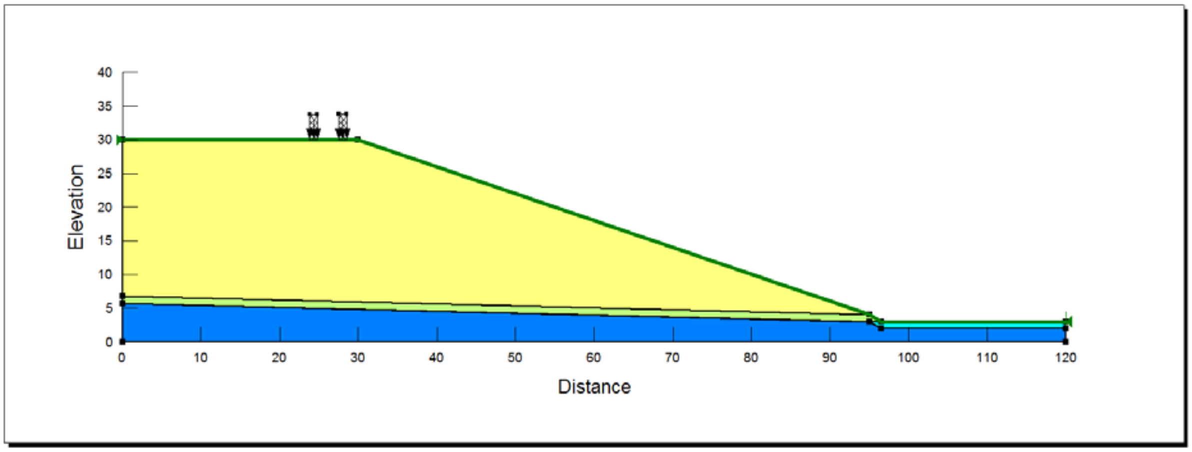


Figure 1: Critical Section of the ore stockpile used for the slope stability analysis.

The critical slip surface was evaluated under two conditions; for a free standing ore stockpile without consideration of haul truck wheel loads at the crest, and with wheel loads. A sample calculation for haul truck wheel loading is included as Attachment 1. Both rotational slip surfaces and blocks failure modes were considered in each case.

The Project site is located in a stable seismic zone of Canada with low peak ground accelerations. Because of this, the stability analysis under seismic conditions was not assessed.

Graphic results for the critical slip surfaces of each analysis are presented in Attachment 2. In each case where haul truck wheel loads are included, a load induced failure occurs near the crest of the pile. For the case where no wheel loads are considered, the critical slip surface appears as a shallow skin failure along the outer edge of the pile.

Table 2: Calculated Factors of Safety from SLOPE/W Models

	Calculation Method	Numerical Method	Factor of Safety	Critical Slip Surface Location
Haul Truck Wheel Loads Considered	Entrance and Exit	Morgenstern-Price	1.189	Load induced failure occurs near the crest of the stockpile
		Bishop	1.124	
	Block Specified	Morgenstern-Price	1.058	
		Bishop	1.370	
Free Standing Ore Stockpile	Entrance and Exit	Morgenstern-Price	2.029	Shallow skin failure along the outer edge of the stockpile
		Bishop	2.029	
	Block Specified	Morgenstern-Price	2.033	
		Bishop	2.058	

A stability rating for the temporary ore stockpile was completed in accordance with the guidelines set by the British Columbia Mine Waste Rock Pile Research Committee (1991). For frozen foundation conditions the stability rating of the temporary ore stockpile is 200 (Class I Stability), while for unfrozen foundation conditions the stability rating increases to 400 (Class II Stability) (Attachment 3). The level of stability analysis, presented in this memo, is in accordance with the stability rating as assessed by the British Columbia Mine Waste Rock Pile Research Committee (1991).

Measures should be implemented to ensure proper setback distances for haul trucks from the operating crest of the ore stockpile.

3 References

SRK Consulting (Canada) Inc. 2010. Secondary Road Bridge Abutment Slope Stability Analysis. Prepared for Hope Bay Mining Limited. Project Number: 1CH008.033, May 25, 2010.

British Columbia Mine Waste Rock Pile Research Committee, 1991. Mined Rock and Overburden Piles Investigation and Design Manual Interim Guidelines.

Attachment 1
Sample Calculation of Haul Truck Wheel Loading

SRK Consulting
Engineers and Scientists

Project No. 1CH008.027 Site Vancouver
Prepared by Murray McGregor Date Nov. 23, 2010
Approved by ________ Date ________

Subject Vehicle Loading on Waste Rock Piles Calculation Sheet 1 of 1

From Manufacturer Website:

CAT 773 Gross Opperating Weight: 222,000 lbs = 100,698 Kg

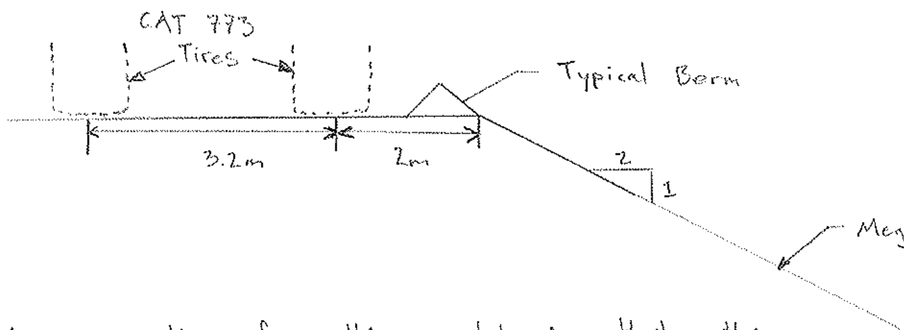
Load Weight Distributions: Front 35% Rear 65%

Rear Tire Load: $(100{,}698\ \text{kg})(65\%)\left(\frac{1\ \text{tire}}{\text{Axle}\ (2)}\right)\left(\frac{9.81\ \text{N}}{\text{kg}}\right) = 321\ \text{KN}$

Centerline Front Tire Width: 10.5 ft ≅ 3.2 m

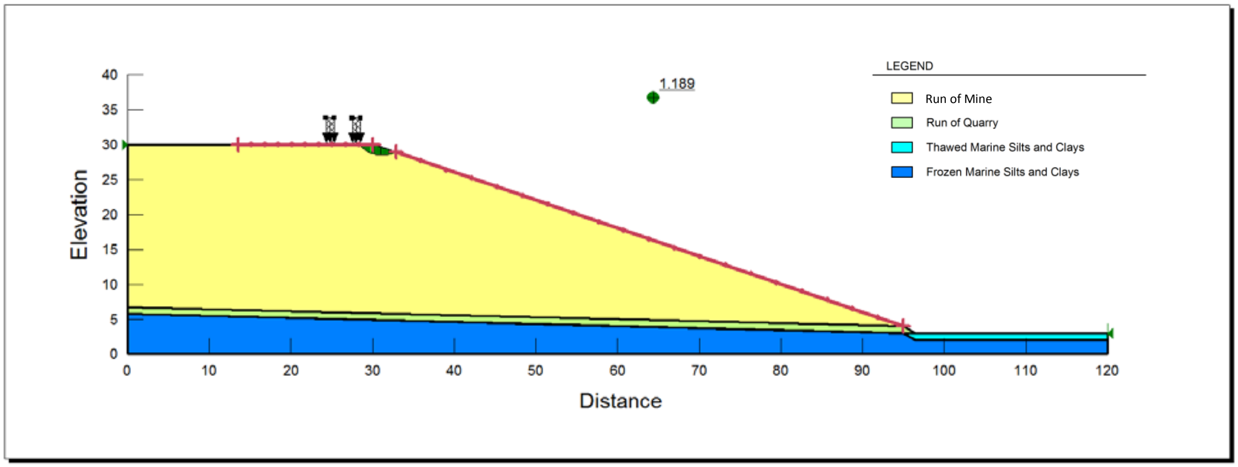
Offset from Slope Edge: (Berm width) + (½ tire width) ≅ 2.0 m

Typical Berm Width = 1 meter minimum

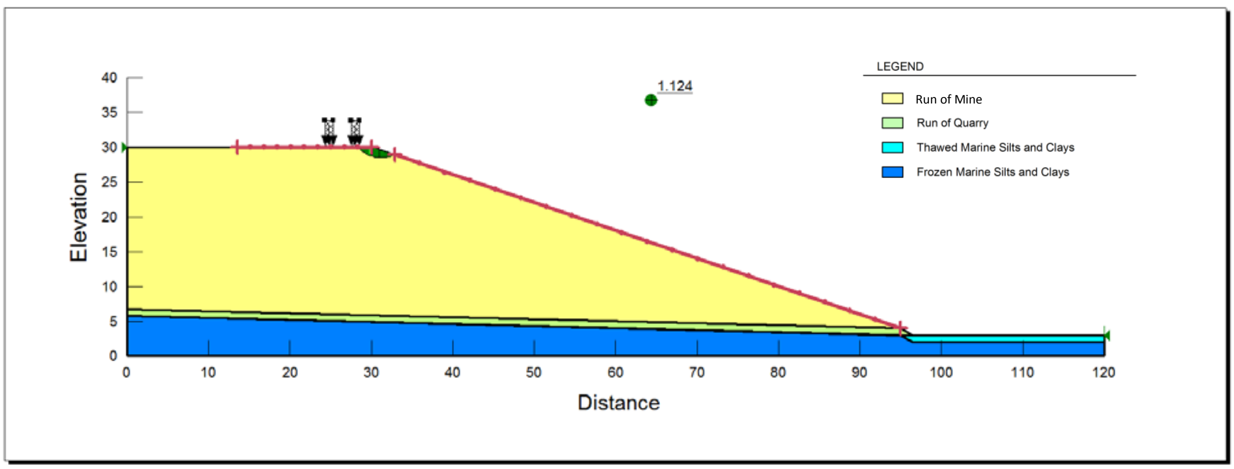


An assumption for this model is that the tires act as equal pressure loads over 1m² areas.

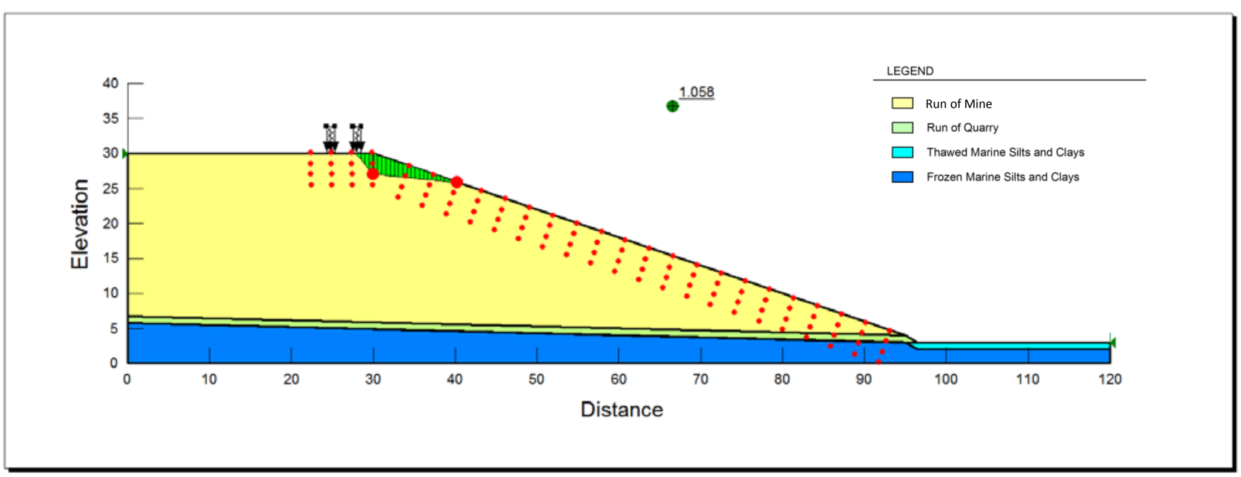
Attachment 2
Graphical Results of Critical Slip Surfaces



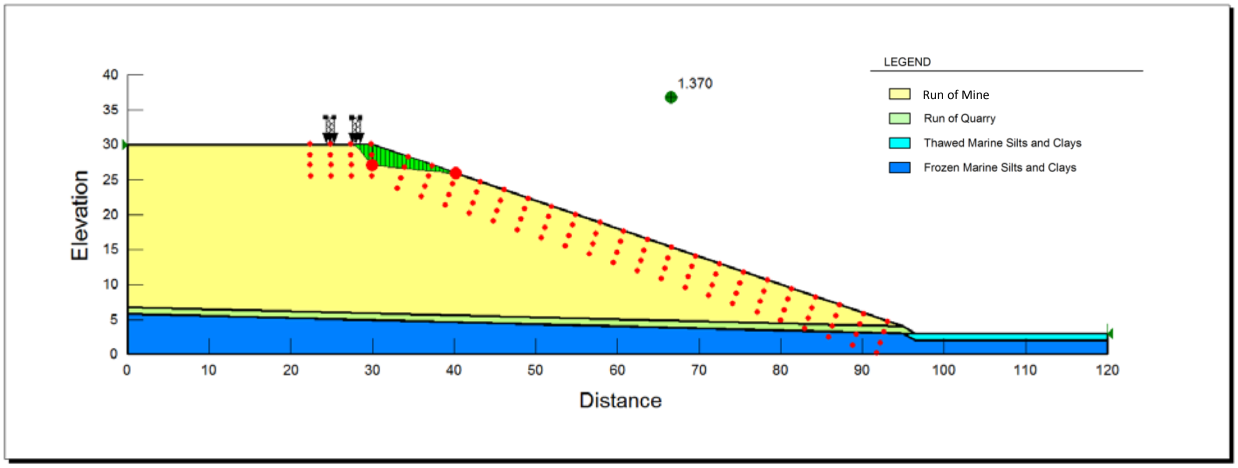
Entry-exit critical slip surface using Morgenstern-Price method with applied wheel loads.



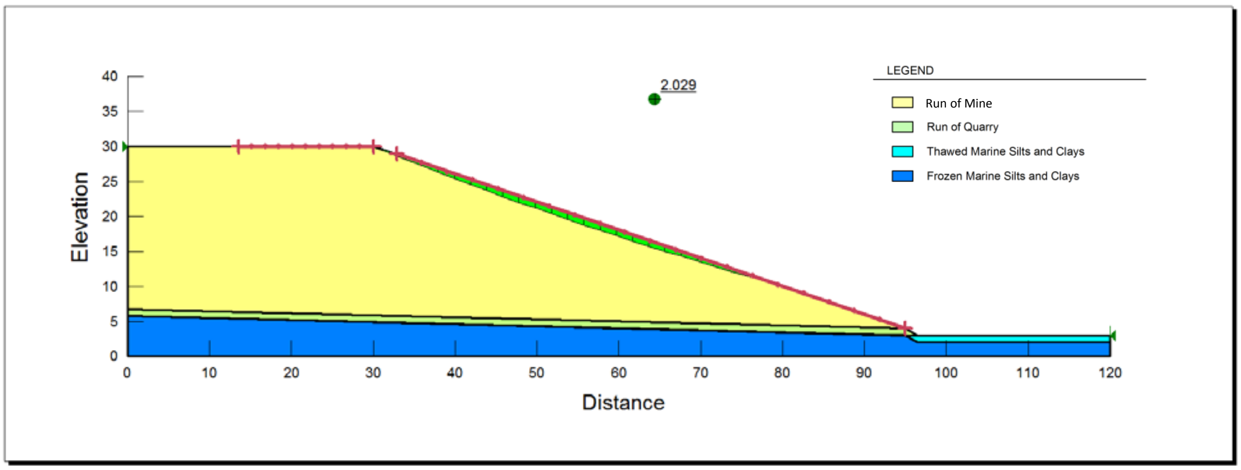
Entry-exit critical slip surface using Bishop method with applied wheel loads.



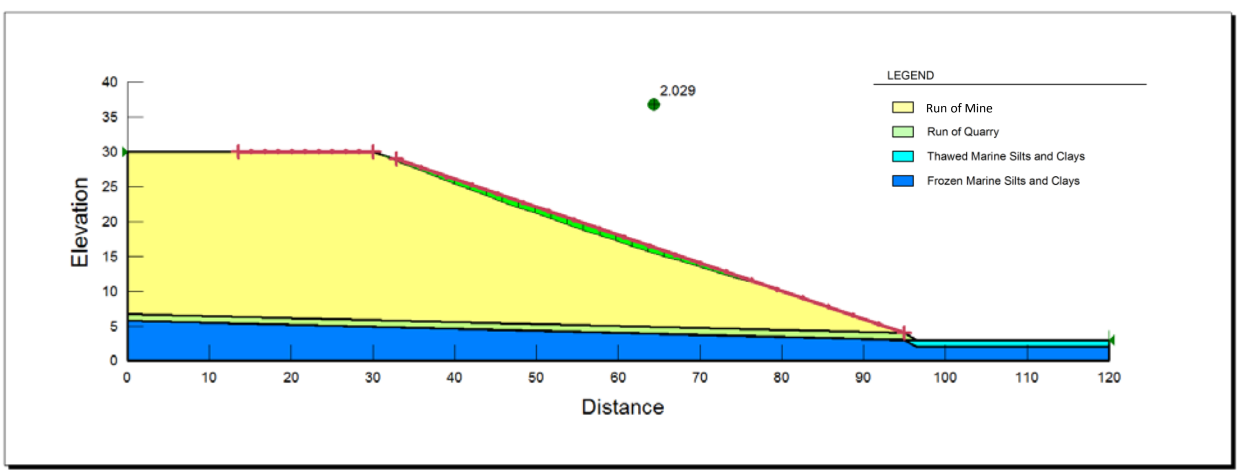
Block specified critical slip surface using Morgenstern-Price method with applied wheel loads.



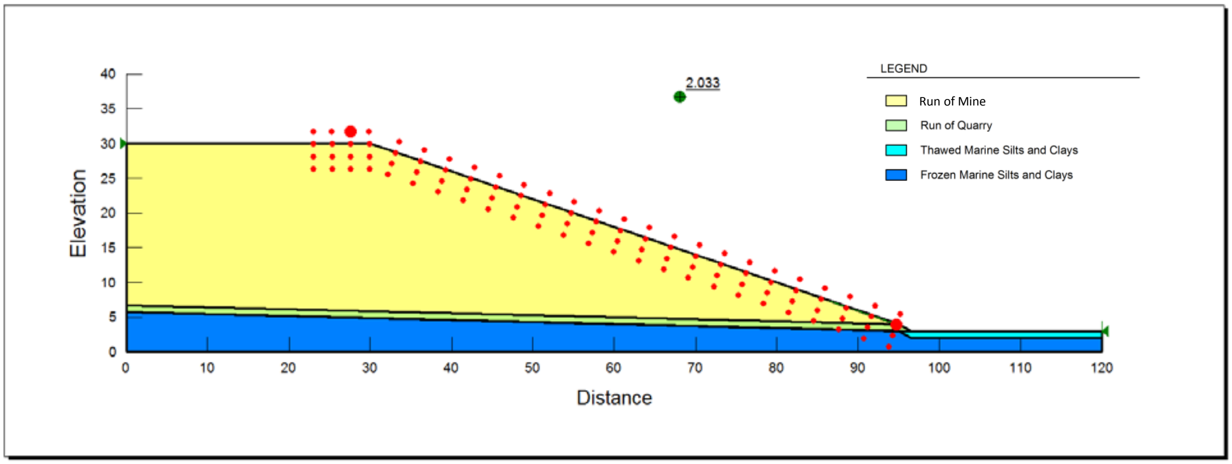
Block specified critical slip surface using Bishop method with applied wheel loads.



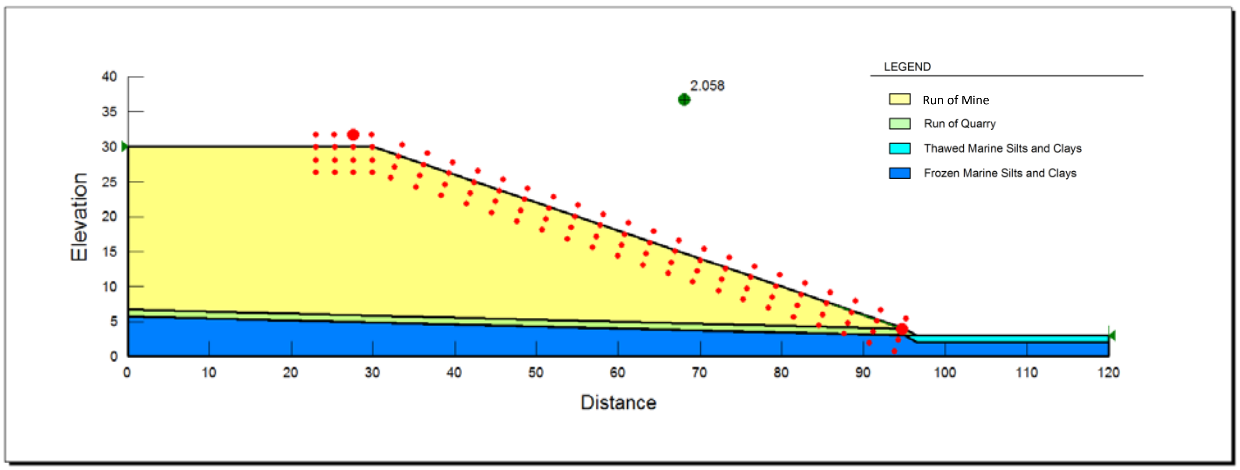
Entry-exit critical slip surface using Morgenstern-Price method for the free standing pile.



Entry-exit critical slip surface using Bishop method for the free standing pile.



Block specified critical slip surface using Morgenstern-Price method for the free standing pile.



Block specified critical slip surface using Bishop method for the free standing pile.

Attachment 3
Ore Stockpile Stability Ratings

Stability Factor	Description	Points
Dump Height	Maximum 26m	0
Dump Volume	306,800m^3	0
Dump Slope	2.5:1 = 21.8° Flat	0
Foundation Slope	5° < 10° Flat	0
Confinement	Convex pile shape - (Unconfined)	100
Foundation Type	Compotent (Frozen) / Weak (Unfrozen)	0 / 200
Dump Material Quality	Strong - (High)	0
Construction Method	Lifts <25m - (Favourable)	0
Peiziometric / Climate	High infiltration into dump - (Intermediate)	100
Dumping Rate	5m^3 per liniar meter per day (Slow)	0
Seismicity	Low seizmic risk zone	0
	Total	200 / 400

Package 6
Engineering and Design Documents

P6-12 Tailings Geochemistry

Geochemical Characterization of Tailings from the Doris Deposits, Hope Bay

Prepared for

TMAC Resources Inc.

Prepared by

SRK Consulting (Canada) Inc.
1CT022.002
June 2015

Geochemical Characterization of Tailings from the Doris Deposits, Hope Bay

June 2015

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File Name: TailingsCharacterizationDoris_1CT022-002_als_kss_20150603_final

Technical Summary

This report provides the results for the geochemical characterization of tailings from the Doris deposits at the Hope Bay Project, in Nunavut, Canada. TMAC Resources Inc. (TMAC) is advancing plans for underground mining of the Doris deposits, which are comprised of three main ore zones: North, Connector and Central. This report was prepared in support of the Type A Water License Amendment Application for the Doris North Project for submission to the Nunavut Water Board.

The project was acquired by TMAC in March 2013 from the previous owner Hope Bay Mining Ltd., a subsidiary of Newmont Mining Corporation. The geochemical characterization program for tailings was designed by Newmont Metallurgical Services (NMS) in close collaboration with SRK to characterize the metal leaching/acid rock drainage (ML/ARD) potential of three separate tailings products: bulk flotation tailings, detoxified tailings (i.e. detoxified tailings from cyanide leaching of ore concentrates) and mixed tailings that represent a combination of bulk flotation tailings and detoxified tailings, generated from several rounds of metallurgical testing on ores from the Doris North, Connector and Central ore zones. The majority of tailings samples in the program were generated by NMS. In addition, a more recent round of metallurgical testing on high and low grade ore samples from the Doris North stockpile was also conducted by TMAC that better represents the currently proposed metallurgical flowsheet. The characterization program for metallurgical tailings included mineralogical analysis, static tests and kinetic tests, as well as tailings slurry process water chemistry and aging tests. It is noted that TMAC plans to discharge flotation tailings to the Tailings Impoundment Area (TIA), and detoxified tailings to the underground workings. Therefore, although mixed tailings were included in the historical characterization programs, production and disposal of mixed tailings is not anticipated.

All tailings types had abundant neutralization potential and thus buffering capacity typically in the form of ferroan dolomite with minor calcite and/or siderite. Sulphide content, in the form of pyrite, was dependent on tailings type with high levels in the detoxified tailings, modest amounts in the mixed tailings and relatively low levels in the flotation tailings from all three ore zones.

The results of static and humidity cell tests indicate that the detoxified tailings are clearly PAG and the flotation tailings are non-potentially acid generating (PAG). The mixed tailings, which are primarily classified as having uncertain potential for ARD in the static tests, were projected to be non-PAG based on humidity cell tests. The exception was the Doris Central mixed tailings sample that was projected to generate ARD in the laboratory humidity cell test.

Several metals in the tailings solids occur at concentrations in excess of crustal abundances. These include consistently elevated silver, arsenic, gold, cadmium, lead and selenium, and inconsistently elevated copper, molybdenum and tungsten in the detoxified tailings, as well as elevated gold, arsenic and selenium in the mixed tailings, and elevated gold in the flotation tailings. Many of these metals are associated with sulphides and as indicated will be concentrated within the detoxified tailings. Copper in one of the recent Doris North detoxified tailings samples generated under the direction of TMAC was five times higher than copper levels in the Doris Connector and Central detoxified tailings generated by NMS.

Long-term humidity cell tests indicate that after the initial flushing of the samples, there was an increased tendency for arsenic leaching under neutral pH conditions from the Doris North tailings (flotation, mixed and detoxified tailings) as well as the Doris Connector mixed tailings. Leaching of ammonia, arsenic, cadmium, copper, iron, selenium and silver also occurred in the Doris North detoxified tailings, and leaching of cadmium and selenium occurred in the Doris Central detoxified tailings. Acidic conditions developed in the Doris Central detoxified tailings after 202 weeks of testing. At the onset of acidic pH conditions, increased concentrations of cadmium, cobalt, copper, iron, manganese, nickel, lead and zinc were noted. Marginally elevated median concentrations of copper and lead in the Doris Central flotation tailings humidity cell tests and marginally elevated selenium in the Doris North mixed tailings were also observed.

Process water chemistry associated with the tailings slurry samples, which provides an indication of possible water chemistry in discharges to the tailings facility, indicated elevated levels of several metals that varied by tailings type and ore zone. Process water associated with the detoxified tailings was alkaline and typically elevated in sulphate, total cyanide, ammonia, silver, cadmium, copper, chromium, and likely selenium. Process water from the Doris North detoxified tailings was also marginally elevated in arsenic, iron, molybdenum, nickel, lead and zinc. With aging, the detoxified tailings process water chemistry generally improved with decreases in cyanide products and most metals in particular silver, arsenic, copper, nickel and selenium. Process water chemistry between the Doris Central and Connector solutions was notably different with the Doris Central process water characterized by higher metals. Molybdenum, iron and chromium were elevated in both solutions, but the Doris Central flotation tailings water also elevated in silver, cadmium, copper, lead and zinc. The Doris North flotation tailings process water was not available for analysis. The Doris Connector mixed tailings process water was elevated in aluminum, silver, chromium, copper, iron, molybdenum, selenium and zinc.

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1 Introduction

TMAC Resources Inc. (TMAC) are advancing plans for underground mining of the Doris deposit, which is comprised of three main ore zones: North, Connector and Central. SRK Consulting (Canada) Inc. (SRK) was asked to complete an assessment of the metal leaching and acid rock drainage and (ML/ARD) potential of metallurgical tailings from the Doris deposits. This report presents the findings of the ML/ARD assessment, and is intended to be a supporting document for the Type A Water License Amendment Application for the Doris North Project.

2 Overview of Tailings Characterization Program

The project was acquired by TMAC in March 2013 from the previous owner Hope Bay Mining Ltd. (HBML), a subsidiary of Newmont Mining Corporation. Prior to TMAC's ownership of Hope Bay, HBML and SRK undertook a comprehensive geochemical characterization program of mine wastes at the Doris ore zones. The program was in support of feasibility study requirements, environmental assessments and permitting studies. The characterization program for metallurgical tailings included mineralogical analysis, static tests, kinetic tests and aging tests on three separate tailings products from each of the Doris ore zones: bulk flotation tailings, detoxified tailings (i.e. detoxified tailings from cyanide leaching of ore concentrates)[1] and mixed tailings that represent a combination of bulk flotation tailings and detoxified tailings. The testing program was developed in close collaboration with Newmont Metallurgical Services (NMS), and NMS was responsible for implementation. SRK was responsible for interpretation and reporting of the results.

In addition to the tailings samples generated by NMS, a Doris North mixed tailings sample and a Doris Central flotation tailings sample were generated by the previous owner Miramar Hope Bay Ltd. (Miramar).

A more recent round of metallurgical testing has also been conducted by TMAC that better represents the currently proposed metallurgical flowsheet. This consisted of metallurgical testing on two ore samples; a high grade sample (sample ID Doris North) and a low grade sample (sample ID DC-02), sourced from the Doris North surface stockpile, and resulted in samples of flotation tailings and detoxified tailings from each head sample.

Table 2.1 provides an inventory of samples that are within the scope of the Doris tailings geochemical characterization program including the various metallurgical studies relating to each tailings sample, the proponent responsible for the metallurgical program and the responsible party for the geochemical characterization program.

[1] These were assigned various names in different phases of testing, and may be identified as cyanide or CND residues in original lab files and/or the report appendices.

Table 2.1: Overview of Doris Tailings Samples, Hope Bay Project

Ore Zone	Tailings Type	Humidity Cell ID	Other ID	Proponent	Metallurgical Reference	Geochemistry Program
North	Mixed	Historic[1]	--	Miramar	AMEC (2005)	AMEC
	Flotation	HC-66	--	NMS	CSM (2012)	SRK
	Detoxified tailings	HC-67	--	NMS	CSM (2012)	SRK
	Mixed[2]	HC-68	--	NMS	CSM (2012)	SRK
	Flotation	--	Doris North Flot. tails	TMAC	Gekko (2014a)	SRK
	Flotation	--	DC02 Flot. tails	TMAC	Gekko (2014b)	SRK
	Detoxified tailings	--	Doris North Detox tails	TMAC	Gekko (2014a)	SRK
	Detoxified tailings	--	DC02 Detox tails	TMAC	Gekko (2014c)	SRK
Connector	Flotation	HC-57	--	NMS	NMS (2008); Gekko (2010)	SRK
	Detoxified tailings	--	NM2100531	NMS	NMS (2008); Gekko (2010)	SRK
	Mixed[3]	HC-69	--	NMS	CSM (2012)	SRK
Central	Flotation	HC-1	--	Miramar	PRA (2008)	SRK
	Detoxified tailings	HC-1b	--	NMS	NMS (2008)	SRK
	Mixed[4]	HC-15	--	NMS	NMS (2008)	SRK

[1] HC-1 from AMEC (2005) mixed proportions not documented

[2] Doris North mixed tailings (HC-68) composition= 85% flotation tailings, 15% detoxified tailings

[3] Doris Connector mixed tailings (HC-69) composition= 92% flotation tailings, 8% detoxified tailings

[4] Doris Central mixed tailings (HC-15) composition= 91% flotation tailings, 9% detoxified tailings

3 Methods

3.1 Sample Selection and Preparation

The program for the Doris tailings characterization was designed to include all potential tailings streams and scenarios. Samples were generated in a number of metallurgical testing rounds. The objective of sample acquisition was to obtain representative samples of potential flotation tailings, detoxified tailings and mixed tailings for each of the Doris North, Connector and Central ore zones. SRK relied on the metallurgists to determine which samples were representative of each respective ore zone.

For the NMS samples, ore composites for metallurgical processing were selected by Newmont geology and were composites of drill core. NMS in Englewood, Colorado prepared a tailings sample for each required test type (e.g. static, humidity cell, sub-aqueous column) and shipped the samples to Maxxam Analytics (Maxxam) for analysis. Appendix A of SRK (2015) provides additional details for each sample.

The recent Doris North tailings samples were generated in 2014 at Gekko Systems Ltd. (Gekko) in Ballarat, Australia under the direction of TMAC. Gekko prepared flotation tailings and detoxified tailings from each high grade (labelled Doris North) and low grade (labelled DC-02) ore sample and shipped the samples to ALS Environmental-Springvale in Melbourne, Australia for analysis.

Tailings samples were submitted for mineralogical characterization, static testing, humidity cell tests and subaqueous column tests as outlined in Table 3.1.

Table 3.1: Doris Tailings Static Test Characterization

Ore Zone	Tailings Type	Humidity Cell/Sub-Aqueous Column ID	Other ID	Initial Tailings[1]					Residual Tailings[2]	
				ABA	ICP	XRD	MLA	SEM	ABA	ICP
North	Mixed	Historic[3]	--	x	x	x			x	x
	Flotation	HC-66	--	x	x	x			x	x
	Detoxified tailings	HC-67[a]	--			x			x	x
	Mixed	HC-68/SAD-4	--	x	x	x			x	x
	Flotation	--	Doris North Flot. tails	x	x					
	Flotation	--	DC02 Flot. tails	x	x					
	Detoxified tailings	--	Doris North Detox tails							
	Detoxified tailings	--	DC02 Detox tails	x	x					
Connector	Flotation	HC-57/SAD-5	--	x	x	x	x	x	x	x
	Detoxified tailings	--	NM2100531	x	x					
	Mixed	HC-69	--	x	x	x			x	x
Central	Flotation	HC-1/SAD-2	--	x	x	x		x	x	x
	Detoxified tailings	HC-1b	--	x	x	x			x	x
	Mixed	HC-15		x	x	x		x	x	x

[1] Initial tailings = sample prior to any kinetic testing
[2] Residual tailings = sample residual after kinetic testing
[3] Historic = HC-1 from AMEC (2005)
[a] No pre-humidity cell test data available for Doris North detoxified tailings

A sample for static testwork was not provided for the Newmont Doris North detoxified tailings (HC-67) or the TMAC Doris North detoxified tailings (Doris North detox tailings sample ID).

3.2 Mineralogy

Mineralogy analyses were performed on the tailings samples tested in the humidity cells.

Bulk mineralogy was typically determined at NMS by quantitative X-Ray diffraction (QXRD) using Rietveld refinement and whole pattern fitting. Further mineralogical work was performed by NMS on a sub-set of the tailings samples using mineral liberation analysis (MLA) for trace mineralogy with emphasis on carbonates and sulphides, as well as scanning electron microscope (SEM) to determine the stoichiometric formulas of iron carbonate minerals.

3.3 Static Geochemical Tests

Static geochemical tests provide the basis for evaluating the potential reactivity and ML/ARD potential of a sample.

The initial static tests typically consisted of acid-base accounting (ABA) including paste pH, total sulphur, sulphate sulphur, fizz test and neutralization potential (NP) by the modified Sobek method (MEND 1991), total inorganic carbon (TIC) and trace element content by ICP-MS following an aqua regia digestion (ICP). Acid potential (AP) was calculated based on the total sulphur content. An exception was the Doris Central bulk flotation tailings (HC-1) which used the Standard Sobek NP Method (Sobek et al. 1978).

Once kinetic tests (discussed below) were complete, ABA and trace element content analyses were also conducted on the humidity cell and column residues.

Static tests on the Newmont tailings samples were typically conducted by Maxxam (formerly Cantest Ltd.) in Burnaby, B.C. Analytical instructions for each test were provided to Maxxam by SRK.

Static tests on the more recent Doris North flotation tailings and detoxified tailings samples generated for TMAC were analyzed at ALS Environmental-Springvale in Melbourne, Australia. Analytical instructions for each test were provided to ALS by SRK.

3.4 Humidity Cell Tests

Humidity cell tests were conducted to evaluate the kinetic geochemical behaviour and resultant seepage water quality of the Doris flotation, detoxified tailings and mixed tailings over time. A summary of the Doris tailings humidity cell test program and duration of testing is provided in Table 3.2.

Table 3.2: Summary of Doris Humidity Cell Test Program

Ore Zone	Tailings Type	Mixed Tailings Composition	Humidity Cell ID	Began Operation	Terminated Operation	Cycles Operated[2]
North	Mixed	unknown	Historic[1]	12-Aug-03	7-Sep-05	109[a]
	Flotation	N/A	HC-66	21-Dec-11	14-Mar-12	12
	Detoxified tailings	N/A	HC-67	21-Dec-11	14-Mar-12	12
	Mixed	85% flotation; 15% Detoxified tailings	HC-68	21-Dec-11	26-Sep-12	40
Connector	Flotation		HC-57	19-May-10	22-Feb-12	92
	Mixed	92% flotation; 8% Detoxified tailings	HC-69	29-Feb-12	24-Oct-12	35
Central	Flotation	N/A	HC-1	5-Feb-08	6-Jan-09	48
	Detoxified tailings	N/A	HC-1b	20-Oct-08	24-Oct-12	210
	Mixed	91% flotation; 9% Detoxified tailings	HC-15	13-May-09	22-Feb-12	145

[1] HC-1 from AMEC (2005)
[2] Cycles are weekly
[a] No cycle 0

The humidity cell tests were primarily conducted at Maxxam using the ASTM (2001) method. Two exceptions include the Doris Connector flotation tailings (HC-1) which was tested at Process Research Associates Ltd. (PRA) in Richmond, B.C. using the ASTM (2001) method and the Doris North mixed tailings (historic) which was tested at Vizon Laboratory in Vancouver, B.C. using the Price (1997) method.

Table 3.3 outlines the list of analytes and the analytical frequency used for the humidity cell test work. All analyses were conducted at Maxxam except cyanide species (total, weak acid dissociable (WAD) and free) were conducted at Inter-Montane Laboratories Inc. (IML) in Sheridan, Wyoming and cyanide degradation products (cyanate and thiocyanate) were analyzed by NMS.

Table 3.3: Analytical Parameters and Frequency of Humidity Cells

General Parameters	Typical Frequency	Flotation	Detoxified Tailings	Mixed
pH, EC, SO_4	Weekly	x	x	x
Alkalinity, acidity	Weekly	x	x	x
ORP or Eh	Weekly	x	x	x
Metals		x	x	x
ICP-MS (trace elements)	0, 1, 2, 4, 8, 12, 16, etc.	x	x	x
ICP-OES suite[1]	Weekly	x	x	x
Hg by CV	0, 1, 2, 4, 8, 12, 16, etc.	x		
Cyanide Species[2]				
Total, WAD, Free	0, 1, 2, 4, 8, 12, 16, etc.	x	x	x
SCN, CNO	0, 1, 2, 4, 8, 12, 16, etc.	x	x	x
Ions and Nutrients				
F, Cl, P, TDS	0, 1, 2, 4, 8, 12, 16, etc.	x	x	x
NO_2, NO_3, NH_3	0, 1, 2, 4, 8, 12, 16, etc.	x	x	x

[1] Al, Ca, Cu, Fe, Mg, K, Na and Zn
[2] Cyanide species analyzed for detoxified tailings and mixed tailings only

Humidity cell data were provided to SRK on a monthly basis and each report underwent quality assurance/quality control (QA/QC) by SRK.

Once the humidity cell tests were complete, ABA and trace element content analyses were conducted on the humidity cell residues. These post-test analyses followed the same method as the pre-test sample characterization described above.

3.5 Sub-Aqueous Column Tests

Three tailings humidity cells were selected to be tested as sub-aqueous columns to evaluate leaching under water saturated conditions. A summary of the Doris tailings sub-aqueous column test program and duration of testing is provided in Table 3.4.

Table 3.4: Summary of Doris Sub-Aqueous Column Tests

Ore Zone	Tailings Type	Mixed Tailings Composition	Column Test ID	HC Test ID	Began Operation	Terminated Operation	Total # Cycles[1]
North	Mixed	85% flotation; 15% detoxified tailings	SAD-4	HC-68	18-Jan-12	26-Oct-12	10
Connector	Flotation	N/A	SAD-5	HC-57	18-Jan-12	26-Oct-12	10
Central	Flotation	N/A	SAD-2	HC-1	12-May-10	17-Feb-12	23

[1] Cycles are monthly

The methodology for the sub-aqueous column test setup and testing protocol is described in detail in Appendix B (Volume II).

Samples were shipped from NMS to Maxxam for the column test work. Pre-test sample characterization was not performed for the columns. The flotation tailings for Doris Central (SAD-2) and Doris Connector (SAD-5) was prepared and provided by NMS and stored fully saturated and refrigerated at the lab prior to testing. The material in the Doris North mixed tailings sample (SAD-4) was prepared at Maxxam under the direction of SRK as per instructions provided by NMS. The Doris North mixed tailings sample was prepared using unsaturated flotation tailings and detoxified tailings, according to the proportions listed in Table 3.4. Deionized water was added to the sample to create a slurry representative of the mixed tailings. The corresponding humidity cell tests are listed in Table 3.4.

Table 3.5 outlines the list of analytes and the analytical frequency used for the column test work. Column test data were provided to SRK on a monthly basis and each report underwent QA/QC by SRK.

Once the column tests were complete, ABA and trace element content analyses were conducted on the column residues.

Table 3.5: Analytical Parameters and Frequency for Sub-Aqueous Columns

Parameter	Frequency
General Parameters	
pH, EC, ORP	monthly (in situ)
SO_4, acidity, alkalinity	monthly
Ions and Nutrients	
F, Cl, P, TDS	monthly
NO_2, NO_3, NH_3	monthly
Metals	
ICP-MS (trace elements)	monthly
ICP-OES[1]	
Hg (CVAF)	monthly

[1] Al, Ca, Cu, Fe, Mg, K, Na and Zn

3.6 Process Water Analyses

Tailings process or supernatant water produced during metallurgical testing was analyzed where available.

NMS completed a number of metallurgical tests on the Doris ores. Samples that are representative of the current process include flotation samples from Doris Central, Doris Connector and Doris North, as well as detoxified tailings samples from Doris Central. For each of these samples, decant water was collected and analyzed for general parameters and dissolved metals if possible. This included pH, conductivity, alkalinity, total dissolved and suspended solids, cyanide species, nitrogen species, anions and total and dissolved metals by ICP-MS including major ions (Na, Ca, Mg, K). Analyses were typically conducted by NMS in Englewood, Colorado.

Similar analyses were requested for process water from the two Doris North detoxified tailings samples (Doris North and DC02) produced by Gekko for TMAC; however, insufficient solution volume precluded the analysis of some parameters. No process water from either flotation tailings sample (Doris North and DC02) was available for testing. A list of priority analyses was provided to ALS in Melbourne, Australia by SRK. The resulting analyses were limited to pH, total cyanide, thiocyanate and dissolved metals by ICP-MS on both samples, as well as total metals by ICP-MS on solution sample DC02 only. No sulphate or other general parameters were analyzed.

3.7 Aging Tests

Tailings process water generated during metallurgical testing was subjected to oxic and anoxic aging tests to assess chemical changes to the process water over time. A summary of the Doris tailings aging tests is presented in Table 3.6.

For the aging tests conducted at SGS in Lakefield, Ontario (Doris Central flotation tailings), samples were shipped from PRA where the tests were operated under the direction of SRK using the protocol in Appendix C (Volume II). The aging tests for the other tailings samples were conducted at the Colorado School of Mines (CSM) in Golden, Colorado using the method outlined in Appendix D (Volume II). Analytical work for these latter aging tests was performed at NMS.

For all tests, limited sample volume precluded the re-analysis of samples. For aging tests operated at CSM from January to June of 2012 (Doris Connector flotation and mixed tailings), SRK's understanding from CSM is that NMS experienced QA/QC problems for metals analysis for samples containing cyanide species. Despite the samples having been acidified prior to ICP analysis, precipitates were found in the bottom of sample containers. Consequently, during the time period mentioned above, NMS began digesting unpreserved samples prior to analysis. The resulting trace element data generated for these tests was apparently questionable.

An inventory of the parameters that were analyzed in each of the aging tests is presented in Table 3.7.

Table 3.6: Inventory and Metallurgical Background for Doris Aging Test Samples

Ore Zone	Tailings Type	Proponent	Metallurgical Reference	Laboratory Where Aging Test Performed	Oxic	Anoxic	Mixed Tailings Composition	Corresponding HC ID	Corresponding Aqueous Column ID
Central	Flotation	Miramar	PRA (2008)	SGS Lakefield	yes	yes	N/A	HC-1	SAD-2
	Detox. Tailings	NMS	NMS (2008)	Colorado School of Mines	yes	yes	N/A	HC-1b	N/A
Connector	Flotation	NMS	CSM (2012)	Colorado School of Mines	yes	yes	N/A	HC-57[a]	SAD-5
	Mixed	NMS	CSM (2012)	Colorado School of Mines	yes	yes	92% flotation; 8% detox tailings	HC-69	N/A

[a] Sample for humidity cell test from previous Doris Connector metallurgical test work (NMS (2008) and Gekko (2010))

Table 3.7: Oxic and Anoxic Aging Test Analytes for Doris Tailings Samples

Parameter*	Doris			
	Central		Connector	
	Flotation Tailings	Detoxified Tailings	Flotation Tailings	Mixed Tailings
Temp Upon Receipt		x		
pH (unfiltered)		x		
EC (unfiltered)		x		
EMF (unfiltered)		x		
E_H	x	x		x
DO		x		
pH	x	x	x	x
Alkalinity	x	x	x	x
Conductivity		x		
HCO_3		x		
Carbonate		x		
TDS	x	x	x	x
OH		x		
Cl	x	x	x	x
F	x		x	x
SO_4	x	x	x	x
NO_2	x	x	x	x
NO_3	x	x	x	x
$NH_{3+}NH_4$	x	x	x	x
TOC	x	x	x	x
TIC		x		
C	x	x	x	x
Tot. Reactive P		x		
CN(T)		x	x	x
CN_{WAD}		x	x	x
CNO	x	x	x	x
CNS	x	x	x	x
CN(F)		x	x	x
$(S_2O_3)^{2-}$		x	x	x
Hg	x	x	x	x
Hardness	x	x		
Ag	x	x	x	x
Al	x	x	x	x
As	x	x	x	x
Ba	x	x	x	x
Be	x	x	x	x
B		x		

Table 3.7 (Continued): Oxic and Anoxic Aging Test Analytes for Doris Tailings Samples

Parameter*	Doris			
	Central		Connector	
	Flotation Tailings	Detoxified Tailings	Flotation Tailings	Mixed Tailings
Bi		x		
Ca	x	x	x	x
Cd	x	x	x	x
Co		x		
Cr	x	x	x	x
Cu	x	x	x	x
Fe	x	x	x	x
K	x	x	x	x
Li		x		
Mg	x	x	x	x
Mn	x	x	x	x
Mo	x	x	x	x
Na	x	x	x	x
Ni	x	x	x	x
P	x	x	x	x
Pb	x	x	x	x
Sb	x	x	x	x
Se	x	x	x	x
Si	x	x	x	x
Sn		x		
Sr	x	x	x	x
Ti		x		
Tl	x	x	x	x
U		x	x	x
V		x		
W		x		
Y		x		
Zn	x	x	x	x

Notes:
* All parameters were analyzed on filtered samples, unless specified

4 Results

4.1 Mineralogy

Quantitative phase XRD results for the Doris tailings are tabulated in Table 4.1. A summary of carbonate mineralogy by XRD, MLA and SEM is provided in Table 4.2. Mineralogy reports are provided in Appendix E (Volume II).

The Doris tailings were comprised mainly of quartz with accessory chlorite, muscovite-sericite, pragonite, carbonate, and pyrite in some of the samples. Minor amphibole, plagioclase and trace rutile was also reported in some of the samples.

Ferroan dolomite $(Ca(Fe,Mg)(CO_3)_2$ was the dominant carbonate mineral present in nearly all samples with the exception of the Doris North and Connector mixed tailings. Iron content in the ferroan dolomite was consistently lower than magnesium, with iron (i.e. Fe_x) comprising stoichiometrically up to 0.45 of the iron+magnesium content (Table 4.2). Calcite ($CaCO_3$) and siderite ($FeCO_3$) minerals were present in some samples at significantly lower levels than ferroan dolomite. No siderite was reported in the Doris North tailings samples.

The key mineralogical difference between the tailings types was the abundance of pyrite in the detoxified tailings (upwards of 30% pyrite). No sulphides were detected in the flotation tailings analyzed with the exception of very trace pyrite (0.08%) and arsenopyrite (0.01%) determined by MLA in the Doris Connector flotation tailings. Pyrite levels in the mixed tailings samples were near detection (1 to 3%).

4.2 Static Tests

ABA data for the Doris tailings sample set is provided in Table 4.3. No ABA data was available for two of the Doris North detoxified tailings samples (HC-67 and TMAC sample Doris North detox tails).

Sulphide sulphur content and therefore acid potential (AP) was low in the flotation tailings (typically <0.1% S). The exception was the recent Doris North DC-02 flotation tailings sample that reported slightly higher sulphide sulphur at 0.4%. The detoxified tailings had substantially higher sulphide sulphur content as expected (8% to 26% S). Mixed tailings sulphide content ranged from 1.6 to 1.9% S with the exception of the historic mixed tailings sample that reported a lower content at 0.4% S. Overall, sulphide content is related to tailings type with detoxified tailings greater than mixed tailings greater than flotation tailings.

Neutralization potential (NP) was high in the range of 70 to 210 kg $CaCO_3$ eq/t and relatively similar between the tailings type and ore zone. TIC levels were consistently higher than NP and consistent with the presence of iron carbonate minerals identified by XRD in the tailings samples. This result suggests that NP is more conservative for ARD classifications.

Table 4.1: Results of Quantitative Phase XRD Analysis (%) for Doris Tailings Samples

Ore Zone	Tailings Type	Humidity Cell/ Column ID	Amphibole	Ankerite/Dolomite	Calcite	Chlorite	Diaspore	Kaolinite	Muscovite/Sericite	Paragonite	Plagioclase	Pyrite	Quartz	Rutile	Siderite	Tourmaline
North	Flotation	HC-66[a]	3-4	3-5	1-3	13-38			2-4	3-5	11-18		38-59	<1		
	Detoxified tailings	HC-67[a]	bd-2	3-5	2-3	13-18			3-4	2-4	4-9	31-43	25-31	<1		
	Mixed	Historic[1]		8		1		1	3	4		1	83			
	Mixed	HC-68 /SAD-	4		2	23			5	7	11	3	38	<1		
Connector	Flotation	HC-57 /SAD-5		9					7	7			75	1	1	
	Mixed	HC-69		13	<1	6			7	7		3	62	<1	2	
Central	Flotation	HC-1 /SAD-2		21		3			7	4			61	2	2	tr
	Detoxified tailings	HC-1b		18	2	2	2		6	4		31	30	1	4	
	Mixed	HC-15		19		3			6	4		2	61	1	2	1

Bd=below detection

Tr=trace

[1] Historic = HC-1 from AMEC (2005)

[a] XRD determined on size fractionated sample but bulk weights not available. Range of values are from the various size fractions

Mineral Formulas:
Amphibole – $Ca_2(Mg,Fe,Al)_5(Al,Si)_8O_{22}(OH)_2$
Ankerite/Dolomite – $Ca(Fe,Mg)(CO_3)_2$
Calcite – $CaCO_3$
Chlorite – $(Mg,Fe,Al)_6(Al,Si)_4O_{10}(OH)_8$
Diaspore – $AlO(OH)$
Kaolinite - $Al_2Si_2O_5$
Muscovite/Sericite - $KAl_2(AlSi_3O_{10})(OH)_2$
Paragonite - $NaAl_3Si_3O_{10}(OH)_2$
Plagioclase - $(Ca,Na)(Al,Si)AlSi_2O_8$
Pyrite - FeS_2
Quartz - SiO_2
Rutile - TiO_2
Siderite - $FeCO_3$
Tourmaline - $Na(Fe,Mg)_3Al_6Si_6O_{18}(BO_3)_3(OH)_4$

Table 4.2: Carbonate Mineralogy by XRD, MLA and SEM

Ore Zone	Tailings Type	Humidity Cell/ Column ID	Carbonate Minerals								
			Ferroan Dolomite			Siderite			Magnesite	Calcite	
			$Ca(Fe,Mg)(CO_3)_2$			$FeCO_3$			$MgCO_3$	$CaCO_3$	
			XRD	MLA	SEM	XRD	MLA	SEM	XRD	XRD	MLA
			mineral %			mineral %				mineral %	
North	Flotation	HC-66[a]	3-5	-	-	bd	-	-	bd	1-3	-
	Detoxified tailings	HC-67[a]	3-5	-	-	bd	-	-	bd	2-3	-
	Mixed	Historic (AMEC.HC-1)	8	-	-	bd	-	-	bd	bd	-
	Mixed	HC-68 SAD-4	bd	-	-	bd	-	-	bd	2	-
Connector	Flotation	HC-57 SAD-5	9	9	$Ca(Mg_{0.55}Fe_{0.45})CO_3$	1	1.03	$(Fe_{0.75}Mg_{0.25})CO_3$	bd	bd	0.07
	Mixed	HC-69	bd	-	-	2	-	-	bd	bd	-
Central	Flotation	HC-1 SAD-2	21	-	$Ca(Mg_{0.59}Fe_{0.41})CO_3$	2	-	$(Fe_{0.69}Mg_{0.31})CO_3$	bd	bd	-
	Detoxified tailings	HC-1b	18	-	-	4	-	-	bd	2	-
	Mixed	HC-15	19	-	$Ca(Mg_{0.59}Fe_{0.41})CO_3$	2	-	$(Fe_{0.69}Mg_{0.31})CO_3$	bd	bd	-

[a] XRD determined on size fractionated sample but bulk weights not available. Range of values are from the various size fractions.
bd = below detection.

Table 4.3: Acid-Base Accounting Data

Tailings Type	Ore Zone	Humidity Cell/ Column ID	Other ID	Paste pH	S(T) %S	$S(SO_4)$ %S	$S(S_2)$ %S	AP $kgCaCO_3/t$	Modified Sobek NP[1] $kgCaCO_3/t$	TIC %C	TIC %CO2	TIC $kgCaCO_3/t$	NP/AP	TIC/AP
Flotation	North	HC-66	--	8.49	0.06	0.02	0.03	0.9	98		4.38	100	105	106
	North	--	Doris N Flot tails	8.4	0.02	0.004	0.02	0.5	104	0.78	--	65	207	130
	North	--	DC02 flot tails	8.2	0.53	0.10	0.43	13.4	156	1.43	--	119	12	9
	Connector	HC-57 SAD-5	--	9.2	0.04	<0.01	0.04	1.3	73		5.02	114	58.5	91.3
	Central	HC-1 SAD-2	--	8.1	0.12	0.02	0.10	3.1	113	2.12		177	36.1	56.5
Detoxified tailings	North	HC-67[a]	--	--	--	--	--	--	--	--	--	--	--	--
	North	--	Doris North detox tails[a]	--	--	--	--	--	--	--	--	--	--	--
	North	--	DC02 detox tails	8.1	8.82	0.09	8.73	273	208	2.31	--	193	0.8	0.7
	Connector	--	NM2100531	6.8	26.5	0.23	26.3	820	110	--	8.03	183	0.1	0.2
	Central	HC-1b	--	7.7	17.7	0.06	17.7	552	100	2.13	--	178	0.2	0.3
Mixed	North	Historic[2]	--	7.8	0.38	<0.01	0.38	11.9	71	--	4.95	113	5.9	9.5
	North	HC-68 SAD-4	--	8.3	1.68	0.05	1.63	51	100	--	4.81	109	2.0	2.1
	Connector	HC-69	--	8.1	1.89	0.01	1.86	58	110	--	6.26	142	1.9	2.4
	Central	HC-15		8.2	1.69	0.02	1.67	52	141	--	9.51	216	2.7	4.1

-- indicates data not available
[1] Modified Sobek NP except for HC-1, which is Standard Sobek NP
[2] Historic = HC-1 from AMEC (2005)
[a] No pre-test static data for Doris North detoxified tailings (HC-67) or Doris North detoxified tailings sample (Doris N detox tails)

The ARD potential of the tailings sample set based on static testing is provided in Figure 4.1. In terms of ABA classifications, the detoxified tailings were classified as potentially acid generating or PAG (NP/AP>3) and the flotation tailings were classified as non-PAG (NP/AP<1). For the mixed tailings, the Doris North historic sample classified as non-PAG whereas the other Doris North sample (HC-68), Doris Central and Doris Connector mixed tailings classified as having uncertain potential for ARD (1<NP/AP<3).

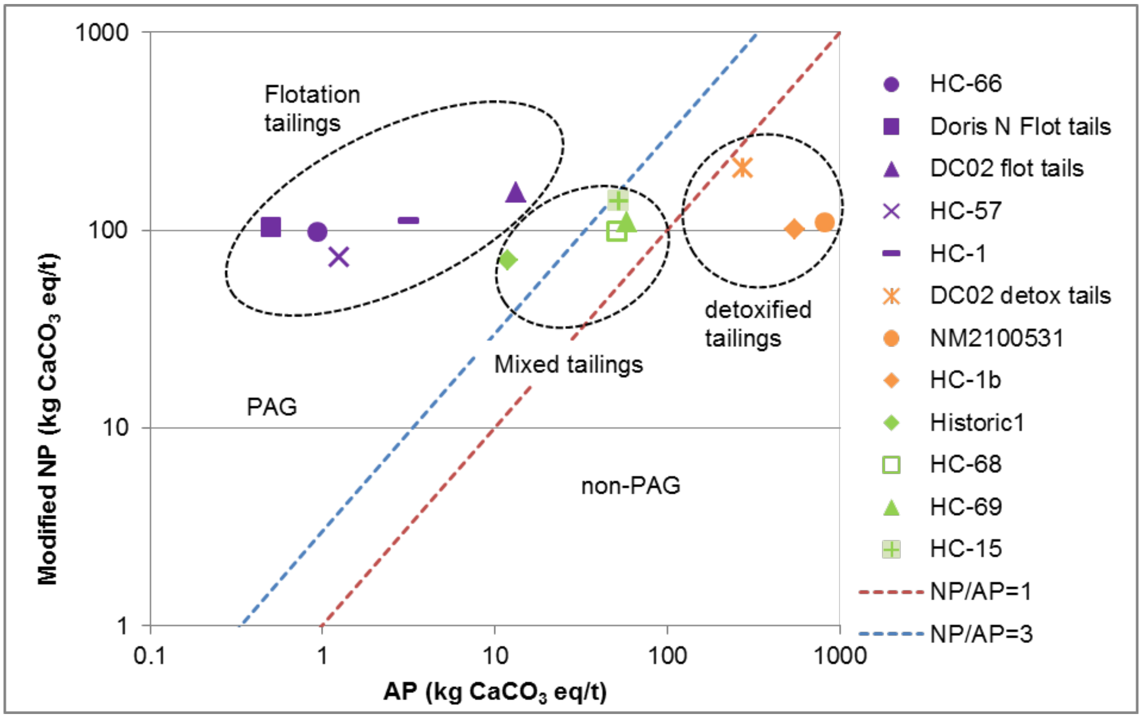

Figure 4.1: ABA Classifications of the Doris Tailings Samples

Trace elements in the tailings samples were analyzed to quantify the bulk geochemical composition of the solids. Trace elements in the tailings samples were compared to ten times crustal abundances for basalt (Price, 1997) to provide an indication of what metals may be elevated in excess of what is considered typical.

Geochemical composition of the Doris tailings samples is summarized in Table 4.4 with complete results provided in Appendix F (Volume II). The bold values in Table 4.4 indicate values that were greater than ten times the concentration in typical basalt. No trace element data was available for two of the Doris North detoxified tailings samples (HC-67 and TMAC sample Doris N detox tails). The trace element data is summarized as follows:

- Gold was the only parameter that exceeded ten times crustal abundances in the flotation tailings samples.
- For the detoxified tailings, silver, arsenic, gold, cadmium, lead and selenium were consistently elevated in all the samples. In addition, copper was elevated in one Doris North

detoxified tailings (TMAC sample DC02 detox tails), molybdenum was elevated in the Doris Connector detoxified tailings (ID NM2100531) and tungsten was elevated in the Doris Central detoxified tailings (HC-1b).

- Copper in the Doris North detoxified tailings (TMAC sample DC02 detox tails) was significantly elevated at five times greater than the other detoxified tailings samples.
- For the mixed tailings, arsenic, gold and selenium were consistently elevated in all the mixed tailings samples.
- Arsenic and selenium were highest in the detoxified tailings, whereas gold in some of the flotation and mixed tailings was higher than the detoxified tailings.

Table 4.4: Doris Tailings Trace Element Data

Tailings Type	Sub-ore Zone	Humidity Cell/ Column ID	Other ID	Ag	As	Au	Cd	Cu	Hg	Mo	Ni	Pb	Sb	Se	W	Zn
				ppm	ppm	ppb	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Flotation	North	HC-66	#N/A	0.3	3	**1720**	0.2	12	<0.01	1.2	38	4.2	<0.1	<0.5	0.3	73
	North	--	Doris N Flot tails	0.07	2.8	**200**	0.03	14	0.01	4.7	82	1.2	0.45	<0.2	0.18	17
	North	--	DC02 flot tails	0.4	10	**1500**	0.1	87	0.01	3.7	72	7.3	0.25	0.4	0.54	69
	Connector	HC-57 SAD-5	--	0.4	3.1	**357**	0.1	25	0.01	5.1	31	3.9	0.1	0.5	0.2	23
	Central	HC-1 SAD-2	--	0.5	<5	--	<0.2	21	<3	9.5	7	17	<5	<5	9	64
Detoxified tailings	North	HC-67	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	North	--	Doris N detox tails	--	--	--	--	--	--	--	--	--	--	--	--	--
	North	--	DC02 detox tails	**2.6**	**123**	**300**	1.4	**2680**	0.05	12.7	269	**64**	1.38	**6.2**	1.35	501
	Connector	--	NM2100531	**1.5**	**408**	**768**	**3.0**	254	0.17	**22**	65	**700**	1.3	**19**	1.2	757
	Central	HC-1b	--	**1.6**	**316**	**732**	**3.1**	451	0.04	10	89	**60**	0.6	**12**	**11**	564
Mixed	North	Historic AMEC.HC-1	--	0.7	**21**	**15379**	0.1	41	0.01	6.4	22	6.1	0.1	**0.5**	1.9	33
	North	HC-68 SAD-4	--	0.5	**31**	**1788**	0.3	73	0.01	2.2	52	41	<0.1	**0.8**	0.4	177
	Connector	HC-69	--	0.5	**34**	**632**	0.4	97	<0.01	5.6	21	4.5	0.2	**1.1**	5.9	99
	Central	HC-15	--	0.4	**34**	**383**	0.4	75	0.01	5.5	33	7.7	0.2	**1.3**	0.9	112
Average crustal abundance for basalt (Price, 1997)				*0.11*	*2*	*4*	*0.22*	*87*	*0.09*	*1.5*	*130*	*6*	*0.2*	*0.05*	*0.7*	*105*

Bold values are greater than 10x average crustal abundances.
Complete results provided in Appendix F (Volume II).

4.3 Humidity Cells

The characteristics of the nine Doris tailings samples in the humidity cell program have been discussed in the sections above.

ARD predictions for each humidity cell test (HCT) were performed using two factors, including:

- Comparison of sulphide with NP and TIC depletion times.
- Comparison of the molar ratio of calcium-plus-magnesium over sulphate with acid base accounting data.

To assess for contaminant leaching, parameters were compared to screening criteria based on the Canadian Council for Ministers of the Environment (CCME) guideline for the protection of aquatic life (CCME 2015) to determine if parameters were elevated. This comparison is made to determine the relative importance of different parameters only, as humidity cell and saturated column tests are lab tests and are not considered representative of source concentrations or concentrations in the receiving environment. Actual leachate concentrations in the field can be either higher or lower than concentrations in the tests depending on scaling factors and other controls on solubility. For parameters discussed without a CCME guideline for the protection of aquatic life, the use of the term “elevated” refers to results that are high in comparison to other humidity cell and saturated column tests.

An assumption in the data analysis is that values below analytical detection are assumed to be equal to the detection limit. This can yield artificially high values that reflect technological limitations rather than a reliable data point. Table 4.5 outlines the parameters that had detection limits higher than the screening criteria. For those parameters listed in Table 4.5, only data above the detection limit were evaluated against these criteria. For some humidity cell tests, the detection limits decreased during the operation of the test, as noted in Table 4.5.

Table 4.5: Parameters with Detection Limits Greater than Screening Criteria

HC ID	Parameter	Notes
HC-1 (AMEC, 2005)	Cd, Hg, P, Se, Free CN	
HC-1	Cd, Hg, Se	
HC-1b	Cd, Free CN	Cd: at cycle 16, DL decreased to just above criteria; as of cycle 76, DL decreased to below criteria.
HC-15	Cd, Free CN	Cd: as of cycle 20, DL decreased to below criteria.
HC-66		
HC-67	Free CN	
HC-68	Free CN	
HC-69	Free CN	

DL = detection limit

Results for each of the Doris tailings humidity cell tests are briefly described in the following sub-sections. A summary of the tailings humidity cell results is provided at the end of this section.

4.3.1 HCT Results

Laboratory results for the humidity cell test work and summaries of key results are provided in Appendix G (Volume II). Figures showing humidity cell time trends are provided in Appendix H (Volume II).

The humidity cell data suggests that ARD will develop or is already present in the detoxified tailings samples from Doris North and Doris Central, respectively. All other samples of metallurgical waste (flotation and mixed tailings) are projected to remain neutral with the exception of the Doris Central mixed tailings sample which is projected to generate ARD (Table 4.6). The humidity cell ARD predictions for the flotation tailings and detoxified tailings are in agreement with ABA tests. The mixed tailings samples that largely classified as having uncertain potential for ARD in static tests were projected to be non-PAG based on humidity cell testing with the exception of the Doris Central mixed tailings sample that is projected to be PAG.

Table 4.6: ARD Classification for Doris Humidity Cell Tailings Samples

Tailings Type	Doris Ore Zone	Humidity Cell ID	NP/AP	TIC/AP	ABA Classification	Kinetic Prediction	
						Neutral	Acidic
Flotation	Connector	HC-57	59	91	non-PAG	likely	
Flotation	Central	HC-1	36	57	non-PAG	likely	
Detoxified tailings	North	HC-67[a]	-	-	PAG		possible
Detoxified tailings	Central	HC-1b	0.2	0.3	PAG		already acidic
Mixed	North	Historic[1]	5.9	9.5	non-PAG	likely	
Mixed	North	HC-68	2.0	2.1	UC	likely	
Flotation	North	HC-66	105	106	non-PAG	likely	
Mixed	Connector	HC-69	1.9	2.4	UC	likely	
Mixed	Central	HC-15	2.7	4.1	UC		possible

[a] No static data available for HC-57; assume PAG ABA classification based on other detoxified tailings tailings samples in the program.
[1] Historic = HC-1 from AMEC (2005)

Sulphate trends, an indication of sulphide oxidation, were related to tailings type with the following observed for sulphate loadings (Table 4.7):

- Rates were highest for detoxified tailings and lowest for flotation tailings, with rates for the mixed tailings decreasing over time to levels between the detoxified tailings and flotation tailings.

- Rates for detoxified tailings exceed the other tailings samples by nearly an order of magnitude.

Table 4.7: Summary of Sulphate Release Rates for Doris Humidity Cell Tailings Samples

Humidity Cell ID	Doris Ore Zone	Tailings Type	Initial Rate [1]	Overall Rate	Stable Rate
			SO_4	SO_4	SO_4
			mg/kg/week		
HC-66	Doris North	Flotation	166	28	4.8
HC-57	Doris Connector	Flotation	37	1.7	1.0
HC-1	Doris Central	Flotation	2.0	14	5.0
HC-67	Doris North	Detoxified tailings[2]	874	329	291
HC-1b	Doris Central	Detoxified tailings	233	284	302
Historic	Doris North	Mixed	6.9	13	8.5
HC-68	Doris North	Mixed	742	53	20
HC-69	Doris Connector	Mixed	136	71	57
HC-15	Doris Central	Mixed	364	35	10

[1] Initial rate = rate from week 1
[2] Historic = HC-1 from AMEC (2005)

Humidity cell trace element concentrations are summarized in Table 4.8 for select parameters (see Appendix G, Volume II for complete results). A number of contaminants of potential concern have been identified (Table 4.9), many of which were identified based only on elevated levels during the initial humidity cell flushing stages. Detection limits were elevated for a number of parameters, including free cyanide, cadmium, mercury and selenium, which often limited data interpretation. Trends for select parameters are noted as follows:

- Ammonia:
  - Levels for the detoxified tailings and mixed tailings samples were comparable and higher than the flotation tailings samples in the initial stages. By cycle 50, detoxified tailings and mixed tailings levels decreased to values more consistent with the flotation tailings samples. There were no ammonia data for the Doris Central flotation or Doris North mixed tailings samples.
  - In general, flotation tailings would be expected to have lower cyanide levels in comparison to the other tailings because they would not contain any of the cyanide degradation products. In contrast, during mining, ammonia may be present in all components of the tailings due to the presence of residual ANFO from blasting.
- Arsenic:
  - Arsenic levels appear to be related to tailings type with flotation tailings greater than mixed tailings greater than detoxified tailings.
  - These results are in contrast to the results of the solids analyses which indicated higher arsenic concentrations in the detoxified tailings. Arsenic concentrations are typically

controlled by adsorption to iron oxides, and may be less mobile in the detoxified tailings due to higher rates of iron released and then precipitated as iron oxides in those samples.

  - Arsenic levels for all tailings types were lower for the Doris Central ore zone than the Doris North and Connector ore zones.

- Copper:
  - Copper levels were initially high for all samples but decreased over time.
  - Although the detoxified tailings samples had significantly higher levels of copper in solid-phase than the other tailings types, median leachate levels for the detoxified tailings were not considered elevated.
  - There are no clear copper trends related to tailings type or ore zone.

- Selenium:
  - Selenium levels for all tailings types were higher for the Doris Central ore zone than the Doris North and Connector ore zones.

Table 4.8: Summary of Humidity Cell Trace Element Concentrations for Selected Parameters

	Humidity Cell ID	Doris Ore Zone	Tailings Type	Total Ammonia	Total CN	Al	Sb	As	Cd	Cr	Co	Cu	Fe	Pb	Mn	Mo	Ni	P	Se	Ag	Zn
				mg/L	mg/l	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/l	mg/L	mg/l	mg/L	mg/L	mg/L	mg/L
Median	HC-66	Doris North	Flotation	0.09	--	0.059	0.00056	0.050	0.00001	0.00010	0.00016	0.0011	0.010	0.00002	0.036	0.0081	0.000001	0.0075	0.00092	0.000005	0.00060
	HC-57	Doris Connector	Flotation	0.05	--	0.049	0.00028	0.0032	0.000005	0.0001	0.000047	0.0005	0.010	0.00002	0.038	0.00075	0.0000002	0.005	0.00007	0.000005	0.0004
	HC-1	Doris Central	Flotation	--	--	0.027	0.00010	0.001	0.00005	0.0005	0.003	0.002	0.018	0.0052	0.029	0.013	0.0004	--	0.0007	0.00005	0.002
	HC-67	Doris North	Detoxified tailings	0.54	0.4	0.013	0.00061	0.020	0.00004	0.0001	0.0130	0.0010	0.010	0.0001	0.24	0.0017	0.0046	0.016	0.010	0.00017	0.015
	HC-1b	Doris Central	Detoxified tailings	0.11	0.02	0.006	0.00010	0.0002	0.00018	0.0002	0.002	0.001	0.010	0.0001	0.17	0.00010	0.001	0.017	0.0091	0.00004	0.003
	Historic[1]	Doris North	Mixed	--	0.0005	0.021	0.0010	0.001	0.0002	0.0010	0.001	0.001	0.050	0.0010	0.004	0.0012	0.001	0.15	0.001	0.0003	0.005
	HC-68	Doris North	Mixed	0.24	0.005	0.044	0.00013	0.012	0.00001	0.00010	0.00045	0.0009	0.012	0.00008	0.072	0.0011	0.00021	0.0073	0.0017	0.000005	0.0014
	HC-69	Doris Connector	Mixed	0.09	0.005	0.0083	0.00004	0.0068	0.00001	0.0001	0.0004	0.0005	0.010	0.00002	0.10	0.0004	0.0010	0.011	0.00014	0.000005	0.0009
	HC-15	Doris Central	Mixed	0.28	0.02	0.002	0.00002	0.0002	0.00001	0.0001	0.0002	0.0004	0.010	0.00002	0.011	0.0013	0.000	0.009	0.00063	0.000005	0.001
Maximum	HC-66	Doris North	Flotation	0.32	--	0.070	0.00095	0.10	0.00001	0.0027	0.00019	0.0033	0.018	0.00003	0.043	0.053	0.000003	0.11	0.0030	0.00002	0.020
	HC-57	Doris Connector	Flotation	0.31	--	0.10	0.0013	0.047	0.00007	0.0005	0.00028	0.23	0.04	0.00050	0.062	0.011	0.000003	0.10	0.00056	0.000026	0.0028
	HC-1	Doris Central	Flotation	--	--	0.11	0.060	0.001	0.006	0.0005	0.090	0.10	0.15	0.59	0.073	0.11	0.020	--	0.0024	0.0001	0.041
	HC-67	Doris North	Detoxified tailings	6.5	10.7	0.042	0.0026	0.063	0.0001	0.0015	0.10	0.0041	7.24	0.0001	1.19	0.022	0.013	0.10	0.025	0.027	0.027
	HC-1b	Doris Central	Detoxified tailings	2.5	0.77	0.72	0.003	0.001	0.003	0.0053	0.045	0.032	3.90	0.0051	0.60	0.034	0.023	0.15	0.020	0.0008	0.18
	Historic[1]	Doris North	Mixed	--	0.12	0.21	0.001	0.026	0.00060	0.0010	0.002	0.008	0.38	0.0010	0.061	0.005	0.006	0.26	0.013	0.0003	0.012
	HC-68	Doris North	Mixed	0.98	--	0.076	0.00080	0.041	0.00003	0.00050	0.0096	0.010	0.15	0.00045	0.29	0.0074	0.0036	0.15	0.0074	0.00011	0.014
	HC-69	Doris Connector	Mixed	0.51	--	0.056	0.0009	0.027	0.00002	0.0004	0.0067	0.0031	0.60	0.00008	0.20	0.084	0.0027	0.25	0.0017	0.0015	0.0070
	HC-15	Doris Central	Mixed	2.80	0.78	0.009	0.0006	0.003	0.00004	0.0011	0.010	0.020	0.57	0.0005	0.15	0.22	0.004	0.13	0.010	0.0003	0.093

Complete results provided in Appendix G (Volume II).
1 Historic = HC-1 from AMEC (2005).

Table 4.9: List of Contaminants of Potential Concern for Doris Tailings Samples

Tailings Type	Ore Zone	Humidity Cell ID	Contaminants of Potential Concern	
			Initial Flush	Longer Term
Flotation	North	HC-66	As, P, Cr, Cu, Se	As
	Connector	HC-57	As, Cu	--
	Central	HC-1	Al, Cd, Cu, Mo, Pb, Se, Zn	Cu, Pb
Mixed	North	Historic	As, Cd, Cu, Fe, Se	--
	North	HC-68	NH_3, As, Cu, Cd, Se	As, Se
	Connector	HC-69	NH_3, P, As, Cu, Se	As
	Central	HC-15	NH_3, Cu, Fe, Mo, Se, Ag, Zn	--
Detoxified tailings	North	HC-67	NH_3, As, Cd, Cr, Cu, Fe, Se, Ag	NH_3, As, Cd, Cu, Fe, Se, Ag
	Central	HC-1b	NH_3, Al, Cd, Cr, Cu, Fe, Ag, Se	Cd, Se at neutral pH, and Cd, Co, Cu, Fe, Mn, Ni, Pb, Zn at acidic pH

4.3.2 HCT Residue Characterization

A comparison of initial sample ABA and trace element results to those conducted on the humidity cell residues following the termination of kinetic testing are summarized in Table 4.10 for select parameters. Trace element data for the kinetic test residues is provided in Appendix F (Volume II).

Results on the residues typically show similar or slightly lower sulphide content to the initial tailings sample, with some within analytical variability. Modified Sobek NP and TIC as NP have reported a slight decrease in the residues compared to the initial composite, and may suggest a decrease in buffering capacity throughout the test durations. However, it is noted that some of these values are also within analytical variability.

The Doris Central mixed tailings sample reported a neutral paste pH (7.3) on the tailings solids residue despite the cell going acidic during the testing period.

Small increases in a number of the elements may be due to sample heterogeneity; however, most of the initial and residual metal contents are quite similar and typically within analytical variability.

Table 4.10: ABA Results comparison between Initial and Residual Tailings Samples

Ore Zone	Tailings Type	HC test ID	Test Sample	Static Test Results					Trace Element Concentrations						
				Paste pH	Sulphide	NP*	TIC	NP/AP	As	Cd	Cu	Mo	Sb	Se	Zn
					(%S)	(kg $CaCO_3$/t)			ppm	ppm	ppm	ppm	ppm	ppm	ppm
North	Flotation	HC-66	Initial	8.5	0.03	98	100	105	3	0.2	12	1.2	<0.1	<0.5	73
			Residue	8.6	0.05	93	93	58	3.4	<0.1	18	1.7	<0.1	<0.5	87
	Detoxified tailings	HC-67	Initial[1]	-	-	-	-	-	-	-	-	-	-	-	-
			Residue	7.6	9.95	89	78	0.3	184	1.3	409	2.6	0.3	6.8	841
	Mixed	HC-68	Initial	8.3	1.63	100	109	2.0	31	0.3	73	2.2	<0.1	0.8	177
			Residue	8.5	1.45	87	91	1.9	34	0.3	77	2.5	0.3	0.6	178
	Mixed	Historic	Initial	7.8	0.38	71	113	5.9	21	0.1	41	6.4	0.1	0.5	33
			Residue	8.0	0.30	70	93	7.5	0.001	<0.0002	<0.001	0.004	<0.001	<0.001	<0.005
Connector	Flotation	HC-57	Initial	9.2	0.04	73	114	59	3.1	0.1	25	5.1	0.1	0.5	23
			Residue	9.3	0.04	70	95	54	9.1	<0.1	20	4.6	<0.1	<0.5	21
	Mixed	HC-69	Initial	8.1	1.86	110	142	1.9	34	0.4	97	5.6	0.2	1.1	99
			Residue	8.0	1.70	105	134	2.0	89	0.3	97	5.9	0.3	1.2	99
Central	Flotation	HC-1	Initial	8.1	0.10	113	177	36	<5	<0.2	21	9.5	<5	<5	64
			Residue	8.4	0.09	177	-	63	6.4	0.3	22	4	4.2	<0.1	111
	Detoxified tailings	HC-1b	Initial	7.7	17.7	100	178	0.2	316	3.1	451	10	0.6	12	564
			Residue	7.3	14.9	24	26	0.1	353	2.9	550	8.7	1.5	10.4	568
	Mixed	HC-15	Initial	8.2	1.67	141	216	2.7	34	0.4	75	5.5	0.2	1.3	112
			Residue	8.7	1.42	133	159	3.0	38	0.5	80	5.3	0.2	0.9	111

* Modified NP except for HC-1, which is Standard Sobek NP

[1] No initial static data available for Doris North detoxified tailings (HC-67)

4.4 Saturated Columns

Summaries of key results data and figures for the sub-aqueous columns are provided in Appendix I and J (Volume II). The characteristics of the three Doris tailings samples in the sub-aqueous columns have been discussed in the sections above.

Doris Central Flotation Tailings Sub-Aqueous Column (SAD-2)

The sub-aqueous column test on the Doris Central flotation tailings operated for 23 monthly cycles. Leachate pH in the sub-aqueous column remained alkaline throughout the test. The column reported an initial flush of sulphate (maximum of 136 mg/L) that rapidly decreased to relatively stable levels (<20 mg/L) by Cycle 3. Elevated trace elements in the initial flushing cycles included phosphorus (maximum of 0.3 mg/L), cadmium (0.0002 mg/L) and copper (0.02 mg/L). Median levels have remained marginally elevated for cadmium (0.00002 mg/L). Most other parameters show steady or decreasing trends at low concentrations.

Doris Connector Flotation Tailings Sub-Aqueous Column (SAD-5)

The Doris Connector flotation tailings sub-aqueous column test was terminated after 10 monthly cycles of testing. Leachate pH was alkaline. This column reported significantly higher sulphate in the initial flush (maximum of 480 mg/L) than the Doris Central flotation (SAD-2) sub-aqueous column; however, sulphate levels were low and comparable to the Doris Central flotation tailings from Cycle 7 onward with values typically <10 mg/L.

Trace element levels elevated during the initial flushing cycles include ammonia (7 mg/L), cadmium (0.00005 mg/L), copper (0.003 mg/L) and phosphorus (0.3 mg/L). Median levels of ammonia (0.5 mg/L) and cadmium (0.00002 mg/L) were marginally elevated. Most metals of interest for this column were generally within the range of the Doris Central (SAD-2) flotation tailings samples. One exception was arsenic (median 0.0005 mg/L) which was much lower than the Doris Central flotation tailings (median 0.002 mg/L).

Doris North Mixed Tailings Sub-Aqueous Column (SAD-4)

The Doris North mixed tailings sub-aqueous column test operated for 10 monthly cycles. The pH of the Doris North mixed tailings remained alkaline. The sulphate concentration for this column had a maximum flush of 197 mg/L followed by a steady decrease to lower levels (range of 30-60 mg/L) from Cycle 4 onward, slightly higher than the steady state levels for the Doris Central and Connector flotation tailings.

Maximum values for ammonia (0.8 mg N/L) and cadmium (0.000036 mg/L) are elevated in the dataset, although these maximum values are not reported in the initial cycles. No median levels were elevated. Metal trends in the Doris North mixed tailings column leachates were generally low and stable and within the range of the Doris Central and Connector flotation tailings column leachates.

4.5 Process Water

Analysis of the tailings process water or supernatant produced during metallurgical testing is provided in Table 4.11 for selected parameters. The complete analysis results are provided in Appendix K (Volume II). Poor detection limits and limited analyses on some of the solutions prevented a detailed comparison of the process water data. Process water data results for the two 2014 Doris North samples generated by Gekko was compiled based on advice from Gekko which included the averaging of values from the final cycles of each detoxified test to provide final values.

To assess metals levels, values were screened against the CCME guidelines for the protection of aquatic life (CCME 2015). As previously mentioned, this screening is for demonstrative purposes only and is not meant to indicate anticipated exceedances in tailings pond water, as controls on solubility, etc. will likely exist in the tailings ponds.

Flotation Tailings Solutions

There was a notable difference in chemistry between the Doris Central, Doris Connector and Doris North flotation tailings solutions, with the Doris Central flotation supernatant generally characterized by higher metals. All three flotation supernatant samples were elevated in chromium, while Doris Central and Doris Connector were elevated in molybdenum and iron. The Doris Central and Doris North flotation samples contained elevated cadmium, copper, and zinc. Selenium was elevated in the Doris Central and Doris North samples, while aluminum and arsenic were only elevated in the Doris North sample.

Detoxified Tailings Solutions

Evaluation and comparison of the Doris Central detoxified tailings and Doris North detoxified tailings solutions was limited due to poor detection limits for cadmium, selenium, chromium and zinc in one or more of the solutions. Elevated metals in all samples included silver and copper, as well as elevated chromium, iron and zinc in the Doris North detoxified solutions and elevated cadmium in the Doris Central detoxified tailings. Marginally elevated arsenic was also reported in the DCO2 detoxified tailings sample, and marginally elevated nickel and molybdenum were noted in the Doris North detoxified tailings sample.

Both flotation and detoxified tailings solutions were buffered with alkaline pH ranging from 8.1 to 8.7. For most metals there was considerable overlap between flotation and detoxified tailings. Higher silver and copper concentrations were typically found in the detoxified tailings water. Sulphate was relatively low in all of the flotation tailings water (on the order of 40 to 70 mg/L) but elevated in the Doris Central detoxified tailings (500 mg/L). Sulphate was not analyzed on the two most recent detoxified cyanide leach tailings samples due to insufficient sample.

Table 4.11: Analytical Results of Process Water Generated in Metallurgical Test Work

Parameter		Units	Screening Criteria	Doris Central	Doris Connector	Doris North	Doris Central	Doris North[1]	Doris North[1]
				Flotation Tailings	Flotation Tailings	Flotation Tailings	Detoxified Tailings	Doris North Detoxified Tailings	DC02 Detoxified Tailings
Final pH			6.5-9	8.4	8.1	8.38	8.5	8.6	8.6
Alkalinity				107	180	164	160	-	-
Sulphate	SO_4	mg/L		48	70	43	530	-	-
Fluorine	F	mg/L		0.45	0.25	0.45	-	-	-
Total Cyanide		mg/L		-	0.06	*0.01*	98	3.8	2.3
Thiocyanate		mg/L				*0.01*		216	132
Nitrate	NO_3	mg/L	2.9	*0.02*	*0.01*	*1*	*0.6*	-	-
Nitrite	NO_2	mg/L	0.06	0.1	*0.01*	*0.01*	*0.5*	-	-
Ammonia as N	NH_3	mg/L	0.41	-	-	*0.01*	-	2.9	1.1
Aluminum	Al	mg/L	0.1	*0.05*	*0.05*	-	*0.01*	0.02	0.058
Silver	Ag	mg/L	0.0001	0.00036	*0.00005*	*0.01*	0.11	0.016	0.0055
Arsenic	As	mg/L	0.005	0.0024	0.0018	0.17	*0.02*	0.002	0.0068
Calcium	Ca	mg/L		35	27	*0.00005*	0.65	706	162
Cadmium	Cd	mg/L	0.000017	0.00035	*0.00002*	0.006	0.0014	*0.0001*	*0.0001*
Cobalt	Co	mg/L		-	-	0.24	0.0142	0.056	0.069
Chromium	Cr	mg/L	0.001	0.0035	0.0027	0.0073	*0.05*	0.005	0.0063
Copper	Cu	mg/L	0.002*	0.018	0.0019	0.00025	0.071	0.079	0.46
Iron	Fe	mg/L	0.3	4.9	0.78	-	0.22	0.73	0.99
Mercury	Hg	mg/L	0.000026	*0.0001*	*0.0001*	16	0.0001	0.0001	0.0001
Magnesium	Mg	mg/L		15	16	0.00008	0.34	20	19
Manganese	Mn	mg/L		0.17	0.064	0.0002	0.01	0.032	0.063
Molybdenum	Mo	mg/L	0.073	0.13	0.11	0.0028	0.015	0.082	0.071
Sodium	Na	mg/L		19	114	0.0025	-	-	-
Nickel	Ni	mg/L	0.025*	0.0045	0.0039	*0.05*	0.03	0.07	0.009
Phosphorus	P	mg/L	0.1	0.12	1.4	*0.0001*	*0.01*	-	-
Lead	Pb	mg/L	0.001*	0.0027	0.0002	32	*0.002*	0.0025	0.002
Antimony	Sb	mg/L		0.00093	0.00038	0.022	*0.002*	0.13	0.034
Selenium	Se	mg/L	0.001	0.0008	0.0034	8.4	*0.1*	*0.01*	*0.01*
Zinc	Zn	mg/L	0.03	0.028	0.0098	0.015	*0.1*	0.04	0.026

blue italics = value equals laboratory detection limit. Detection limit shown.

[a] Screening criteria are based on CCME guidelines for protection of aquatic life. Where these are hardness dependent, the minimum guideline is shown.

[1] Process water data compiled based on advice from Gekko which included the averaging of values from the final cycles of each detoxified test to provide final values.

4.6 Aging Tests

The raw data from the oxic and anoxic tailings slurry aging tests are presented in Appendix L (Volume II). Graphs showing concentrations over time are presented in Appendix M (Volume II).

Aging tests completed for the Doris ore zones included the Doris Connector and Central flotation tailings, as well as the Doris Central detoxified tailings and Doris Connector mixed tailings. The three tailings types for Doris North were not tested. Metal results are not discussed for the Doris Connector mixed tailings sample due to quality assurance and quality control issues with metal analyses for samples containing cyanide species as discussed in Section 3.7.

Apparent trends observed in the oxic and anoxic aging test data are outlined as follows:

- All tailings samples maintained alkaline pH throughout the aging testing period. The pH values for the Doris Central flotation tailings and detoxified tailings oxic tests appear to have increased with aging.
- Overall increase in alkalinity for the Doris Central and Connector flotation tailings and Doris Central detoxified tailings oxic and anoxic aging tests. The Doris Connector mixed tailings oxic test decreased in alkalinity.
- With respect to major elements, increases in sulphate and magnesium with oxic aging were observed for all tailings samples. Other major ion concentrations remained constant. The increase in magnesium raises the solution hardness; this may help aquatic organisms better tolerate any metal contaminants that may be in the solutions.
- Decrease in total cyanide and cyanate for the Doris Central detoxified tailings and Doris Connector mixed tailings oxic and anoxic tests, an indication of residual cyanide degradation in both tests.
- Increase in total ammonia for the Doris Central detoxified tailings and Doris Connector mixed tailings oxic and anoxic tests. Total ammonia is a product of cyanide degradation.
- Decreases in metal concentrations with oxic and anoxic aging were more apparent in the detoxified tailings than the flotation tailings samples. Notable decreases in the Doris Central detoxified tailings included silver, arsenic, copper (anoxic only), nickel and selenium.

Although not as definitive as the above trends, slight increases in zinc with anoxic aging were observed in the Doris Central and Connector flotation tailings samples.

5 Summary and Conclusions

Results of the geochemical characterization program on tailings from the Doris ore zones indicate the following:

- All tailings types had abundant neutralization potential and thus buffering capacity typically in the form of ferroan dolomite with minor calcite and/or siderite.
- Sulphide content, in the form of pyrite, was dependent on tailings type with high levels in the detoxified tailings, modest amounts in the mixed tailings and relatively low levels in the flotation tailings from all three ore zones.
- The results of static and humidity cell tests indicate that the detoxified tailings are clearly PAG and the flotation tailings are non-PAG. The mixed tailings, which primarily classified as having uncertain potential for ARD in the static tests, were projected to be non-PAG based on humidity cell tests. The exception was the Doris Central mixed tailings sample that was projected to generate ARD in the laboratory humidity cell test.
- Several metals in the tailings solids occur at concentrations in excess of crustal abundances. These included consistently elevated silver, arsenic, gold, cadmium, lead and selenium, and inconsistently elevated copper, molybdenum and tungsten in the detoxified tailings, as well as elevated gold, arsenic and selenium in the mixed tailings, and elevated gold in the flotation tailings. Many of these metals are associated with sulphides and as indicated will primarily partition in to the detoxified tailings.
- Long-term humidity cell tests indicate that after the initial flushing of the samples, an increased tendency for neutral pH metal leaching of arsenic from the Doris North tailings (flotation, mixed and detoxified tailings) as well as the Doris Connector mixed tailings.
- The detoxified tailings also showed a propensity for leaching of several metals in the humidity cell tests. In addition to arsenic, neutral pH metal leaching of ammonia, cadmium, copper, iron, selenium and silver was reported in the Doris North detoxified tailings, and cadmium and selenium in the Doris Central detoxified tailings. Acidic conditions developed in the Doris Central detoxified tailings after 202 weeks of testing. At acidic pH, increased metal leaching of Cd, Co, Cu, Fe, Mn, Ni, Pb, and Zn was noted.
- Marginally elevated median concentrations of copper and lead in the Doris Central flotation tailings humidity cell tests may indicate possible leaching of these metals from the Doris Central flotation tailings. Marginally elevated selenium was also reported in the Doris North mixed tailings.
- Process water chemistry associated with the tailings slurry samples, analyzed to provide an indication of possible water chemistry to be discharged to the tailings facility, indicated elevated levels for several aqueous phase metals that varied by tailings type and ore zone.
- Process water associated with the detoxified tailings was alkaline and typically elevated in sulphate, total cyanide, ammonia, silver, cadmium, copper, chromium, and likely selenium. Process water from the Doris North detoxified tailings was also marginally elevated in

arsenic, iron, molybdenum, nickel, lead and zinc. With aging, the detoxified tailings process water chemistry generally improved with decreases in cyanide products and most metals in particular silver, arsenic, copper, nickel and selenium.

- Process water chemistry between the Doris Central, Doris Connector and Doris North solutions was notably different with the Doris Central process water characterized by higher metals. Chromium was elevated in all three solutions; molybdenum, and iron were elevated in both Doris Central and Connector solutions; while cadmium, copper, and zinc were elevated in Doris Connector and Doris North Solutions. The Doris Central and Doris North flotation tailings water were also elevated in silver and lead, and aluminum and arsenic, respectively.

This report, **Geochemical Characterization of Tailings from the Doris Deposits, Hope Bay**, was prepared by SRK Consulting (Canada) Inc.

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All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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Package 6
Engineering and Design Documents

P6-13 Tailings Management System

Doris North Project
Tailings Management System Design

Prepared for

TMAC Resources Inc.

Prepared by

SRK Consulting (Canada) Inc.
1CT022.002.200.560
May 2015

Doris North Project
Tailings Management System Design

May 2015

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Appendices

1 Introduction

1.1 Background

TMAC Resources Ltd. plan to revise their Tailings Management System (TMS) to accommodate a greater volume of tailings at the Doris North Project, located in Nunavut, approximately 160 km southwest of Cambridge Bay (Drawing DN-TIA-01).

The current licensed TMS entails subaqueous deposition of about 0.4 Mt of tailings into the designated Tailings Impoundment Area (TIA). This TIA is a former natural lake (Tail Lake), which has been delisted in accordance with Schedule II of the Metal Mining Effluent Regulations (MMER). To ensure environmental containment, the TIA would be impounded though construction of two frozen core water retaining dams, the North and South Dams. At closure, once environmental discharge criteria would have been met within the TIA, the North Dam would be breached returning the water level, in the TIA, to the pre-mining elevation of 28.3 m providing a permanent water cover over the tailings of about 4 m.

TMAC has revised their mine plan, increasing the total amount of ore that will be processed through the mill, and subsequently the tailings generated to about 2.5 Mt. With this increased amount of tailings, assuming the TMS remains unchanged, both the North and South Dams would have to remain as perpetual water retaining structures. Since this is not deemed to be a sustainable option, a revised TMS is required.

The TMS has subsequently been redesigned to incorporate a sub-aerial deposition strategy starting at the south end of the TIA. Tailings will be deposited along the southern end of the TIA and will be contained by a new Interim Dike about 1,500 m north of the South Dam (which has not yet been constructed). The remaining portion of the TIA between the Interim Dike and the existing North Dam (completed in 2012, SRK (2012)) will not contain any tailings, and will act as a Reclaim Pond. Tailings will be spigotted from a number of points along the eastern perimeter of the TIA and from the South Dam creating a landscape that drains towards the Interim Dike at an average slope of about 1%.

The South Dam was originally designed as a frozen core dam (SRK 2007a), as it was intended to retain water for a period of up to 20 years. With the proposed revised tailings management system, the South Dam is no longer required to retain water since the tailings will be beached from the face of the dam from the start of operations. As a result, the South Dam design has been changed to a frozen foundation dam consisting of a compacted rock fill dam with a geosynthetic clay liner (GCL) keyed into the permafrost overburden foundation. This change will result in a reduced overall dam footprint from what was previously proposed.

Upon closure, the tailings surface will be covered with a nominal waste rock cover of 0.3 m thickness. The function of the cover is to prevent wind and water erosion. The cover will terminate at the Interim Dike, and the Interim Dike will be levelled to match the elevation of the cover. Once the water quality in the Reclaim Pond has reached the required environmental discharge criteria, the North Dam will be breached as originally intended.

1.2 Scope of Work

SRK Consulting (Canada) Inc. was contracted by TMAC to carry out the preliminary design of the revised TMS for the Doris North Project. The design and related information provided in this report has been prepared in accordance with industry best practice, which includes, but is not limited to the Canadian Dam Safety Guidelines, as documented by the Canadian Dam Association (CDA) (CDA 2007, 2013), the Technical Bulletin on Application of Dam Safety Guidelines to Mining Dams (CDA 2014), various Mining Association of Canada guidelines (MAC 2011a, b, c) and publications and bulletins published by the International Commission of Large Dams (ICOLD).

In addition, in recognition of the 2014 Mt. Polley tailings dam failure in British Columbia, the design takes into consideration the key recommendations as outlined in the subsequent Independent Expert Engineering Investigation and Review Panel Report (IEEIRP 2015).

The design as presented, is considered preliminary engineering. In the context of this report, this refers to a design that defined to the same level of detail as previously presented (SRK 2005a, 2007a) to the Nunavut Impact Review Board (NIRB), and the Nunavut Water Board (NWB) for issuance of the Doris North Project Certificate and Water License respectively.

1.3 Report Structure

Section 2 of this report provides a summary discussion of the TMS concept including a comparison of the existing licenced TMS with the proposed revised TMS and the rationale used to select a preferred TMS alternative. The TMS design criteria are presented in Section 3, and summary details of the new containment structure design analysis are provided in Section 4. Section 5 list the TMS construction details, including construction material take-off quantities. The TMS operational plan which includes the deposition plan is described in Section 6. TMS closure concludes the report in Section 7.

A comprehensive list of appendixes is included which provides details pertaining to the TMS options analysis, tailings deposition plan, hydro-technical design and engineering analysis (seepage, stability, thermal and consolidation). A comprehensive set of supporting drawings for the new containment structures are also included as an Appendix.

1.4 Reliance on Previous Reports

This report is considered complimentary to reports that have been filed on the public registries as part of the original TMS regulatory approval process or for subsequent compliance reporting. Since much of this information remains valid, the reader is referred to these reports for background information such as general site characterization data which remain unchanged. Table 1 summarizes the key previous reports referred to in this context.

Table 1. Pertinent Previous Reports Relied upon for the Revised TMS Design

Reference	Report Function
SRK Consulting (Canada) Inc. (2005a). *Preliminary Tailings Dam Design, Doris North Project, Hope Bay, Nunavut, Canada*. Report prepared for Miramar Mining Corporation, Project number 1CM014.006, October.	This report was submitted as part of the Final Environmental Impact Assessment for the Doris North Project (MHBL 2005), which ultimately led to issuance of the Project Certificate.
SRK Consulting (Canada) Inc. (2007a). *Design of the Tailings Containment Area, Doris North Project, Hope Bay, Nunavut, Canada*. Report Prepared for Miramar Hope Bay Limited. Project number 1CM014.008.165, March.	This report was submitted as part of the Water Licence Application for the Doris North Project (MHBL 2007), which ultimately led to issuance of the Original Water Licence (2AM-DOH0713).
SRK Consulting (Canada) Inc. (2012a). *Hope Bay Project, North Dam As-Built Report*. Report Prepared for Hope Bay Mining Limited. Project number 1CH008.058, October	This report was submitted to the NWB in fulfillment of a Licence Condition after completion of construction of the North Dam.

2 Tailings Management System Concept

2.1 Current Licensed Tailings Management System

The current licensed TMS for the Doris North project entails subaqueous tailings deposition within the designated TIA (SRK 2007a). This TIA was a natural lake, Tail Lake, which was delisted in accordance with Schedule II of the Metal Mining Effluent Regulations (MMER) specifically for use as a tailings facility.

Under the current licenced plan, environmental containment for the TIA would be provided through the construction of two water retaining frozen core dams, the North Dam and the South Dam. About 397,000 tonnes (307,083 m^3) low solids density slurry tailings was to be deposited subaqueously over a period of about two years at a tailings production rate of about 800 tpd. This included a mixed stream consisting of both flotation and detoxified cyanide leach tailings. At closure, once environmental discharge criteria have been met, the North Dam would have been breached, allowing the TIA to return to its pre-mining elevation of 28.3 m, which meant the tailings would have a permanent water cover of 4 m.

2.2 New Tailings Storage Requirements

Further mine planning has resulted in an overall revised mine plan for the Project with a targeted ore volume of about 2,500,000 tonnes (1,938,000 m^3). The tailings production rate will be 1,000 tpd for the first two years, after which it will increase to 2,000 tpd for the remainder of the life of the Project.

About 6% (i.e. 150,000 tonnes or 116,000 m^3) of the tailings are comprised of detoxified cyanide leach tailings, and this tailings stream will be sent underground where it will be mixed with underground waste rock for use as structural mine backfill. The remaining 2,350,000 tonnes (1,822,000 m^3) of flotation tailings will be sent to the TIA; however, this volume exceeds the amount that can subaqueously be deposited in the TIA while maintaining the current licenced closure strategy of breaching the North Dam.

2.3 Selection of Preferred Revised Tailings Management System

Appendix B contains a comprehensive qualitative description of alternative tailings management strategies that was developed in support of the revised mine plan. The alternatives evaluation is considered an extension of the earlier alternatives assessments carried out for the project during the assessment and licensing phases (SRK 2005b). The conclusions of this assessment can be summarized as follows:

- The preferred tailings disposal site is the existing licenced TIA.
- The preferred tailings disposal strategy is subaerial slurry tailings deposition between the South Dam and a new Interim Dike, confining tailings deposition to the southern limit of the TIA.

- The preferred tailings closure strategy is a dry cover over the subaerial tailings surface, and breaching of the North Dam which impounds the Reclaim Pond during the operational stage.
- To eliminate long term closure risk with application of a dry cover, only flotation tailings will be discharged to the TIA. All detoxified cyanide leach tailings will be deposited underground as part of the mine backfill.

2.4 Existing/Unchanged Tailings Management System Infrastructure

2.4.1 North Dam

The North Dam, which is the primary containment structure for the TMS was completed in 2012 (SRK 2012) following a two season construction period. This structure is a water retaining frozen core dam, with a design life of 20 years. Under the proposed new TMS the North Dam will remain fully functional as a water retaining dam for the life of the project, retaining the water in the Reclaim Pond. In accordance with the proposed site wide water management plan (TMAC 2015) informed by the site wide water and load balance (SRK 2015) the water level in the Reclaim Pond will typically vary between 27.3 m and 32.5 m under normal operating conditions. The dam however has a Full Supply Level (FSL) of 33.5 m providing ample additional storage capacity in case of unforeseen or upset conditions. No changes are proposed to this structure to support the revised TMS presented in this report.

Since its construction, the North Dam has been subject to Annual Geotechnical Inspections by a Professional Geotechnical Engineer Licensed to Practice in Nunavut in accordance with the stipulated Water Licence conditions (SRK 2013, 2014a, and 2014b). The inspection reports, which includes a comprehensive analysis of the rigorous dam instrumentation, confirm that the dam is functioning as designed.

2.4.2 North Dam Spillway

The water level in the TIA will be actively managed through annual discharges to Roberts Bay. Water quality modeling confirms that there are no plausible scenarios where the TIA will ever reach the North Dam FSL and therefore an outflow spillway will not be required.

However, as a matter of best practice, an operational spillway has been designed for the TIA at the North Dam, at the FSL of 33.5 m. This side-spillway will be 18 m wide, about 180 m long along its centerline, with an average gradient of about 0.8%. The Inflow Design Flood (IDF) of 3.3 m^3/sec, will pass through the spillway with a maximum flow depth of about 0.2 m at a sub-critical flow velocity of about 1.1 m/sec (SRK 2007a).

Construction of the spillway will however be deferred until such time as the most conservative water balance evaluations suggest that the FSL level will be reached within two calendar years. This will allow sufficient time to mobilize equipment and materials with which to construct the spillway.

2.5 Tailings Management System Changes

Table 2 summarize the proposed changes to the TMS presented in this report, compared against the existing licensed TMS.

Table 2. Summary of Proposed TMS Changes

Component	Existing Licensed TMS	Proposed Revised TMS
Tailings volume (tonnes)	0.4 million	2.5 million
Tailings Make-up	Mixed stream of flotation and detoxified cyanide leach tailings	Only flotation tailings; detoxified cyanide leach tailings is deposited underground
Deposition Method	Subaqueous (single point discharge; multiple locations)	Subaerial (single point discharge; multiple locations)
North Dam	Frozen core with secondary GCL and horizontal thermosyphons; Crest elevation 37.5 m	No change; construction completed in 2012
South Dam	Frozen core with secondary GCL and secondary thermosyphons; Crest elevation 38.0 m	Frozen foundation with secondary GCL; Crest elevation 38.0 m
Interim Dike	Did not exist	New containment structure
Spillway	Spillway at North Dam capable of passing the IDF; construction deferred until water balance demonstrates need	No change
TIA Discharge Strategy	Seasonal discharge to Doris Creek; Not to exceed 10% of Doris Creek hydrograph; CCME guidelines for the protection of aquatic life (fresh water) to be met downstream of Doris Creek waterfall	Seasonal discharge to Roberts Bay; Fixed constant discharge rate; CCME guidelines for the protection of aquatic life (marine) to be met beyond mixing zone in Roberts Bay
Closure Strategy	Breach North Dam; Permanent water cover of 4 m	Breach North Dam; 0.3 m thick dry cover

3 Tailings Management System Design Criteria

3.1 Dam Hazard Classification

The design, construction, operation and monitoring of dams in Canada have to be completed in accordance with appropriate territorial, provincial, and federal regulations and industry best practices. The foremost guidance documents in this regard are the Canadian Dam Safety Guidelines (CDA 2013) and the Technical Bulletin on Application of Dam Safety Guidelines to Mining Dams (CDA 2014) published by the CDA.

A key component of the guidelines is classifying the dam(s) in question into hazard categories (dam class) that establish appropriate geotechnical and hydro-technical design criteria. Table 3 is a reproduction of the recommended dam classifications as presented in the CDA guidelines. This classification is based on the incremental consequence of a dam failure (as opposed to total consequence). The incremental consequences of failure are defined as the total damage from an event with dam failure, less the damage that would have resulted from the same event (e.g., a large earthquake or a large flood event) had the dam not failed.

Table 3. Dam Hazard Classification as per CDA (2013)

Dam Class	Population at Risk[1]	Incremental Losses		
		Loss of Life[2]	Environmental and Cultural Values	Infrastructure and Economics
Low	None	0	Minimal short-term loss No long term loss	Low economic losses; area contains limited infrastructure or services
Significant	Temporary Only	Unspecified	No significant loss of fish or wildlife habitat Loss of marginal habitat only Restoration or compensation in kind highly possible	Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes
High	Permanent	10 or fewer	Significant loss or deterioration of important fish or wildlife habitat Restoration or compensation in kind highly possible	High economic losses affecting infrastructure, public transportation, and commercial facilities
Very High	Permanent	100 or fewer	Significant loss or deterioration of critical fish or wildlife habitat Restoration or compensation in kind possible but impractical	Very high economic losses affecting important infrastructure or services (e.g. highway, industrial facility, storage facilities for dangerous substances)
Extreme	Permanent	More than 100	Major loss of critical fish or wildlife habitat Restoration or compensation in kind impossible	Extreme losses affecting critical infrastructure or services (e.g. hospital, major industrial complex, major storage facilities for dangerous substances)

[1] Definitions for population at risk:
None – There is no identifiable population at risk, so there is no possibility of loss of life other than through unforeseen misadventure.
Temporary – People are only temporarily in the dam-breach inundation zone (e.g. seasonal cottage use, passing through on transportation routes, participating in recreational activities).
Permanent – The population at risk is ordinarily located in the dam-breach inundation zone (e.g. as permanent residents); three consequence classes (high, very high, extreme) are proposed to allow for more detailed estimates of potential loss of life (to assist in decision-making if the appropriate analysis is carried out).

[2] Implication of loss of life:
Unspecified – The Appropriate level of safety required at a dam where people are temporarily at risk depends on the number of people, the exposure time, the nature of their activity, and other conditions. A higher class could be appropriate, depending on the requirements. However, the design flood requirement, for example, might not be higher if the temporary population is not likely to be present during the flood season.

Determination of the appropriate hazard rating is often subjective and is dependent on site-specific circumstances that may require an agreement between the proponent, regulators, and stakeholders. During the dam classification process, each of the four hazard rating components, in Table 3 (i.e., population at risk, loss of life, environmental and cultural values, and infrastructure and economics) is considered individually and the overall dam hazard rating is defined by the component with the highest (i.e., most severe) rating. It is important to note that the hazard rating refers to the downstream consequences in the inundation zone of a dam breach.

The North and South Dams were previously designated with a hazard classification of LOW (SRK 2005a, 2007a). This hazard classification was however based on the previous CDA guidelines (CDA 1999), prior to the 2007 revision (CDA 2007). The revised TMS therefore requires revisiting of the hazard classification assigned to the existing North Dam, as well as the revised South Dam and proposed new Interim Dike.

For the North and South Dams, the "*Population at Risk*" has been generously selected as "*Temporary Only*" due to very infrequent need for personnel to monitor the dams and areas in the likely dam breach inundation zone. The "*Loss of Life*" has again conservatively been selected as "Unspecified" to reflect that there will be small periods of time where persons will be present, but exposure time is very limited and infrequent. For the Interim Dike, the "*Population at Risk*" is considered "*None*", and the likely "*Loss of Life*" is conceivably "*Zero*", since a breach of this structure would not impact an area beyond the confines of the TIA. Importantly, a breach of this structure will also not put either the North or South Dam at risk.

The "*Environment and Cultural*" impacts associated with breach of the Interim Dike are very low due to the fact that the breach will not extend beyond the confines of the TIA. Although such a breach may result in release of tailings solids into the Reclaim Pond, it would not extend to the North Dam. A breach of the North Dam will result in release of supernatant water (not solids), which will exceed CCME guidelines for protection of aquatic life (fresh water) to Doris Lake and subsequently Doris Creek. A breach of the South Dam could result in release of tailings solids and supernatant water into Ogama Lake, and subsequently supernatant water into Doris Lake. Ogama and Doris Lake are considered significant habitat, but restoration of this habitat would be highly possible.

"*Economic*" consequences of a breach of any of the three structures could be significant in terms of direct costs to the proponent, including reputational loss, but would be very minimal in terms of losses to infrastructure or services that might affect other parties.

Based on these factors, the three containment structures are assigned a dam hazard classification as summarized in Table 4.

Table 4. Dam Hazard Classification of TIA Containment Structures

Dam Class	Population at Risk	Loss of Life	Environmental and Cultural Values	Infrastructure and Economics	Overall Hazard Classification
North Dam	SIGNIFICANT	SIGNIFICANT	HIGH	LOW	HIGH
South Dam	SIGNIFICANT	SIGNIFICANT	HIGH	LOW	HIGH
Interim Dike	LOW	LOW	LOW	LOW	LOW

3.2 Design Life

The Doris North Project has a design life of about six years, with subsequent closure taking about four years. Therefore, the TIA operational life (i.e. the period prior to full closure) is about 10 years. The North Dam, which was completed in 2012 (SRK 2012) had an original design life of 20 years as a water retaining structure, assuming it was operating at full supply level (33.5 m) 100% of the time. Since its completion the normal water level in the TIA has been about 28.5 m, with a peak of 29.3 m. The most up to date monitoring confirms that the structure is performing in accordance with the design (SRK 2014b) and therefore it is reasonable to conclude that the structure still has a useable design life of 20 years.

At closure, the Interim Dike and the South Dam will continue to be required to contain tailings solids. These structures must therefore remain in perpetuity.

3.3 Tailings Storage Requirement

The revised mine plan for the Doris North Project has a targeted ore volume of about 2,500,000 tonnes. Tailings physical testing for the Project was carried out which confirmed that the tailings dry density will be about 1.29 tonnes/m^3 (SRK 2007a). The tailings production rate will be 1,000 tpd for the first two years, after which it will increase to 2,000 tpd for the remainder of the life of the project.

About 6% of the tailings are comprised of detoxified cyanide leach tailings, and these tailings will be sent underground where it will be mixed with underground waste rock for use as structural mine backfill. For the purpose of design this reduction in volume is not considered important. Ice entrainment during subaerial tailings deposition is a common problem for arctic projects (BGC 2003). A design allowance of 20% has been accounted for in the TIA. Complete Project tailings storage requirements are summarized in Table 5.

Table 5. Tailings Storage Requirements

Component	Value	Source
Tailings storage requirement	1.93 Mm^3 (2.5 Mt)	Quantity based on TMAC mine plan; volume conversion based on dry density listed below in this table.
Tailings production	1,000 tpd (Years 1 and 2) 2,000 tpd (Year 3 onwards)	Supplied by TMAC.
Tailings production period	4 years, 5 months	Based on total tailings volume processed at the stated production rates.
Ice entrainment allowance	0.39 Mm^3 (20% by volume)	Contingency allowance based on engineering judgement and case studies reported by BGC (2003).
Total storage requirement	2.32 Mm^3	Sum of tailings storage requirement and ice entrainment allowance.
Run-off and contact water allowance	Not required	Additional storage capacity not required as water will be directed towards the Interim Dike, which will retain solids but not water. Overall water management will be via the Reclaim Pond downstream of the Interim Dike.
Deposited tailings dry density	1.29 t/m^3	From laboratory testing (SRK 2007a; Knight Piesold 2009, Pocock 2009).

3.4 Tailings Beach Slope

Tailings placement will result in beach development. No specific tailings physical characterization has been carried out to confirm the expected tailings beach slope angle for the Project; however, typical gold tailings deposited sub-aerially are known to have beach slope angles that range between 0.5 and 2% (Vick 1990). Where the tailings beach transition to a pond, the slope angle can increase to between 5 and 7%. An overall beach slope angle of 1% has been assumed for the purpose of tailings deposition modeling for the project (Appendix C). Should the actual slope be substantially different, additional deposition points will be added into the overall tailings deposition plan to ensure that the final landform can still be developed.

3.5 Stability Criteria

The minimum factors of safety (FOS) that are required to be achieved for the revised South Dam and the Interim Dike, are defined by the Canadian Dam Safety Guidelines (CDA 2013), and are reproduced in Table 1.

Table 6. Minimum Required Factors of Safety for the South Dam and Interim Dike in Accordance with CDA (2013)

Stability Condition	Minimum Factor of Safety	Slope
Static Assessment		
During, or at end of construction	Greater than 1.3 depending on risks assessed during construction	Typically downstream
Long-term (steady-state seepage, normal reservoir level)	1.5	Downstream
Full or partial rapid drawdown	1.2 to 1.3	Upstream slope where applicable
Seismic Assessment		
Pseudo-static	1.0	Downstream
Post-earthquake	1.2	Downstream

Note: This table is summarized from Tables 3-4 and 3-5 in CDA (2013)

3.6 Design Earthquake

Based on the dam hazard classification of HIGH and LOW assigned to the South Dam and Interim Dike respectively, the Annual Exceedance Probability (AEP) earthquake design ground motion will be 1/100 (0.01) and 1/2475 (0.002) using both the risk-informed and standards based approaches (CDA 2013).

The seismic hazard calculation for the Project site using the 2010 National Building Code of Canada (NBC 2010) yields a peak ground acceleration (PGA) of 0.036 g. This value assumes a 2% probability of exceedance in 50 years (0.0004). Commensurate with the North Dam design (SRK 2005a, 2007a), this value was adopted for design of the South Dam and Interim Dike. This value has an AEP of one order of magnitude smaller than the minimum required as described above and is therefore extremely conservative.

3.7 Inflow Design Flood

For the Interim Dike with a hazard classification of LOW, the AEP for floods for both the risk-informed and standards-based approaches is 1/100 (0.01). For the North and South Dams, which has a hazard classification of HIGH, the risk-informed approach suggest use of AEP of 1/2475 (0.002) when using the risk based approach, and a value 1/3 between 1/1000 (0.001) and the probable Maximum Flood (PMF) when using the standards-based approach (CDA 2013).

The North Dam spillway has been designed for an Inflow Design Flood (IDF) of 24-hour duration with a recurrence interval of 500 years. This is equivalent to an AEP of 0.005, which exceeds the requirements of the guidelines. As an added measure of conservatism, the spillway flood capacity calculation assumes a 100% runoff factor, and zero attenuation of the flood peak within the TIA catchment.

3.8 Wave Run-up

Wave run-up for the North and South Dam was previously calculated as 1.7 m (SRK 2005a). This was considered too conservative and was re-evaluated to be 0.3 m (SRK 2007a). Appendix D contains details of the wave run-up calculation for the Interim Dike, which is equal to 1.56 m.

3.9 Design Freeboard

The FSL for the North Dam is 33.5 m, which corresponds to the invert elevation of the spillway. The normal freeboard is 1.8 m, which exceeds the minimum required for wave run-up of 0.3 m (SRK 2007a). Since the North Dam integrity relies on maintaining a frozen core, it requires thermal insulation above the frozen core (and GCL termination at elevation 35.3 m) of 2.2 m. This brings the crest elevation to 37.5 m, for an overall freeboard of 2.2 m, which 0.4 m greater than the normal freeboard.

The South Dam is no longer primarily a water retaining structure. Once the tailings beach develops, there will not be any water adjacent to the structure. The GCL will terminate at elevation 37.0 m which is 3.5 m higher than the TIA FSL, and 1.7 m above the normal freeboard height of the TIA. Tailings deposition will terminate at elevation 36.5 m at the South Dam, and with the Dam crest at 38.0 m this leaves a total freeboard of 1.5 m.

Appendix D contains details of the freeboard assessment for the Interim Dike, yielding a value of 1.8 m. At the FSL of 33.5 m, this would require the Interim Dike to have a crest elevation of 35.3 m. Overtopping, or even complete inundation, of this structure is not really a concern as long as the structure remains in place. Therefore the goal is not to ensure maintenance of the full hydraulic freeboard of this structure at all times. The normal operating level of the TIA is expected to be between 27.3 m and 32.5 m under normal operating conditions, and as a result the Interim Dike will initially be constructed to an elevation of 31.0 m. This structure may be raised over the life of the Project if required.

3.10 Summary of TMS Design Criteria

A complete summary of the TMS containment dam design criteria are listed in Table 6, and are consistent with Best Management Practices, including the Canadian Dam Association (CDA 2013, 2014) guidelines.

Table 7. Summary of TMS Containment Dam Design Criteria

Component	Criteria
Dam Hazard Classification	North Dams (HIGH) South Dam (HIGH) Interim Dike (LOW)
Design Life • Active use period as water retaining structure • Design basis as active water retaining structure • Active use period as solids retaining structure • Design basis as solids retaining structure • Total life until breach	 North Dam (10 years); South Dam (1 year) North Dam (20 years); South Dam (5 years) South Dam (5 years); Interim Dike (5 years) South Dam (100 years); Interim Dike (100 years) North Dam (10 years)
Dam staging	North Dam (none) South Dam (none) Interim Dike (none planned, but can be raised)
Tailings production rate	1,000 tonnes per day for first 2 years 2,000 tonnes per day for remaining mine life
Tailing slurry content	36.1% solids (by weight)
Tailings solids specific gravity	2.7
Tailings settled density	1.29 t/m^3
Tailings storage requirement • By mass • By volume	 2.5 Mt 1.93 Mm^3
Ice entrainment allowance • Percentage of tailings capacity • By volume	 20% 0.39 Mm^3
Tailings beach slope • Subaerial tailings • Sub-aqueous tailings	 1% 1%
Tailings deposition method	Single point spigot subaerial discharge (six locations over the life of mine)
Maximum design earthquake	1:2,475 year recurrence event; PGA of 0.036 g
Inflow design flood	1/3 between 1:1000 year event and probable maximum flood; approx. 131 mm
Freeboard requirement	North Dam (1.8 m normal, 4 m total) South Dam (0.5 m normal, 1.5 m total) Interim Dike (1.5 m normal, 1.5 m total)
Stability Factors of Safety (Static)	1.3 during construction 1.5 during operation and closure 1.2 to 1.3 partial or rapid drawdown
Stability Factors of Safety (Pseudo-Static)	1.0 during earthquake 1.2 post earthquake

4 South Dam and Interim Dike Design

4.1 Foundation Conditions

4.1.1 South Dam

Rigorous foundation characterization has been carried out at the proposed South Dam alignment (SRK 2003b, 2005a, 2007a). The foundation conditions are variable, with the overburden thickness thinning significantly towards the abutments, as illustrated in Drawing DN-TIA-05. Towards the center of the proposed alignment, the overburden profile is at its maximum thickness. The upper approximately 5.5 m of the profile consists of marine silt, which transitions to marine silt and clay to a depth of about 24 m below ground surface (i.e. about 18.5 m thick). Beneath these sediments is a layer of gravelly till of about 10 m thickness overlying the host basalt bedrock. The entire profile is cold permafrost (-8ºC surface temperature), with an active layer thickness of about 1 m. The marine silts and clays are ice rich, and there are clear ice lenses present. Salinity results from samples collected in the footprint of the South Dam foundation indicate salinity ranges from 30 to 46 parts per thousand, with an average of about 41 parts per thousand. This results in a depressed freezing point of about -2.3ºC in accordance with Velli and Grishin’s empirical formulation (Andersland and Ladani 2004).

4.1.2 Interim Dike

There has been no geotechnical characterization of the foundation conditions beneath the proposed alignment of the Interim Dike. A series of condemnation holes were drilled in Tail Lake, approximately 1,700 m north of the proposed Interim Dike location (SRK 2003b). These holes suggest that the overburden thickness is likely to be in the order of 5 to 22 m thick, but provide little detail of the material. Detailed characterization of lake bed sediments in nearby Doris and Patch Lakes (SRK 2009), suggest lake bed thickness (i.e. overburden thickness) of between 4.8 and 35.8 m would not be unreasonable to expect. Foundation conditions beneath the North Dam (SRK 2007a, 2012) are similar to those under the proposed South Dam alignment; however, the overall overburden thickness is shallower beneath the North Dam since there is no evidence of the gravelly till zone being present.

All of this anecdotal evidence, together with the fact that Tail Lake, the original lake forming the TIA is a much smaller lake than either the Doris or Patch Lakes, and is geomorphologically different, was used to conservatively adopt foundation conditions beneath the Interim Dike similar to those observed under the South Dam, but with the following modifications as illustrated in Drawing DN-TIA-03. The upper 5 m of the profile was assumed to be unconsolidated lake bed sediments overlying about 18.5 m of marine silt and clay. This once again overlies about 10 m of gravelly till over in-situ basalt bedrock. The TIA is believed to host a closed talik underneath it; however, this has not been conclusively demonstrated (SRK 2003a). For the purpose of this assessment the entire profile underneath the proposed Interim Dike was assumed to be within this talik. This profile is considered very conservative.

Based on the assumed soft, unconsolidated nature of the lake bed sediments, the top 2.5 m of sediments under the Interim Dike footprint will be assumed to have mixed with, or be displaced by the rock fill construction material, improving the material parameters in the zone of disturbance (i.e. mixing zone).

4.2 Functionality and Design Parameters

Tailings will be retained between the South Dam and the Interim Dike. The South Dam was originally designed as a frozen core dam (SRK 2005a, 2007a), as it was intended to retain water for a period of up to 20 years. With the proposed revised TMS, the South Dam is not required to retain water since the tailings will be beached from the face of the dam early on during the tailings deposition plan. As a result, the South Dam design has been changed to a frozen foundation dam consisting of a compacted rock fill dam with a geosynthetic clay liner (GCL) keyed into the permafrost overburden foundation.

The South Dam has been designed with a crest width of 10 m and an upstream slope of 4:1 H:V and downstream slope of 2:1 H:V. The crest elevation is set at 38.0 m and results in a maximum dam height of 6 m. The key trench will be about 4 m deep, have a base width of 4 m with 2H:1V, and 1H:1V upstream and downstream slopes respectively. The GCL will be placed along the entire base of the key trench, along the upstream face of the key trench and then slope back within the center of the dam at a slope of 3H:1V.

The Interim Dike is a homogeneous run of quarry (ROQ) rock fill dike placed in the TIA, directly on the existing lake bed sediments, without dewatering the TIA. The Interim Dike will have a crest elevation of 31.0 m, a crest width of 10 m, and upstream and downstream slopes of 3H:1V. The maximum height of the Interim Dike will be about 7.5 m, with the bottom 4.8 m being below the pre-existing water level in the TIA of 28.3 m. The Interim Dike is not required to hold back tailings supernatant water, but is expected to retain tailings solids.

The key design parameters of the TMS containment structures are summarized in Table 8.

Table 8. Summary of TMS Containment Structure Design Parameters

Parameter	South Dam	Interim Dike
Structure type	Frozen foundation rock fill dam with geomembrane	Homogeneous rock fill dam
Geomembrane type	GCL (Geosynthetic Clay Liner)	None
Geomembrane deployment slope	3H:1V	n/a
Structure crest centerline length	375 m	225 m
Structure maximum height	6.0 m	7.5 m
Structure crest elevation	38.0 masl	31.0 masl
Full supply level (FSL)	33.5 masl	33.5 masl
Total freeboard	1.5 m	1.5 m
Spillway	None	None
Structure crest width	10 m	10 m
Upstream structure slope	4H:1V	3H:1V
Downstream structure slope	2H:1V	3H:1V
Key trench depth	4 m	n/a
Key trench upstream slope	2H:1V	n/a
Key trench downstream slope	1H:1V	n/a

4.3 South Dam Components

4.3.1 Key Trench

Considering the foundation conditions along the proposed alignment of the South Dam, the key trench will be excavated in the frozen overburden soils underlying the dam to a depth of about 4 m (see Drawing DN-TIA-06). The key trench will terminate on frozen overburden soil; however, should any massive ice be encountered, the key trench must be deepened until all the massive ice has been removed. The upstream slope of the key trench will be excavated to 2H:1V to accommodate the deployment of the geomembrane. The downstream slope will be excavated to a grade of 1H:1V to minimize the excavation.

Excavation of the key trench must be completed in the winter when the ground is completely frozen. This is necessary to ensure that the ground is as cold as possible before backfilling starts to facilitate the bond between the foundation and the geosynthetic liner. Drill and blast methods will be required to excavate the key trench, and due to the possible high ice content and nature of the soils, a tight drill pattern and high blast load factor will be required. The excavated material will have to be hauled away and disposed of in designated overburden dump, most likely at Quarry #3.

4.3.2 Geosynthetic Clay Liner

The GCL will be the water retaining element of the dam and will be frozen into the key trench to provide the necessary seal. The GCL will be deployed in a chevron shape, starting at the base of the key trench, along the upstream 2H:1V key trench slope, and then sweeping back on a 3H:1V to an elevation of 37.0 m, which is 1 m below the dam crest (see Drawing DN-TIA-06). The top edge of the GCL will be terminated in an appropriately sized tuck trench. The GCL will be deployed in vertical strips (the width of the GCL rolls). Overlaps will be at least 0.5 m wide, and all overlaps will have a bead of granular bentonite spread between them.

In the base of the key trench, the GCL will be placed directly onto the prepared and clean foundation with imperfections filled with granular bentonite. In all other areas, the GCL will be sandwiched between two 0.3 m thick compacted layers of crushed gravel (pea gravel size).

4.3.3 Dam Bulk Fill

The bulk fill of the South Dam, including the key trench, will consist of geochemically suitable run-of-quarry (ROQ) material. The quarry rock size will be limited to material with a maximum size of 600 mm and well graded with a good mix of fines. This material must be placed in lifts no greater than 1 m and must be compacted with a 15 tonne vibratory compactor or using wheel traffic from loaded haul trucks.

4.3.4 Transition Zone

The GCL is protected using a fine crushed gravel (pea gravel) produced from ROQ material. To minimize losses of this bedding material, a transition zone of 150 mm minus crushed ROQ material will be placed between the bedding and dam bulk fill zones. The material must be well graded with sufficient fines. This bedding layer will be about 1 m thick, will be placed in a single lift, and compacted using the same means as the dam bulk fill.

4.3.5 Bedding Zone

The GCL will be sandwiched between two 0.3 m thick compacted layers of bedding material for protection. This material will be ROQ material crushed to pea gravel size.

4.3.6 Dam Shell

No special dam armouring is required, and no special upstream or downstream riprap is required. The dam shell will be constructed using the same ROQ material as the dam bulk fill.

4.3.7 Monitoring Instrumentation

A series of ground temperature cables and survey prisms will be installed at the South Dam to monitor the thermal regime of the foundation and overall deformation performance.

Vertical ground temperature cables will be installed in boreholes drilled through the dam fill after the completion of the dam. The portion of the boreholes within the rockfill may require temporary casing. Horizontal ground temperature cables will be placed within the liner bedding layer along the upstream side of the key trench.

Survey prisms will be permanently installed in large boulders within the dam shell.

4.4 Interim Dike

4.4.1 Dike Bulk Fill

The bulk fill of the Interim Dike will consist of ROQ material. The ROQ material size will be limited to material with a maximum size of 1,000 mm and well graded with a good mix of fines. This material must be end dumped from one end of the structure from a constructed platform about 1 m above the TIA water level at the time of construction. Once this primary base lift has been constructed all the way across the proposed alignment, subsequent lifts to the 31.0 m crest height must be placed in lifts no greater than 1.5 m and must be compacted using wheel traffic from loaded haul trucks.

4.4.2 Filter Zone

Although the Interim Dike is not intended to retain liquids, it should retain the bulk of the tailings solids. The upstream face of the Interim Dike will, if required be clad with a layer of graded rock that would act as a filter to ensure tailings solids does not migrate through the dike. Alternately, the upstream slope will be clad with a geotextile to serve this filtering function.

4.4.3 Dike Shell

No special dike armouring is required, and no special upstream or downstream riprap is required. The dam shell will be constructed using the same ROQ material as the dike bulk fill. Consideration should however be given to using more gap graded material on the outer shell with less fines; this will stand up better over the long term avoiding fines washout, especially along the downstream slope.

4.4.4 Monitoring Instrumentation

A series of survey pins permanently embedded into large boulders will be installed on the crest and along the upstream and downstream slopes of the Interim Dike to monitor settlement and deformation of the structure.

4.5 Stability Analysis

A comprehensive stability analysis was carried out to confirm whether the South Dam and Interim Dike meets the appropriate design requirements as stipulated in Section 3.5. Complete details of this analysis are presented in Appendix E and the results are summarized in Tables 9 and 10.

Table 9. South Dam Minimum Factors of Safety

Stability Condition	Required Minimum Factor of Safety (CDA 2013)	Assessed Minimum Factor of Safety
Short Term (Construction)	Greater than 1.3	1.7
Long Term	1.5	1.6
Full or Partial Rapid Drawdown	1.2 to 1.3	Not applicable
Pseudo-static	1	1.5

The South Dam readily meets all the required minimum slope stability FOS as prescribed by CDA (2013). This applies even for the most conservative assumption of a fully thawed foundation condition. Detailed site characterization, and associated material property testing have been carried out under the proposed South Dam alignment, and as a result there is a high level of confidence in these results.

Table 10. Interim Dike Minimum Factors of Safety

Stability Condition	Required Minimum Factor of Safety (CDA 2013)	Assessed Minimum Factor of Safety
Short Term (Construction)	Greater than 1.3	1.5
Long Term	1.5	1.5
Full or Partial Rapid Drawdown	1.2 to 1.3	1.3
Pseudo-static	1	1.2

The Interim Dike stability assessment results clearly demonstrate that initial bearing capacity failure is expected in the very weak layer of surficial lakebed sediments. As construction progresses, a mixing zone will develop which will serve to buttress the Interim Dike, with the resultant effect of achieving the required CDA (2013) FOS. Sensitivity analysis has also demonstrated that flattening the Interim Dike side slopes to 5H:1V would have an effect of increasing the required FOS without the need for development of a deep mixing zone. The approximate 40% additional ROQ material required to construct this requirement is not considered significant; therefore this potential mitigation strategy is very realistic. Sensitivity analysis results also demonstrate that a 30% increase in undrained shear strength would result in a dramatic increase in the Interim Dike FOS.

4.6 Settlement Analysis

Settlement of the South Dam could occur as a result of one of two reasons; dam fill consolidation, or foundation consolidation. Since the dam fill is compacted ROQ material, and the total dam height is limited, there is no expectation of any appreciable fill settlement.

Foundation settlement beneath the South Dam could occur as a result of thaw consolidation. Normal thaw consolidation can also be exacerbated by thaw of massive ice which may be present in the foundation soils. Thermal analysis (Appendix F) has however demonstrated that that the foundation will remain frozen for the design life of the structure, and as a result thaw consolidation is not expected to be of concern during the period when this facility is in active operation.

The Interim Dike will be constructed over unconsolidated lake bed sediments and as a result consolidation settlement is expected. A complete settlement analysis is presented in Appendix G, with the resultant conclusion that total settlement of the Interim Dike could be between 1.6 and 4.1 m. The calculated time to consolidation was 39 years for 50% consolidation and 170 years for 90% consolidation. Since the time to consolidation is relatively long, it is not expected that continual maintenance of the Interim Dike would be required. The dike can be monitored throughout deposition and ROQ material could be added as required if settlements compromise the design freeboard.

4.7 Deformation (Creep) Analysis

The South Dam will be subject to creep deformation over the very long term. Creep has previously been assessed for the South Dam (SRK 2007a), and no further analysis was completed. Deformation monitoring during the operational phase of the structure will be undertaken, and if required the downstream dam slope will be flattened to 4H:1V as was the case for the original South Dam design. The revised thermal analysis (Appendix F) however suggest that this will likely not be required. Notwithstanding this possible mitigation strategy, the South Dam will not retain saturated tailings and therefore the structure can tolerate a large amount of long term deformation.

4.8 Thermal Analysis

4.8.1 South Dam

Rigorous thermal modeling was completed to determine whether the frozen foundation South Dam would function as proposed. Complete details of this thermal assessment are provided in Appendix F. The modeling confirms that, using conservative assumptions, the GCL would remain frozen into the underlying foundation for the required mine life, and if fact perpetuity. The design freezing point depression used in the analysis was -2.3ºC, to allow for the known freezing point depression as a result of overburden soil pore water salinity. The thermal modeling did take into consideration climate change of +4.1ºC over 100 years.

4.8.2 Tailings

Thermal modeling was also completed to assess the freeze back time rate of placed tailings (Appendix F). The tailings are not expected to have a high salinity; therefore, a 0ºC freezing temperature has been adopted. Based on this freezing temperature, the time to complete tailings freeze back has been estimated at less than 4 years where the ground surface is exposed, and 6 years where lake talik has developed. These estimates are based on the very conservative assumption that the tailings will maintain at 4ºC throughout the deposition period. The actual freeze back time is likely to be significantly less and may be measured in months rather than years due to progressive freeze back over the life of project.

The active layer within the exposed tailings surface over the first decade is approximately 2 m deep, but this gradually increases to about 3 m over 100 years as a result of climate change.

4.9 Tailings Consolidation Analysis

Tailings consolidation would result in a change of storage capacity over the life of the facility, as well as create a change in landform post closure. A rigorous assessment of the consolidation characteristics of the tailings surface was however undertaken (Appendix H) to assess the possible range of settlement.

These results confirmed that consolidation will be about 0.7 m at the expected maximum thickness of tailings of about 10 m. In addition, assuming fully thawed conditions beneath the tailings, an additional settlement of 1.2 to 3.1 m might be experienced as a result of settlement of the underlying foundation soils due to loading of the tailings.

The tailings thermal analysis has however demonstrated that freeze back will occur relatively quickly, and therefore the expected settlement is not likely to materialize.

4.10 Dam Break Analysis

In accordance with the Canadian Dam Safety Guidelines (CDA 2013) a dam break analysis may be required when a dam has a hazard rating of HIGH or greater. The purpose of a dam break analysis is to determine the inundation zone downstream of the dam in question should a catastrophic breach occur.

In determining the dam hazard classification, consideration was given to tailings supernatant water and tailings solids reaching the receiving environment. For the North Dam this would include Tail Lake outflow, Doris Lake, Doris Creek and further downstream Little Roberts Lake. For the South Dam this would include Ogama Lake, Ogama Lake outflow and subsequently Doris Lake.

As previously explained, there is no conceivable chance of tailings solids being released as a result of a breach of the North Dam. Supernatant water would conceivably reach the entire downstream catchment all the way to Roberts Bay.

A breach of the South Dam would result would result in release of tailings solids into Ogama Lake. There is a very remote chance that some solids may find their way into the Ogama Lake outflow, and ultimately Doris Lake. Tailings solids would however not be transported any further. Supernatant water would however progress all the way along the water system to Roberts Bay.

The breach scenarios described above is intuitive, although likely extremely conservative. None the less, these scenarios was adopted in assigning the dam hazard classification for the structures. Completion of a dam breach analysis would not result in a different conclusion being reached and therefore it was not done.

4.11 TSF Water Balance

A site wide water and load balance, including the TIA, has been developed for the Project (SRK 2015). The TIA is designed to contain site-wide contact water, mill process water as well as treated domestic waste water. Reclaim water will be drawn from the TIA Reclaim Pond for re-use in the Process Plant.

There are no non-contact surface water diversions upstream of the TIA. The TIA is located in an isolated catchment, and the benefits of any diversions are outweighed by the relative cost and complexity of constructing them.

4.12 Seepage Analysis

The purpose of the South Dam is to retain tailings and supernatant water. Tailings deposition will be done such that a beach will develop upstream of the dam, which will have the resultant effect of ensuring that there would never be any water in close proximity of the Dam. At closure, the beach will be the entire distance between the South Dam and the Interim Dike, of over 1.6 km. There may be short periods, while the tailings beach is being developed, where some water may be in close proximity of the South Dam. However, as it has been demonstrated by the seepage analysis (Appendix H), the maximum amount of seepage that might occur under the worst case scenario is about 0.6 m^3/day. This would be if the TIA is at its full supply level of 33.5 m, and ignoring the fact that the foundation is frozen.

The Interim Dike is designed to ensure that water can pass unhindered through the structure. The seepage analysis demonstrates that this target is easily achieved for all conceivable flow conditions.

4.13 Seepage Collection

No seepage collection is planned for either the North or South Dams since the design analysis confirm that seepage is not expected (SRK 2007a and Appendix H). Should seepage be identified as part of the routine monitoring, a collection system will be implemented and the seepage returned to the TIA.

5 South Dam and Interim Dike Construction

5.1 Construction Materials

Construction material for the South Dam and Interim Dike consist of bedding, transition and run of quarry material. The granular fill will be produced on site from one of many local approved quarries, with Quarry #3 likely being the primary source. Complete geological, mineralogical and geochemical details on these quarry sites are documented in (SRK 2007b, 2008).

Other materials that will be used to construct these structures GCL and geotextile. Complete details of all these materials are provided in the Technical Specifications (SRK 2011).

5.2 Construction Equipment

Typical construction equipment will be used at the South Dam and Interim Dike. A contractor fleet consisting of 100 tonne trucks will be used for hauling the excavated overburden and the dam fill, with smaller articulated trucks used in the narrower areas near the top of the dam. Bulldozers and smooth drum vibratory compactors will be used to complete the fill placement. Hydraulic excavators may be used for special tasks as required. Drilling and blasting will be done using conventional tracked blast hole drills.

5.3 Construction Quality Control and Quality Assurance

Complete details of the Quality Assurance and Quality Control (QA/QC) procedures to be followed for the construction activities are provided in the Technical Specifications (SRK 2011). Quality Control will be the responsibility of the Contractor, and/or the equipment and materials manufacturer. The Engineer of Record, which will be a Registered Professional Engineer in the Nunavut Territory, will carry out Quality Assurance. Complete documentation of all QA/QC data will be provided in the relevant As-Built Reports.

5.4 Construction Schedule

The South Dam key trench excavation and backfill must be completed in the winter to eliminate potential issues caused by thawing of the soft overburden soils as well as to ensure that a thermal blanket is completed to protect the permafrost in the foundation.

The Interim Dike could be completed during any season.

5.5 Material Quantities

Material quantities for the construction of the South Dam and Interim Dike are summarized in Table 11. All fill and excavation volumes represent neat volumes, i.e. “in place”, with no allowance for swelling and compaction. The liner quantities are neat quantities, with no allowance for seams and waste.

Table 11. South Dam and Interim Dike Material Quantities

Material	Quantity
South Dam	
Liner Bedding (m^3)	5,030
GCL (m^2)	8,385
Run of quarry (m^3)	34,390
Transition Fill (m^3)	11,930
Key-trench excavation (m^3)	12,770
Interim Dike	
Run of quarry (m^3)	1,915
Transition Fill (m^3) (Allowance)	4,385
Geotextile (m^2) (Allowance)	4,385

6 Tailings Management System Operation

6.1 Operations, Maintenance and Surveillance (OMS) Manual

A standalone Operations, Maintenance and Surveillance (OMS) Manual will be prepared by TMAC Resources Inc. (TMAC) in accordance with requirements under Part G of the mine's current Water Licence, the Mining Association of Canada's (MAC) guideline (MAC 2011), as well as the Canadian Dam Association's Dam Safety Guideline (CDA 2014).

6.2 Tailings Deposition

Complete details of the tailings deposition plan, including the options evaluated are described in Appendix C. The preferred tailings deposition plan ensures that the final tailings surface immediately upstream of the Interim Dike approximately matches the natural outflow elevation once the North Dam is breached. Tailings deposition starts from the South Dam and subsequently progress along the east flank of the TIA, forcing the supernatant pond to the northwest corner of the facility. This deposition plan requires six discharge locations in total. The Interim Dike will have a crest elevation of 31.0 m with a 1.5 m freeboard, and the final tailings elevation immediately upstream of the Interim Dike will range between 29.5 and 28.3 m, which means that at closure the elevation difference between the tailings surface and the natural outflow elevation of the TIA will be between 1.2 and 0 m once the North Dam is breached at 28.3 m.

6.3 Dust Management

A comprehensive assessment of possible dust management practices for the tailings surface is presented in Appendix I. The tailings deposition plan has been developed to as far as practical minimize the area of exposed inactive tailings surface that might be prone to dusting. Beyond such mitigation by design, the primary dust control measure of the project site TIA will be the use of environmentally suitable chemical dust suppressants. The application of these suppressants will be reviewed on an ongoing basis to ensure that any areas that may be at risk will be adequately covered. Generally annual application of chemical suppressants will be applied; however it is recognized that more frequent applications may be required as discharge locations are changed throughout any year.

In addition to chemical dust suppressants, natural dust control in the form of packed snow when available will be used as far as practical. Again, the effectiveness will vary on a year by year basis depending on how deposition points vary for any given winter season.

Finally, if for any reason, any of the above dust control methods prove to be temporally ineffective, a suitable water cannon will be available to allow for dust suppression in the form of spraying of the areas of concern.

7 Tailings Closure and Reclamation

7.1 Closure Concept

Upon closure, the tailings surface will be covered with a nominal waste rock cover of 0.3 m thickness. The function of the cover is to prevent dust and to minimize direct contact by terrestrial animals. The cover will terminate at the Interim Dike, and the Interim Dike will be levelled to match the elevation of the cover. Once the water quality in the Reclaim Pond has reached the required discharge criteria, the North Dam will be breached as originally intended.

7.2 Closure Components

7.2.1 Landform Design

The tailings deposition plan has been developed to ensure that a free draining tailings surface remain at closure. This tailings surface will be shaped as part of the regular tailings deposition plan (Appendix C), such that there is a primary drainage channel leading from the South Dam towards the Interim Dike. This ensures that there is no requirement for construction of diversion structures post closure.

7.2.2 Cover System

The TIA will only contain flotation tailings which are non-PAG with abundant neutralization potential and thus buffering capacity. Although several metals in the tailings solids occur at concentrations in excess of crustal abundances, many of these metals are associated with sulphides and as such will primarily partition into the detoxified tailings which means they will not be of concern in the TIA. Long-term humidity cell tests indicate that after the initial flushing of the samples, an increased tendency for neutral pH metal leaching of arsenic, copper and lead may occur.

The TIA water and load balance (SRK 2015) suggest that possible neutral metal leaching does not pose a limitation in ensuring that the water quality in the TIA meet closure water quality criteria, and therefore no infiltration reduction cover is required on the exposed tailings surface. The tailings surface will however be susceptible to wind erosion with the resultant effect of dust exposure.

Similarly, although the tailings surface is landscaped to allow free drainage, the tailings is susceptible to hydraulic erosion, which will mobilize tailings towards the Reclaim Pond with a resultant increase in total suspended solids.

Therefore, a tailings cover that functions to prevent wind and water erosion will be constructed over the entire tailings surface.

The minimum thickness of cover that can practically be placed over the tailings surface would be about 0.3 m thick, and therefore the cover design has been set at 0.3 m thick run-of-quarry material.

Part of the tailings will not be trafficable for some years following tailings placement. Therefore, in order to place the cover winter construction over a frozen tailings surface will be required in those areas. Although thermal modeling has demonstrated that the bulk of the tailings mass will freeze back in the long term, and remain frozen (Appendix F), consolidation settlement in the active zone (about 2 m thick) can still be expected (Appendix G). In addition, should ice lenses develop within the tailings beach, these ice lenses, if present in the active zone could further contribute towards long term differential settlement of the tailings surface and subsequently any associated cover system. Such differential settlement will not negatively affect the cover performance since localized ponding that might result would not prohibit the cover from ensuring that wind and water erosion is mitigated.

7.2.3 Water Management

Conveyance Channel

Although the tailings will be landscaped to ensure positive drainage of the entire tailings surface area, the resultant effect will be a dedicated primary conveyance channel along the west side of the facility. This channel will be sized and armoured to allow conveyance of the 1 in 500 year, 24 hour duration storm event. Based on the channel geometry, the peak flow is expected to be about 4.3 m^3/second, requiring rip rap with a D_{50} of 0.1 m. This rock is similar to the proposed run-of-quarry cover material and therefore no special requirements for the primary conveyance channel is required, other than possible local thickening of the cover. For bonding cost estimates, it has been assumed that this localized cover thickening would occur over a zone about 20 m wide, along the entire length of the channel. This section will have an increased cover thickness of 0.6 m.

Discharge Criteria

A key closure objective is to ensure a walk away closure scenario and therefore the water retaining North Dam must be breached. This can however only occur when the water quality in the Reclaim Pond meets environmental discharge criteria. The TIA, once breached will discharge into Doris Lake which in turn discharges into Doris Creek. The environmental discharge criteria for the TIA are therefore the CCME guidelines for the protection of aquatic life (fresh water).

7.2.4 Containment Structures

North Dam

Water in the Reclaim Pond will continue to be managed via active pumping to the Roberts Bay Discharge System until such time as the environmental discharge criteria can be met within the Reclaim Pond. At that time, the water in the Reclaim Pond will be pumped down to its pre-mining elevation of 28.3 m, and the North Dam will be breached. The breach design will consist of a slot cut through the dam down to the pre-construction elevation. The cut will measure about 20 m wide, with 4H:1V side slopes on either side. The cut slopes will be covered with a 2.5 m thick layer of run of quarry material to ensure physical and thermal stability (EBA 2006).

Tail Lake Outflow will be re-established along the base of the cut and suitable bedding material will be put in place to ensure channel stability.

South Dam

The south dam will be left in place during closure as it will not be retaining any water. No additional closure activities are required.

Interim Dike

The Interim Dike will be lowered upon closure to match the final covered tailings surface.

7.3 Monitoring and Maintenance

7.3.1 Monitoring

Throughout the operational phase of the Project, the containment structures (North, South and Interim) will be subject to rigorous monitoring to evaluate their performance. This will include thermal, settlement and other general deformation monitoring. In addition, thermal monitoring of the tailings profile will be carried out to confirm tailings freeze-back assumptions. All of the above will be subject to annual inspections by a qualified professional engineer as part of routine annual inspections. The frequency of these inspections may be reduced as time progresses in accordance with the inspection engineer’s recommendations.

Once environmental discharge criteria in the Reclaim Pond has been reached and the North Dam has been breached it is expected that routine monitoring will proceed for a period of about five years, after which it may be demonstrated that the system is stable and no further action is required.

7.3.2 Maintenance

Throughout the active closure period it is conceivable that some tailings settlement and Interim Dike settlement could occur. Where necessary maintenance in the form of additional cover or fill material will be allowed for to address any areas of concern.

This document, ***"Doris North Project Tailings Management System Design"***, was prepared by

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All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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Appendix A – Engineering Drawings for the Tailings Management System Design