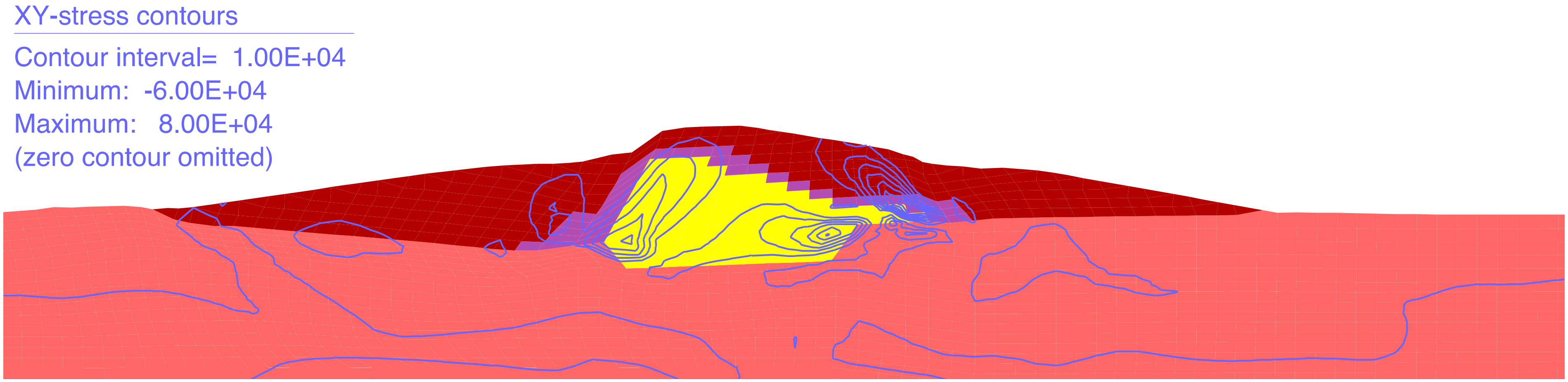
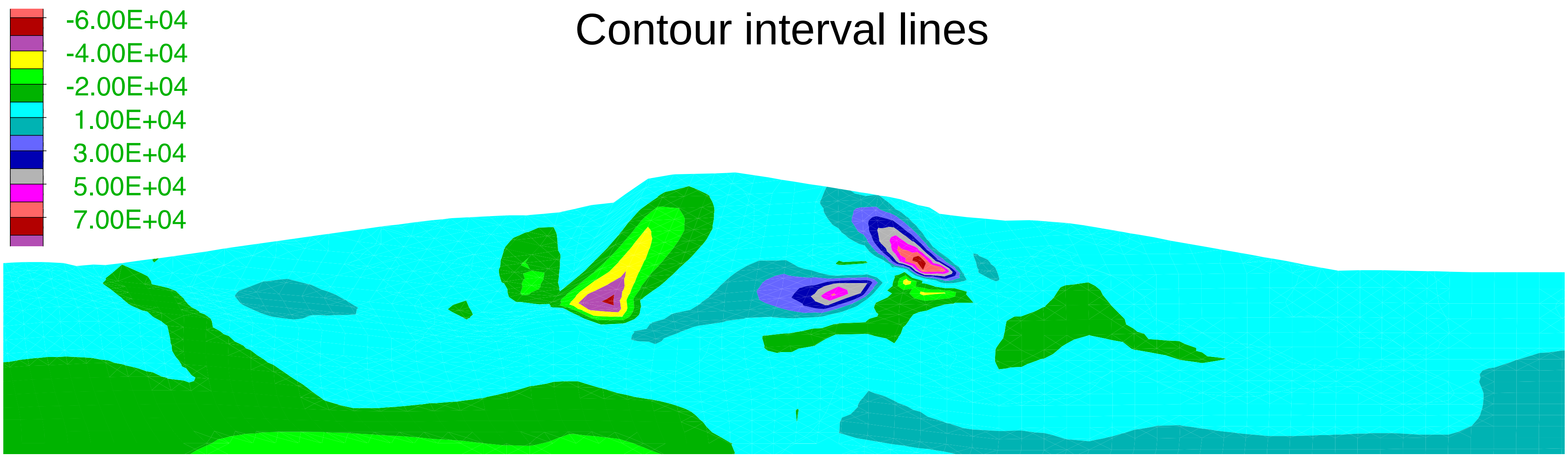


Contour interval lines



Contour intervals

Notes:
1. Units in Pascals
2. Foundation layer is shown until bedrock
3. Results for a salinity of 39 ppt in the clayey silt foundation and a threshold stress of σ_{th}=30 kPa

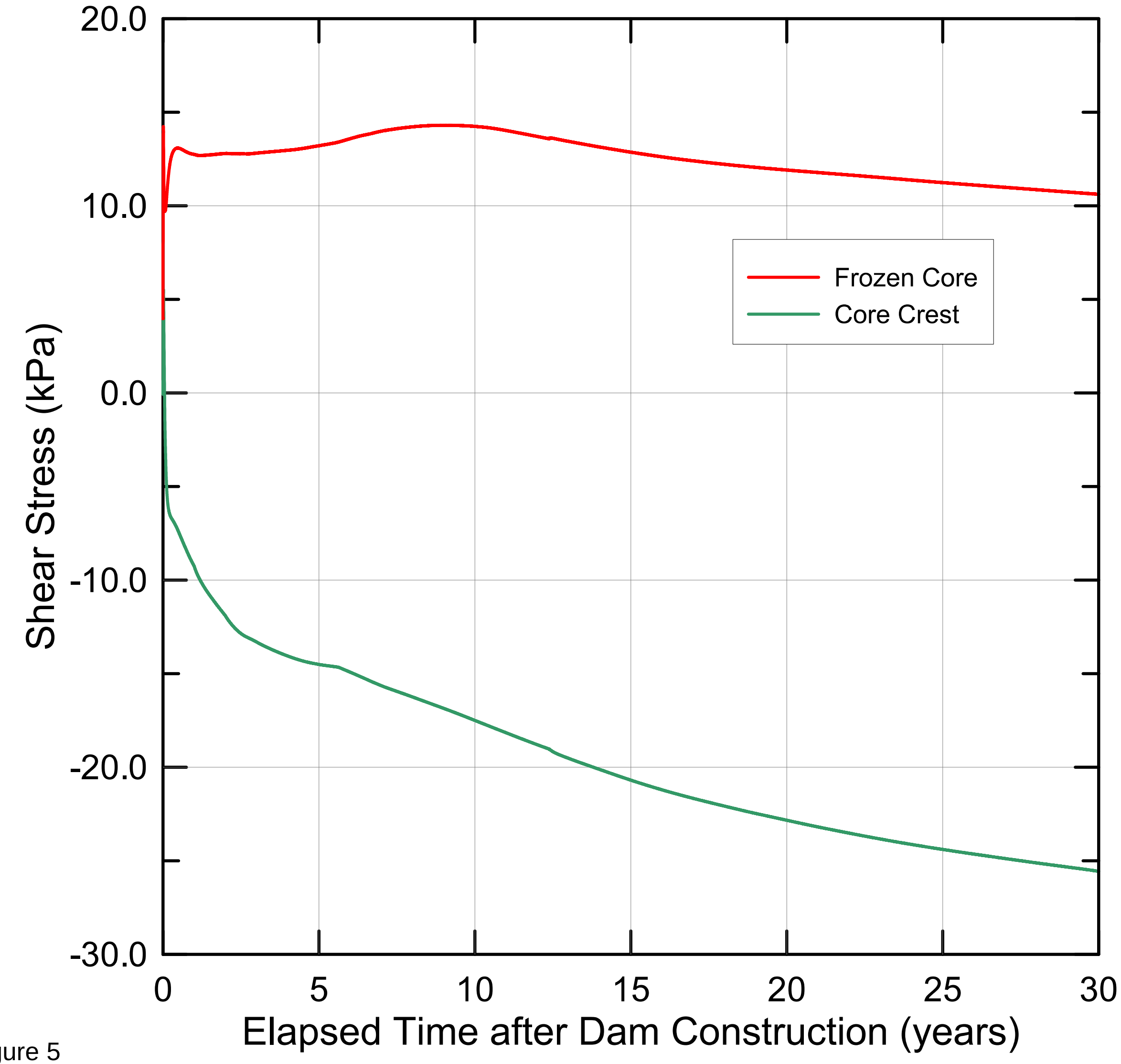
srk consulting

MAC RESOURCES

North Dam Creep Deformation Analysis

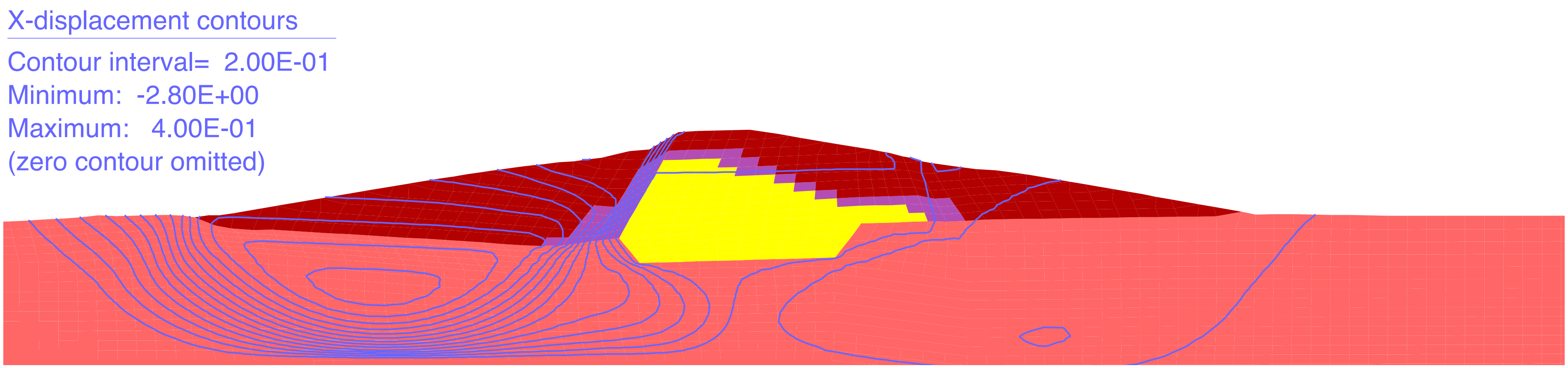
Shear Stresses
30 Years After Dam Construction

Job No: 1CT022.004 Filename: NorthDam_CreepAnalysis.pptx	HOPE BAY PROJECT	Date: 8/17/2016	Approved: AL	Figure: **16**

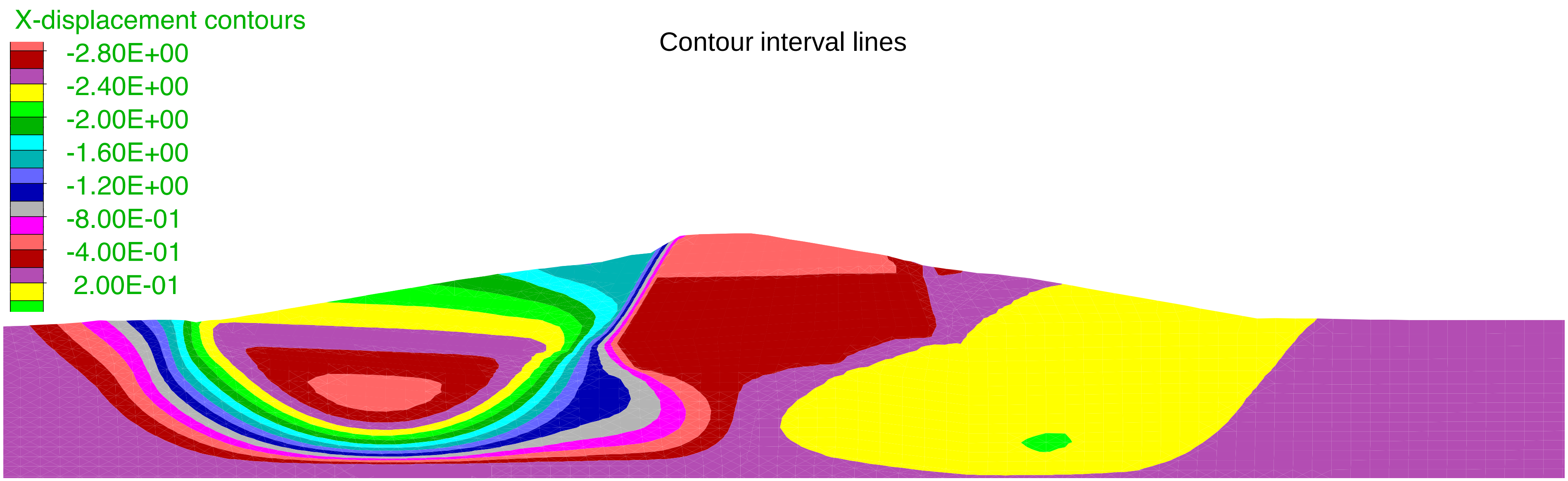


Notes:
1. Core crest is point A in Figure 5
2. Frozen core is point B in Figure 5
3. Results for a salinity of 39 ppt in the clayey silt foundation and a threshold stress of σ_{th}=30 kPa

srk consulting	MAC RESOURCES	North Dam Creep Deformation Analysis **Shear Stresses History of two Points in the Core**
Job No: 1CT022.004 Filename: NorthDam_CreepAnalysis.pptx	HOPE BAY PROJECT	Date: 8/17/2016 Approved: AL Figure: **17**



Contour interval lines



Contour intervals

Notes:

1. Units in meters
2. Foundation layer is shown until bedrock
3. Results for a salinity of 39 ppt in the clayey silt foundation and a threshold stress of σ_{th}=30 kPa

srk consulting

MAC RESOURCES

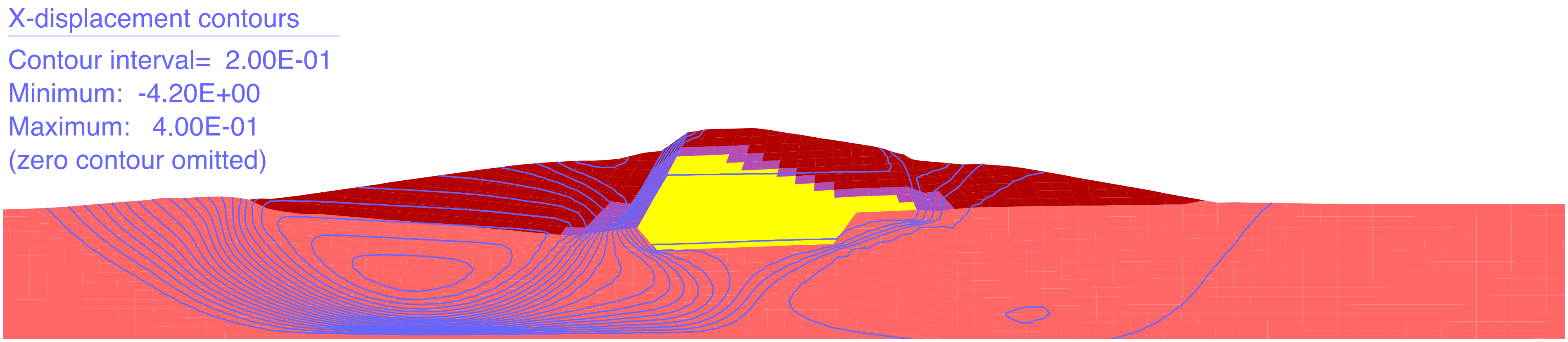
North Dam Creep Deformation Analysis

Horizontal Displacements
Ten Years After Dam Construction

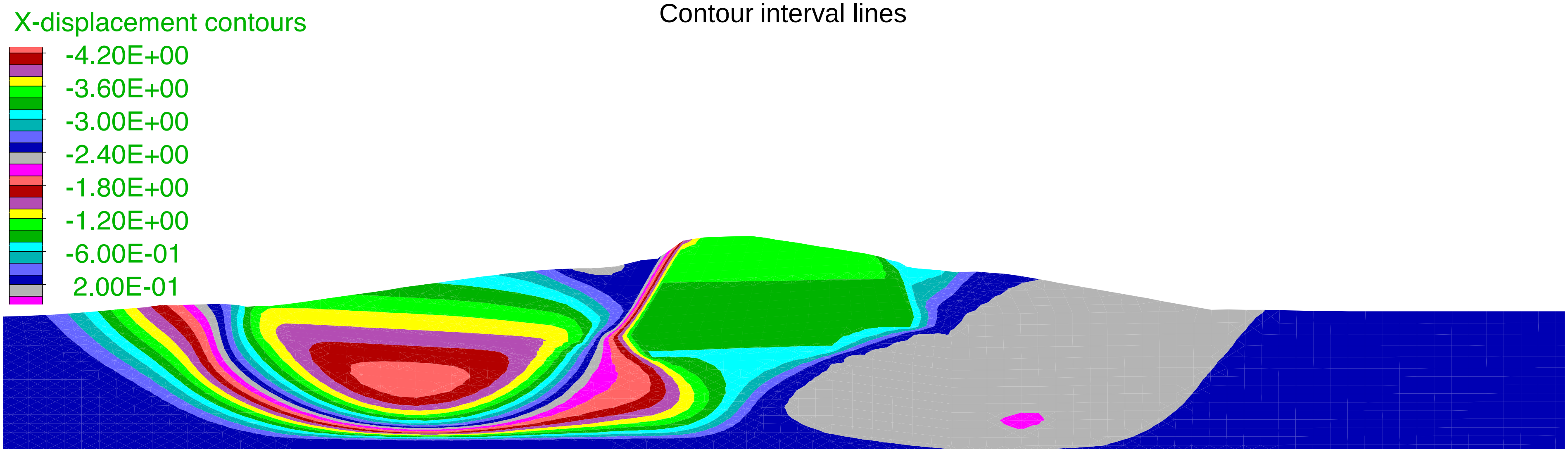
Job No: 1CT022.004
Filename: NorthDam_CreepAnalysis.pptx

HOPE BAY PROJECT

Date: 8/17/2016
Approved: AL
Figure: **18**



Contour interval lines



Contour intervals

Notes:

1. Units in meters
2. Foundation layer is shown until bedrock
3. Results for a salinity of 39 ppt in the clayey silt foundation and a threshold stress of σ_{th}=30 kPa

srk consulting

MAC RESOURCES

North Dam Creep Deformation Analysis

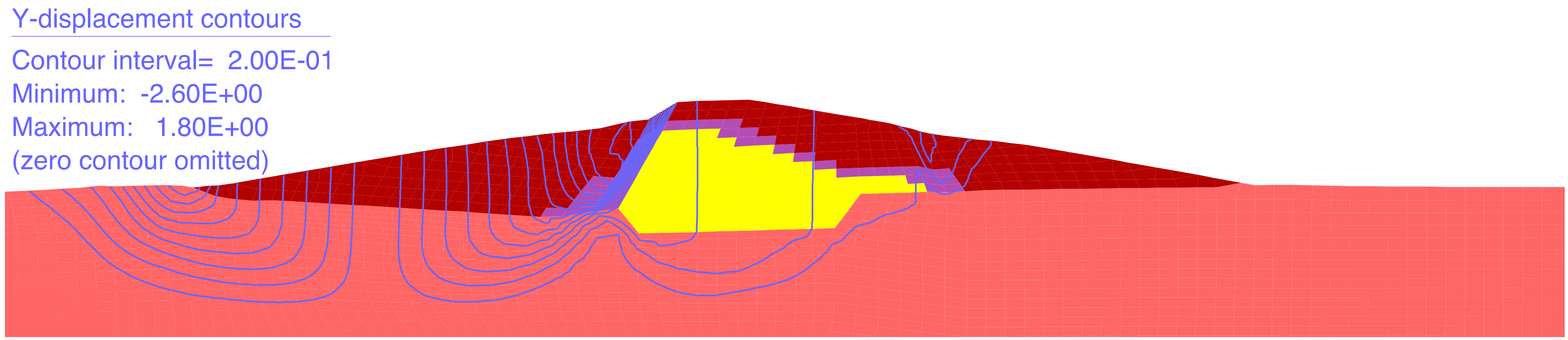
Horizontal Displacements
30 Years After Dam Construction

Job No: 1CT022.004

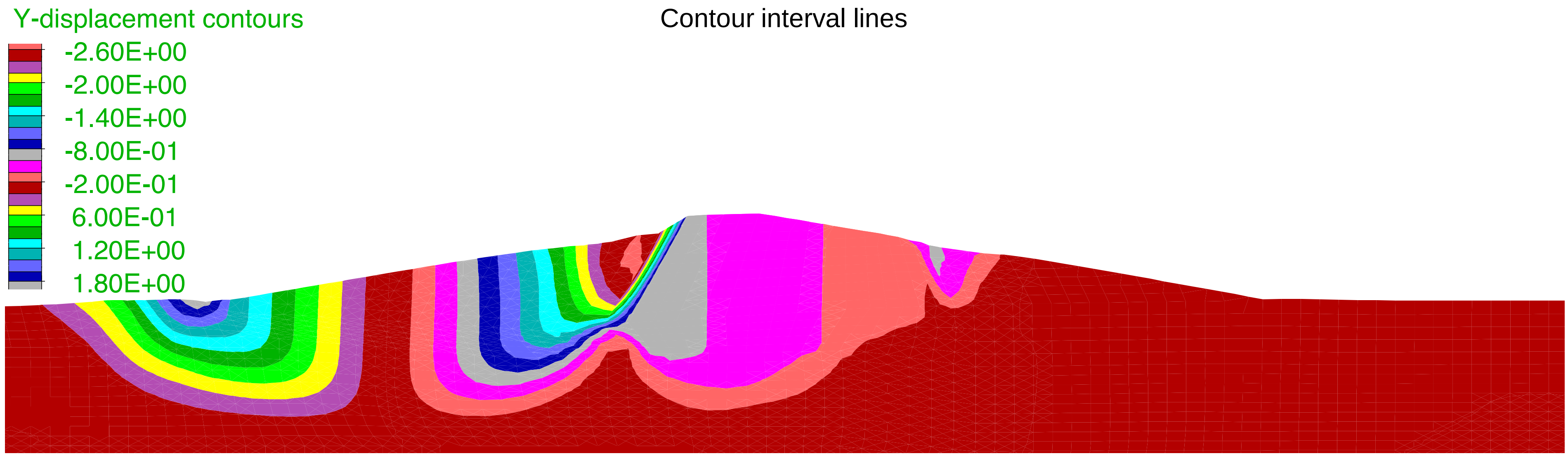
Filename: NorthDam_CreepAnalysis.pptx

HOPE BAY PROJECT

Date:	Approved:	Figure:
8/17/2016	AL	**19**



Contour interval lines

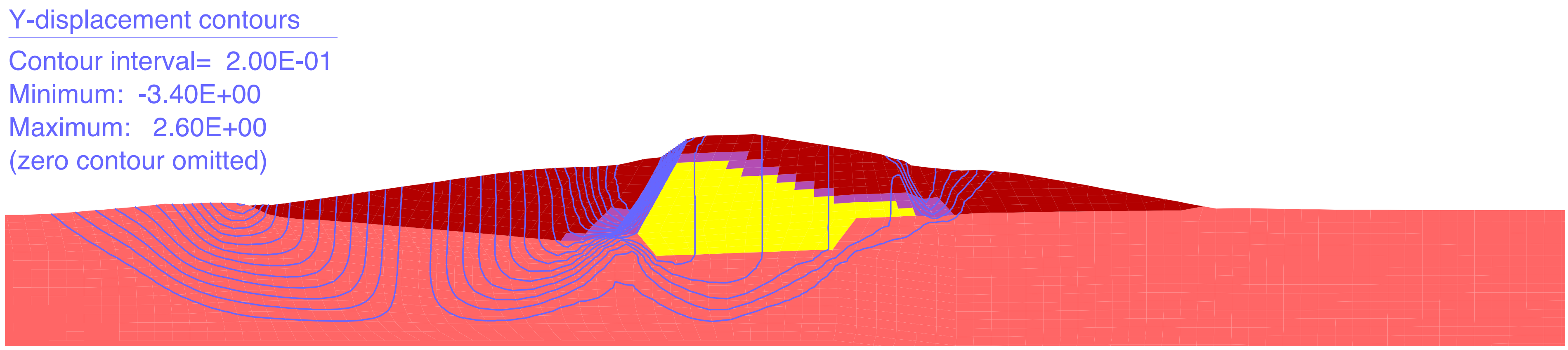


Contour intervals

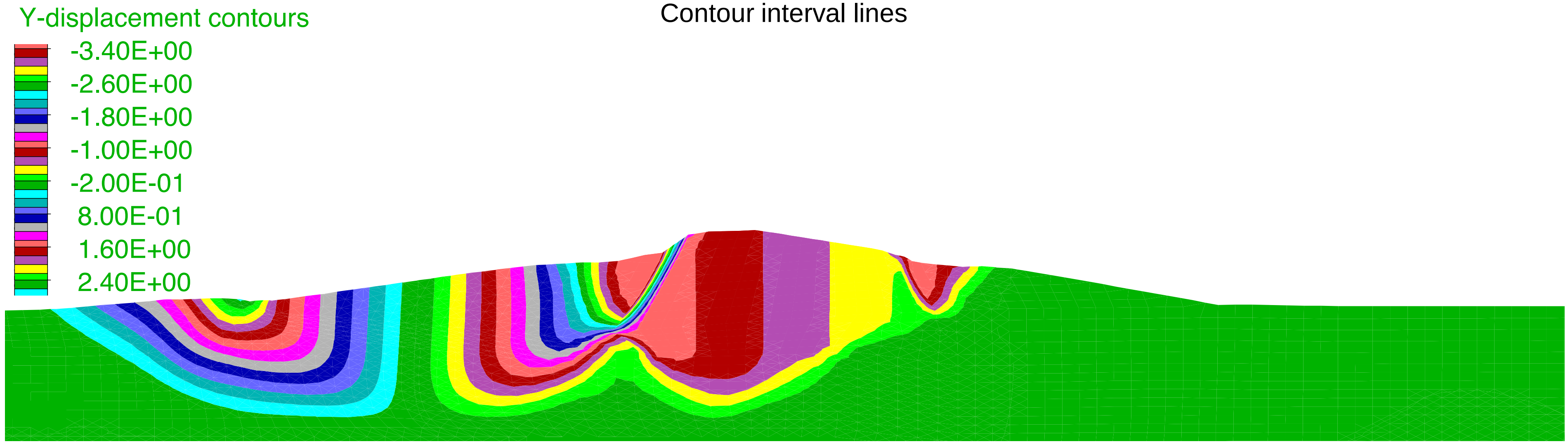
Notes:

1. Units in meters
2. Foundation layer is shown until bedrock
3. Results for a salinity of 39 ppt in the clayey silt foundation and a threshold stress of σ_{th}=30 kPa

srk consulting	MAC RESOURCES	North Dam Creep Deformation Analysis **Vertical Displacements Ten Years After Dam Construction**
Job No: 1CT022.004 Filename: NorthDam_CreepAnalysis.pptx	HOPE BAY PROJECT	Date: 8/17/2016 / Approved: AL / Figure: **20**



Contour interval lines



Contour intervals

Notes:

1. Units in meters
2. Foundation layer is shown until bedrock
3. Results for a salinity of 39 ppt in the clayey silt foundation and a threshold stress of σ_{th}=30 kPa

srk consulting

MAC RESOURCES

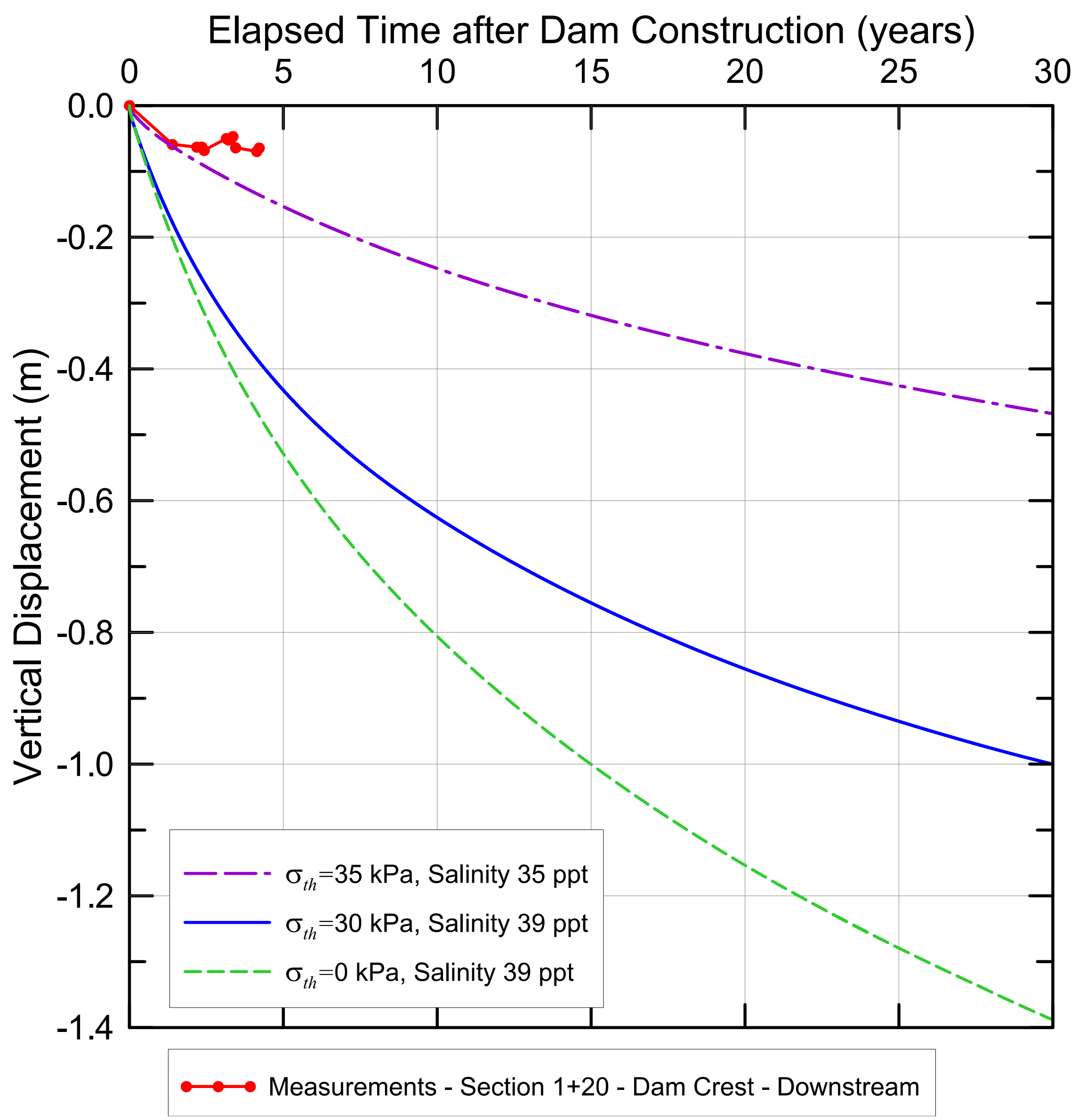
North Dam Creep Deformation Analysis

Vertical Displacements
30 Years After Dam Construction

Job No: 1CT022.004
Filename: NorthDam_CreepAnalysis.pptx

HOPE BAY PROJECT

Date: 8/17/2016
Approved: AL
Figure: **21**



srk consulting	MAC RESOURCES	North Dam Creep Deformation Analysis
		Vertical Displacement History of the Core Crest
Job No: 1CT022.004 Filename: NorthDam_CreepAnalysis.pptx	HOPE BAY PROJECT	Date: 8/17/2016 Approved: AL Figure: **22**

Appendix E – Hope Bay Project: Doris, Madrid and Boston Tailings Geotechnical Properties

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Memo

To:	John Roberts, PEng, Vice President Environment	**Client:**	TMAC Resources Inc.
From:	Erik Ketilson, PEng Trevor Podaima, PEng	**Project No:**	1CT022.004
Reviewed By:	Maritz Rykaart, PhD, PEng	**Date:**	December 13, 2016
Subject:	Hope Bay Project - Doris, Madrid and Boston Tailings Geotechnical Properties		

1 Introduction

1.1 General

The Hope Bay Project (the Project) is a gold mining and milling undertaking of TMAC Resources Inc. The Project is located 705 km northeast of Yellowknife and 153 km southwest of Cambridge Bay in Nunavut Territory, and is situated east of Bathurst Inlet. The Project comprises of three distinct areas of known mineralization plus extensive exploration potential and targets. The three areas that host mineral resources are Doris, Madrid, and Boston.

The Project consists of two phases; Phase 1 (Doris project), which is currently being carried out under an existing Water Licence, and Phase 2 which is in the environmental assessment stage. Phase 1 includes mining and infrastructure at Doris, while Phase 2 includes mining and infrastructure at Madrid and Boston located approximately 10 and 60 km due south from Doris, respectively.

Two tailings areas are planned for Phase 2. The existing Doris tailings impoundment area (TIA) will be expanded, and a new Boston tailings management area (TMA) will be developed. Doris TIA tailings deposition will consist of subaerial tailings deposition, while the Boston TMA will be comprised of filtered tailings developed as a dry-stack. Two tailings streams will be produced; flotation tailings, comprising approximately 92-94% of the overall volume, and detoxified leach tailings (following cyanidation, and subsequent cyanide destruction), comprising about 6-8% of the overall volume. Only flotation tailings will be deposited in the Doris and Boston tailings areas. The detoxified leach tailings will be filtered, mixed with mine waste rock and used for underground mine backfill.

1.2 Objective

Dating back to 2003, there has been multiple campaigns of tailings geotechnical testing carried out for the Project. This memo summarizes all this information, and serves to provide definitive geotechnical design data for the Project with respect to tailings properties.

2 Tailings Property Test Programs

Three separate tailings geotechnical test campaigns have been carried out between 2003 and 2009, as outlined in Table 1.

Table 1: Hope Bay Tailings Geotechnical Test Programs

<table>
<tr><th rowspan="2">Testing Date</th><th rowspan="2">Testing Agency</th><th colspan="3">Tailings Tested</th></tr>
<tr><th>Area</th><th>Type</th><th>Method</th></tr>
<tr><td>2003</td><td>AMEC Earth Engineering Pty. Limited in Perth Australia</td><td>Doris</td><td>Mixed detoxified leach / flotation</td><td>Slurry</td></tr>
<tr><td rowspan="6">2009</td><td rowspan="3">Knight Piésold Consulting (Denver)</td><td>Doris Central</td><td>Flotation only
Mixed detoxified leach / flotation
Detoxified leach only</td><td rowspan="3">Slurry</td></tr>
<tr><td>Boston</td><td>Flotation only
Mixed detoxified leach / flotation
Detoxified leach only</td></tr>
<tr><td>Madrid</td><td>Flotation</td></tr>
<tr><td rowspan="3">Pocock Industrial Inc. (Denver)</td><td>Doris Central</td><td>Flotation only
Mixed detoxified leach / flotation
Detoxified leach only</td><td rowspan="3">Thickened</td></tr>
<tr><td>Boston</td><td>Flotation only
Mixed detoxified leach / flotation
Detoxified leach only</td></tr>
<tr><td>Madrid</td><td>Floatation</td></tr>
</table>

Table 2 summarizes the specific testing completed during the 2003 test campaign (SRK 2003). A single combined tailings sample (mixture of flotation and detoxified leach tailings) was prepared by Bateman Engineering from pilot scale metallurgical tests.

Table 2: 2003 Laboratory Tests on Single Combined Tailings Sample

Test	Test Method (Australian Standards)
Grain Size Distribution	Sieve and Hydrometer (AS 1289.3.6.2)
Plastic Properties	Casagrande (AS 1289.3.1.1,.3.2.1,.3.3.1,.3.4.1,.2.1.1)
Particle Density	AS 1289.3.5.1
Triaxial Test	Consolidated Undrained Test with Pore Pressure Measurement (AS 1289.6.4.2)
Consolidation Test	One-Dimensional Consolidation (AS 1289.6.6.1)
Undrained Settling Test	SRC-WI-4.8.3
Drained Settling Test	SRC-WI-4.8.2

Table 3 summarizes the laboratory testing completed by Knight Piésold Consulting in 2009 (KP 2009). These tailings samples were prepared by Newmont Metallurgical Services (NMS) as part of pilot scale testing in their Denver laboratories.

Table 3: 2009 Laboratory Tests Conducted by Knight Piésold Consulting

Test	Test Method	Number of Tests
Grain Size Distribution	ASTM D 422	9
Plastic Properties	Not Specified	9
Specific Gravity	ASTM D 854	8
Undrained Settling Test	Lab specific procedure – no specific ASTM	12
Drained Settling & Falling Head Permeability Test	Lab specific procedure – no specific ASTM	12
Settling and Drying Test	Lab specific procedure – no specific ASTM	12

NMS also submitted samples to Pocock Industrial Inc. for additional laboratory testing associated with flocculent screening, gravity sedimentation, pulp rheology, pressure filtration, and vacuum filtration (Pocock 2009).

3 Tailings Properties Used Historically

Different tailings management strategies have been assessed for the Project between 2003 and 2015, and many different geotechnical parameters for tailings were used in these designs. Some of which were based on the test data listed in Section 2, while others were based on engineering judgement. Table 4 summarizes these values.

Table 4: Tailings Geotechnical Properties Used Historically

Parameter		Reported Values					
		2003 & 2005	2007	2009	2011	2012	2015
Reference(s)		SRK (2003, 2005)	SRK (2007)	SRK (2009)	SRK (2011)	SRK (2012)	SRK (2015)
Depositional Strategy		Sub-Aqueous	Sub-Aqueous	Thickened	Sub-Aqueous	Not Specified	Sub-Aerial
% Solids		36.1%	36.1%	57.0%	65.0%	65.0%	36.1%
Specific Gravity		2.7	2.7	-	-	2.9	2.7
Fines content (<75 micron)		56%	56%	-	-	-	-
Clay content (< 2 microns)		11%	11%	-	-	-	-
Plasticity		Non-plastic	Non-plastic	-	-	-	-
Moist Unit Weight (kN/m^3)		-	-	-	-	-	17.5
	Sub-Aqueous	1.20	1.20	-	-	1.60	-

Parameter		Reported Values					
		2003 & 2005	2007	2009	2011	2012	2015
Void Ratio	Sub-Aerial	-	-	-	-	1.35	-
	Paste/thickened	-	-	-	-	1.10	-
	Filtered	-	-	-	-	0.90	-
In-situ Dry Density	Sub-Aqueous (t/m^3)	1.23	1.23	-	1.29	1.12	-
	Sub-Aerial (t/m^3)	-	-	-	-	1.24	1.29
	Paste/thickened (t/m^3)	-	-	1.36	-	1.39	-
	Filtered (t/m^3)	-	-	-	-	1.53	-
Hydraulic conductivity (m/s)		1×10^{-7}	1×10^{-7}		-	-	5.4×10^{-7}
Friction Angle (degrees)		-	-	-	-	-	40º
Cohesion (kPa)		-	-	-	-	-	0

4 Tailings Geotechnical Test Results

4.1 Index Properties

Index properties include specific gravity (Table 5), particle size distribution (Table 6), and Atterberg limits (Table 7).

Table 5: Tailings Specific Gravity

Test Date	Source	Tailings Type	Specific Gravity		
			AMEC (2003)	KP (2009)	Pockock (2009)
2003	Doris North	Flotation (34% Solids)	2.74	-	-
2009	Doris Central	Flotation (38% Solids)	-	2.76	2.82
	Boston		-	2.90	2.89
	Madrid (Suluk)		-	2.90	2.75
	Madrid (Naartok East)		-	2.84	2.80
	Madrid (Naartok West)		-	2.87	2.86
Average Flotation Tailings			**2.83**		
2009	Doris Central	Mixed Detoxified Leach / Flotation	-	2.85	2.87
	Boston		-	2.97	2.90
Average Mixed Detoxified Leach / Flotation Tailings			**2.90**		
Average of Flotation and Mixed Detoxified Leach / Flotation Tailings			**2.85**		
2009	Doris Central	Detoxified Leach Tailings	-	3.46	3.42
	Boston		-	3.22	3.26
Average Detoxified Leach Tailings			**3.34**		

Table 6: Particle Size Distribution Testing Results

Test Date	Source	Tailings Type	USCS Classification[(1)]	Fines (< 0.075 mm)	%Silt	%Clay	D_{15} (mm)	D_{50} (mm)
2003	Doris North	Flotation (34% Solids)	ML	56%	46%	10%	0.011	0.068
2009	Doris Central	Flotation (38% Solids)	ML	63%	51%	11%	0.003	0.040
	Boston		ML	55%	43%	12%	0.003	0.061
	Madrid (Suluk)		CL-ML	74%	59%	15%	0.002	0.020
	Madrid (Naartok East)		SM	75%	61%	14%	0.002	0.022
	Madrid (Naartok West)		ML	69%	56%	13%	0.003	0.034
Average Flotation Tailings			**ML**	**65%**	**53%**	**13%**	**0.004**	**0.041**
2009	Doris Central	Mixed Detoxified Leach / Flotation	ML	65%	52%	13%	0.003	0.030
	Boston		ML	63%	50%	13%	0.002	0.035
Average Mixed Detoxified Leach / Flotation Tailings			**ML**	**64%**	**51%**	**13%**	**0.003**	**0.033**
Average of Flotation and Mixed Detoxified Leach / Flotation Tailings			**ML**	**65%**	**52%**	**13%**	**0.004**	**0.039**
2009	Doris Central	Detoxified Leach Tailings	ML	99%	84%	15%	0.002	0.010
	Boston		CL	100%	80%	20%	0.001	0.009
Average Detoxified Leach Tailings			**CL-ML**	**100%**	**82%**	**18%**	**0.002**	**0.010**

Notes:

1. USCS: ML = Silt, CL = Clay, SM = Silty Sand

Table 7: Atterberg Limits

Test Date	Sample	Tailings Type	Plasticity Limit (PL %)	Liquid Limit (LL %)	Plasticity Index (PI %)
2003	Doris North	Flotation (34% Solids)	NP	ND	NP
2009	Doris Central	Flotation (38% Solids)	NP	16	NP
	Boston		NP	17	NP
	Madrid (Suluk)		15	19	4
	Madrid (Naartok East)		NP	17	NP
	Madrid (Naartok West)		NP	17	NP
	Doris Central	Mixed Detoxified Leach / Flotation	14	17	3
	Boston		14	17	3
	Doris Central	Detoxified Leach Tailings	22	22	NP
	Boston		20	28	8

Notes:

1. NP = Non-Plastic
2. ND = Not able to be determined

4.2 Consolidation, Saturated Hydraulic Conductivity and Strength

Consolidation and triaxial testing completed on the single 2003 sample (AMEC 2003) are summarized in Table 8 and Table 9, respectively. After measuring the saturated hydraulic conductivity at 400 kPa confining stress, within the triaxial cell, the tailings sample was axially loaded to failure under undrained conditions to measure the frictional strength. These results are summarized in Table 11.

Falling head permeability testing (saturated hydraulic conductivity) was completed in 2009, concurrently with drained settling tests (Section 4.3), with the results summarized in Table 10.

Table 8: One-Dimensional Consolidation Properties of Tailings (AMEC 2003)

Pressure (kPa)	Void Ratio, e (-)	Coefficient of Consolidation, C_v (m^2/year)	Coefficient of Volume Compressibility, M_v, (m^2/kN)	Saturated Hydraulic Conductivity, K (m/sec)
0	0.839	-	-	-
20	0.836	0.648	8.170×10^{-5}	1.69×10^{-11}
40	0.830	0.529	8.183×10^{-5}	1.37×10^{-11}
100	0.833	0.488	2.732×10^{-5}	0.42×10^{-11}
200	0.824	0.455	3.289×10^{-5}	0.47×10^{-11}
300	0.811	0.439	7.178×10^{-5}	9.98×10^{-12}
400	0.797	0.441	7.791×10^{-5}	1.11×10^{-12}
200	0.798	-	-	-
40	0.803	-	-	-

Notes:
1. Initial dry density = 1.49 t/m^3; final dry density – 1.54 t/m^3
2. Initial moisture content = 22.6%, final moisture content = 13.4%
3. Initial saturation = 73.8%; final saturation = 47.3%

Table 9: Undrained Triaxial Compression Test Data (AMEC 2003)

Stage (Confining Stress, σ_3 (kPa))	Coefficient of Consolidation, C_v (m^2/year)	Coeff. of Volume Compressibility, M_v, (m^2/kN)	Hydraulic Conductivity, K (m/sec)	Cohesion, c (kPa)
1 (250 kPa)	113,890	0.153	5.4×10^{-7}	0.825
2 (300 kPa)	3,388	0.108	1.1×10^{-7}	0.010
3 (400 kPa)	1,822	0.040	2.2×10^{-8}	0.007

Table 10: Hydraulic Conductivity Testing (KP 2009)

Test Date	Source	Tailings Type	Falling Head Permeability, $k_{ave.}$ (m/sec)
2003	Doris North	Flotation - 34%	NT
2009	Doris Central	Flotation - 38%	$2.1 x10^{-7}$
	Boston		$2.0 x10^{-7}$
	Madrid (Suluk)		$7.8 x10^{-8}$
	Madrid (Naartok East)		$1.4 x10^{-7}$
	Madrid (Naartok West)		$1.3 x10^{-7}$
Average Flotation Tailings			**$1.5 x10^{-7}$**
Maximum Flotation Tailings			**$2.1 x10^{-7}$**
Minimum Flotation Tailings			**$7.8 x10^{-8}$**
2009	Doris Central	Mixed Detoxified Leach / Flotation (3 Samples)	$9.2 x10^{-8}$; $8.0 x10^{-8}$; $5.4 x10^{-8}$
		Average of 3 Samples	*$7.5 x10^{-8}$*
	Boston	Mixed Detoxified Leach / Flotation (3 Samples)	$7.9 x10^{-8}$; $6.8 x10^{-8}$; $4.6 x10^{-8}$
		Average of 3 Samples	*$6.4 x10^{-8}$*
Average Mixed Detoxified Leach / Flotation Tailings			**$7.0 x10^{-8}$**
Maximum Mixed Detoxified Leach / Flotation Tailings			**$7.5 x10^{-8}$**
Minimum Mixed Detoxified Leach / Flotation Tailings			**$6.4 x10^{-8}$**
Average of Flotation and Mixed Detoxified Leach / Flotation Tailings			**$1.3 x10^{-7}$**
Maximum of Flotation and Mixed Detoxified Leach / Flotation Tailings			**$2.1 x10^{-7}$**
Minimum of Flotation and Mixed Detoxified Leach / Flotation Tailings			**$6.4 x10^{-8}$**
2009	Doris Central	Detoxified Leach Tailings	Not Reported
	Boston		$9.2 x10^{-8}$

Notes:
1. NT = Not Tested

Table 11: Tailings Shear Strength (AMEC 2003)

Parameter	Stage 1	Stage 2	Stage 3
Confining Stress, σ_3 (kPa)	250	300	400
Porewater Pressure, U (kPa)	222	137	134
Effective Confining Stress, (σ_3 – U) (kPa)	28	163	266
Deviator Stress, (σ_1 - σ_3) (kPa)	128	706	1,163
Shear Stress (σ_1 - σ_3)/2 (kPa)	64	353	582
Internal Friction, Φ (degrees)	43.2		
Cohesion, c (kPa)	1.0		
Moisture Content (%)	22.5		
Dry Density (t/m^3)	1.49		
Void Ratio	0.839		
Saturation (%)	73.0		

4.3 Tailings Settling Properties

Undrained and drained settling tests were completed in 2003 (AMEC 2003), while undrained, drained, settling and evaporation tests were completed in 2009 (KP 2009). Settling tests are typically performed in support of determining the amount of fluid released and/or retained by the tailings, and the time required for particles to settle. Undrained settling tests restrict drainage through the base of the sample, while drained settling tests allow water to drain through the base of the sample. The tests also provide an indication of the unconsolidated dry tailings density. Complete summarized results are presented in Table 12, Table 13, and Table 14. Settling times are not discussed in this memo (data provided in AMEC 2003 and KP 2009).

Table 12: Tailings Undrained Settling Properties

Testing Date	Sample Source	Tailings Type	Undrained Settling Test							
			Initial			Final			Total Water Recovery (%)	Portion of Initial Water Retained in Tailings prior to Evap (%)
			Solids Content (%)	Slurry Dry Density (t/m^3)	Moisture Content (%)	Solids content (%)	Slurry Dry Density (t/m^3)	Moisture Content (%)		
2003	Doris Tailings	Flotation - 34%	33.8%	0.428	195.6%	68.1%	1.19	46.9%	76%	24.1%
2009	Doris Central	Flotation - 38%	38.7%	0.515	158.6%	67.9%	1.20	47.4%	70%	29.9%
2009	Boston	Flotation - 38%	38.0%	0.505	162.7%	66.2%	1.16	51.2%	69%	31.4%
2009	Madrid - Suluk	Flotation - 38%	37.9%	0.503	163.7%	69.7%	1.27	43.5%	73%	26.6%
2009	Madrid - Naartok East	Flotation - 38%	38.3%	0.512	161.0%	70.1%	1.30	42.6%	74%	26.5%
2009	Madrid - Naartok West	Flotation - 38%	38.0%	0.614	162.6%	68.0%	1.22	47.0%	71%	29.0%
Average Flotation Tailings			**37.5%**	**0.513**	**167.4%**	**68.3%**	**1.22**	**46.4%**	**72%**	**27.9%**
2009	Doris Central	Mixed tails (CND/Flot.) - Sample 1	65.1%	1.112	53.7%	75.0%	1.44	33.3%	38%	61.9%
		Mixed tails (CND/Flot.) - Sample 2	69.8%	1.263	43.2%	75.5%	1.48	32.4%	25%	75.2%
		Mixed tails (CND/Flot.) - Sample 3	74.7%	1.436	33.9%	78.4%	1.58	27.5%	19%	81.1%
		Average	*69.8%*	*1.270*	*43.6%*	*76.3*	*1.50*	*31.1%*	*27%*	*72.7%*
2009	Boston	Mixed tails (CND/Flot.) - Sample 1	64.7%	1.114	54.7%	74.2%	1.44	34.9%	36%	63.6%
		Mixed tails (CND/Flot.) - Sample 2	70.1%	1.282	42.5%	76.5%	1.53	30.8%	28%	72.4%
		Mixed tails (CND/Flot.) - Sample 3	75.0%	1.481	33.3%	78.0%	1.60	28.2%	15%	84.5%
		Average	*69.9%*	*1.292*	*43.5%*	*76.2%*	*1.52*	*31.3%*	*26%*	*73.5%*
Average Mixed Detoxified Leach / Flotation Tailings			**69.9%**	**1.281**	**43.6%**	**76.3%**	**1.51**	**31.2%**	**27%**	**73.1%**
Average of Flotation and Mixed Detoxified Leach / Flotation Tailings(3)			**45.6%**	**0.705**	**136.4%**	**7**	**1.30**	**42.6%**	**61%**	**39.2%**
2009	Doris Central	Detox tailings	39.9%	NR	NR	NR	1.20	NR	65%	35.1%
2009	Boston	Cyanidation - 45%	45.0%	0.647	122.4%	61.6%	1.06	62.4%	49%	51.0%
Average Detoxified Leach Tailings			**42.5%**	**0.647**	**122.4%**	**61.6%**	**1.13**	**62.4%**	**57%**	**43.1%**

Notes:
1. NT = Not Tested
2. NR = Not Recorded
3. Average is based on the flotation samples and the average as reported for the Mixed tailings

Table 13: Tailings Drained Settling Properties

Testing Date	Sample Source	Tailings Type	Drained Settling Test & Falling Head Permeability								
			Initial			Final			Total Water Recovery (%)	Portion of Initial Water Retained in Tailings prior to Evap (%)	$k_{ave.}$ (m/sec)
			Solids Content (%)	Slurry Dry Density (t/m^3)	Moisture Content (%)	Solids content (%)	Slurry Dry Density (t/m^3)	Moisture Content (%)			
2003	Doris Tailings	Flotation - 34%	33.8%	0.044	195.6%	77.9%	1.43	28.4%	85%	14.5%	
2009	Doris Central	Flotation - 38%	37.9%	0.501	164.0%	71.2%	1.31	40%	75%	24.7%	2.1x10^{-7}
2009	Boston	Flotation - 38%	37.8%	0.501	164.4%	75.5%	1.23	33%	80%	19.7%	2.0 x10^{-7}
2009	Madrid - Suluk	Flotation - 38%	38.2%	0.505	161.9%	73.3%	1.40	36%	78%	22.2%	7.8 x10^{-8}
2009	Madrid - Naartok East	Flotation - 38%	38.0%	0.502	163.6%	74.1%	1.43	35%	79%	21%	1.4 x10^{-7}
2009	Madrid - Naartok West	Flotation - 38%	37.9%	0.503	163.9%	72.6%	1.38	38%	77%	23%	1.3 x10^{-7}
		Average Flotation Tailings	**37.3%**	**0.426**	**168.9%**	**74.1%**	**1.36**	**35%**	**79%**	**21%**	**1.5 x10^{-7}**
2009	Doris Central	Mixed tails (CND/Flot.) - Sample 1	65.2%	1.116	53.4%	77.2%	1.52	30%	44%	56.2%	9.2 x10^{-8}
		Mixed tails (CND/Flot.) - Sample 2	69.9%	1.260	43.2%	78.1%	1.57	28%	35%	64.7%	8.0 x10^{-8}
		Mixed tails (CND/Flot.) - Sample 3	74.8%	1.432	33.8%	79.5%	1.63	26%	22%	77.6%	5.4 x10^{-8}
		Average	*69.9%*	*1.269*	*43.5%*	*78.3%*	*1.57*	*28%*	*34%*	*66.2%*	*7.5 x10^{-8}*
2009	Boston	Mixed tails (CND/Flot.) - Sample 1	64.9%	1.128	54.0%	77.0%	1.54	30%	44%	55.5%	7.9 x10^{-8}
		Mixed tails (CND/Flot.) - Sample 2	69.9%	1.289	42.9%	78.9%	1.61	27%	36%	63.6%	6.8 x10^{-8}
		Mixed tails (CND/Flot.) - Sample 3	74.9%	1.462	33.6%	79.4%	1.66	26%	23%	77.1%	4.6 x10^{-8}
		Average	*69.9%*	1.293	*43.5%*	*78.4%*	*1.60*	*28%*	*34%*	*65.4%*	*6.4 x10^{-8}*
		Average Mixed Detoxified Leach / Flotation Tailings	**69.9%**	**1.281**	**43.5%**	**78.4%**	**1.59**	**28%**	**34%**	**66%**	**7.0 x10^{-8}**
		Average of Flotation and Mixed Detoxified Leach / Flotation Tailings (3)	**45.4%**	**42.6%**	**168.9%**	**74.1%**	**1.42**	**35.1%**	**68%**	**32%**	**1.3 x10^{-7}**
2009	Doris Central	Detox tailings	40.2%	NR	NR	NR	1.37	NR	70.8%	29.2%	NR
2009	Boston	Cyanidation - 45%	44.9%	0.629	122.7%	66.1%	1.19	51%	59%	41.3%	9.2 x10^{-8}
		Average Detoxified Leach Tailings	**42.6%**	**0.629**	**122.7%**	**66.1%**	**1.28**	**51%**	**65%**	**35.3%**	**9.2 x10^{-8}**

Notes:
1. NT = Not Tested
2. NR = Not Recorded
3. Average is based on the flotation samples and the average as reported for the Mixed tailings

Table 14: Tailings Settling and Drying Properties

Testing Date	Sample Source	Tailings Type	Settling and Drying Test				
			Initial	Final			Total Evaporation (mm)
			Solids Content (%)	Solids Content (%)	Slurry Dry Density (t/m^3)	Moisture Content (%)	
2003	Doris Tailings	Flotation - 34%	NT	NT	NT	NT	NT
2009	Doris Central	Flotation - 38%	38.1%	99.1%	1.88	0.9%	27.3
2009	Boston	Flotation - 38%	37.9%	90.0%	1.84	11.1%	21.9
2009	Madrid - Suluk	Flotation - 38%	37.6%	98.2%	1.69	1.8%	28.1
2009	Madrid - Naartok East	Flotation - 38%	37.8%	87.1%	1.98	14.8%	18.4
2009	Madrid - Naartok West	Flotation - 38%	37.8%	99.1%	1.74	0.9%	32.4
		Average Flotation Tailings	**37.8%**	**94.7%**	**1.83**	**5.9%**	**25.6**
2009	Doris Central	Mixed tails (CND/Flot.) - Sample 1	64.9%	96.7%	1.76	3.4%	32.8
		Mixed tails (CND/Flot.) - Sample 2	69.8%	98.2%	1.83	1.8%	32.8
		Mixed tails (CND/Flot.) - Sample 3	74.7%	97.0%	1.85	3.1%	32.8
		Average	*69.8%*	*97.3%*	*1.81*	2.77%	*32.8*
2009	Boston	Mixed tails (CND/Flot.) - Sample 1	64.7%	96.2%	1.85	4.0%	38.6
		Mixed tails (CND/Flot.) - Sample 2	69.8%	91.5%	1.88	9.3%	30.6
		Mixed tails (CND/Flot.) - Sample 3	74.8%	92.7%	1.92	7.9%	30.6
		Average	*69.8%*	*93.5%*	*1.88*	7.1%	*33.3*
		Average Mixed Detoxified Leach / Flotation Tailings	**69.8%**	**95.4%**	**1.85**	**4.9%**	**33.0**
		Average of Flotation and Mixed Detoxified Leach / Flotation Tailings (3)	**47.0%**	**94.7%**	**1.83**	**5.9%**	**27.7**
2009	Doris Central	Detox tailings	39.7%	NR	1.72	NR	46.7
2009	Boston	Cyanidation - 45%	44.7%	98.6%	1.66	1.4%	49.2
	Average Detoxified Leach Tailings		**42.2%**	**98.6%**	**1.69**	**1.4%**	**48.0**

Notes:
1. NT = Not Tested
2. NR = Not Recorded
3. Average is based on the flotation samples and the average as reported for the Mixed tailings

4.1 Vacuum and Pressure Filtration Data

Vacuum and pressure filtration work tests (Pocock 2009) are summarized in Table 15. It should be noted that in many of the scenarios tested, the test objective was to optimize tailings filtration production, with subsequent sizing of the filtration plant. As such, the reported dry densities and moisture contents are conservative. It is also important to consider that the reported data is representative of the material as it comes out of the filtration plant, and it can be assumed that typically lower moisture contents and higher in-situ densities are achieved following placement and compaction of the material.

Table 15: Vacuum and Pressure Filtration Data

Sample Source	Tailings Type	SG	Filtration Tailings (from Vacuum Filter Testing)					Filtration Tailings (from Pressure Filter Testing)		
			Filter Feed Solids (%)	No Flocculent		With Flocculent		Filter Feed Solids (%)	Dry Density (t/m^3)	Cake Moisture (%)
				Cake Dry Density (t/m^3)	Cake Moisture (%)	Cake dry Density (t/m^3)	Cake Moisture (%)			
Boston	Flotation	2.89	59.7%	1.93	18%	1.52	22%	59.1%	1.89	12.5 / 13.4 / 15.1
		2.89	38.6%	1.68	21%	1.52	24%	NR	NR	NR
Doris Central	Flotation	2.82	59.7%	1.78	18%	1.59	21%	58.5%	1.83	12.3 / 13.0 / 14.4
		2.82	38.9%	1.78	22%	1.59	23%	NR	NR	NR
Madrid - Suluk	Flotation	2.75	58.5%	1.84	18%	1.6	23%	38.5%	1.71	14.7 / 15.4 / 16.8
		2.75	38.1%	1.84	19%	1.6	26%	59.1%	1.83	13.7 / 14.6 / 16.4
Madrid - Naartok East	Flotation	2.8	59.0%	1.88	18%	1.46	22%	42.3%	1.72	13.1 / 13.7 / 15.0
		2.8	38.6%	1.88	19%	1.46	23%	59.2%	1.84	13.4 / 14.2 / 15.8
Madrid - Naartok West	Flotation	2.86	59.4%	1.91	18%	1.66	22%	39.4%	1.7	13.5 / 14.1 / 15.0
		2.86	38.6%	1.91	20%	1.66	24%	60.4%	1.91	12.9 / 13.6 / 15.0
	Average Flotation Tailings	**2.82**	**48.9%**	**1.84**	**19%**	**1.57**	**23%**	**25.4%**	**1.8**	**14.2%**
Boston	Mixed tails (CND/Flot)	2.9	59.8%	1.83	19%	1.49	23%	39.5%	1.74	14.2 / 14.9 / 16.1
		2.9	39.1%	1.83	20%	1.49	27%	60.1%	1.74	13.2 / 14.0 / 15.5
Doris Central	Mixed tails (CND/Flot)	2.87	59.8%	1.84	19%	1.52	23%	41.4%	1.75	14.0 / 15.0 / 16.7
		2.87	39.5%	1.84	21%	1.52	24%	60.7%	1.75	12.4 / 13.5 / 15.6
Average Mixed Detoxified Leach / Flotation Tailings		**2.89**	**50.0%**	**1.84**	**20%**	**1.51**	**24%**	**50.4%**	**1.75**	**14.6%**
Average Flotation and Mixed Detoxified Leach / Flotation Tailings[(3)]		**2.84**	**49.1%**	**1.84**	**19%**	**1.55**	**23%**	**17.1%**	**1.78**	**14.4%**

Table 16: Vacuum and Pressure Filtration Data - continued

Sample Source	Tailings Type	SG	Filtration Tailings (from Vacuum Filter Testing)					Filtration Tailings (from Pressure Filter Testing)		
			Filter Feed Solids (%)	No Flocculent		With Flocculent		Filter Feed Solids (%)	Dry Density (t/m³)	Cake Moisture (%)
				Cake Dry Density (t/m³)	Cake Moisture (%)	Cake dry Density (t/m³)	Cake Moisture (%)			
Boston	CIL Residue	3.26	NR	NR	NR	NR	NR	41.4%	1.79	19.0%
		3.26	NR	NR	NR	NR	NR	61.0%	1.79	18.0%
	Cyanidation	NR	NR	NR	NR	NR	NR	42.1%	1.69	19.0%
		NR	NR	NR	NR	NR	NR	61.3%	1.69	18.0%
Doris Central	CIL Residue	3.42	NR	NR	NR	NR	NR	41.2%	1.84	17.0%
		3.42	NR	NR	NR	NR	NR	59.2%	1.84	17.0%
	Cyanidation	NR	59.6%	1.76	24%	1.52	29%	53.4%	1.76	18.0%
		NR	39.7%	1.76	24%	1.52	32%	NR	NR	NR
Average Detoxified Leach Tailings		**3.34**	**49.7%**	**1.76**	**24%**	**1.52**	**31%**	**51.4%**	**1.77**	**18.0%**

Notes:
1. NT = Not Tested
2. NR = Not Recorded
3. Average is based on the flotation samples and the average as reported for the Mixed tailings

4.2 Deposited Tailings Densities

The deposited tailings density is dependent on both the specific gravity of the particles and the void ratio of the resulting deposited material. The densities measured in the undrained settling tests result in an average of 1.3 t/m³ (Table 12), and based on an average specific gravity of 2.85 (Table 5), the resulting void ratio is 1.2. This is consistent with typical void ratios for slurry deposited gold tailings to be between 1.1 and 1.2 (Vick 1990), and is consistent with the observed dry density versus void ratio relationship as illustrated in Figure 1. The data reported in Figure 1 is representative of all reported dry densities in Table 12, Table 13, Table 14, and Table 15. This approach does not factor the potential increase in dry density due to consolidation of the tailings mass, which is considered appropriate as much of the tailings is anticipated to freeze shortly after deposition, and consolidation of the tailings may not be possible. Therefore an average dry density of placed slurried tailings of 1.3 t/m³ is deemed appropriate for the Project tailings.

The available pressure filtration data of the Boston ore indicates an average dry density of 1.8 t/m³ for the tailings coming from the filtration plan (Table 15). Based on the reported relationship in Figure 1, the resulting void ratio would be approximately 0.6, which results in a gravimetric water content of approximately 20.5%, and correlates with a degree of saturation of 100%. As the drystack will be constructed with a degree of saturation less than 100%, these values are considered conservative.

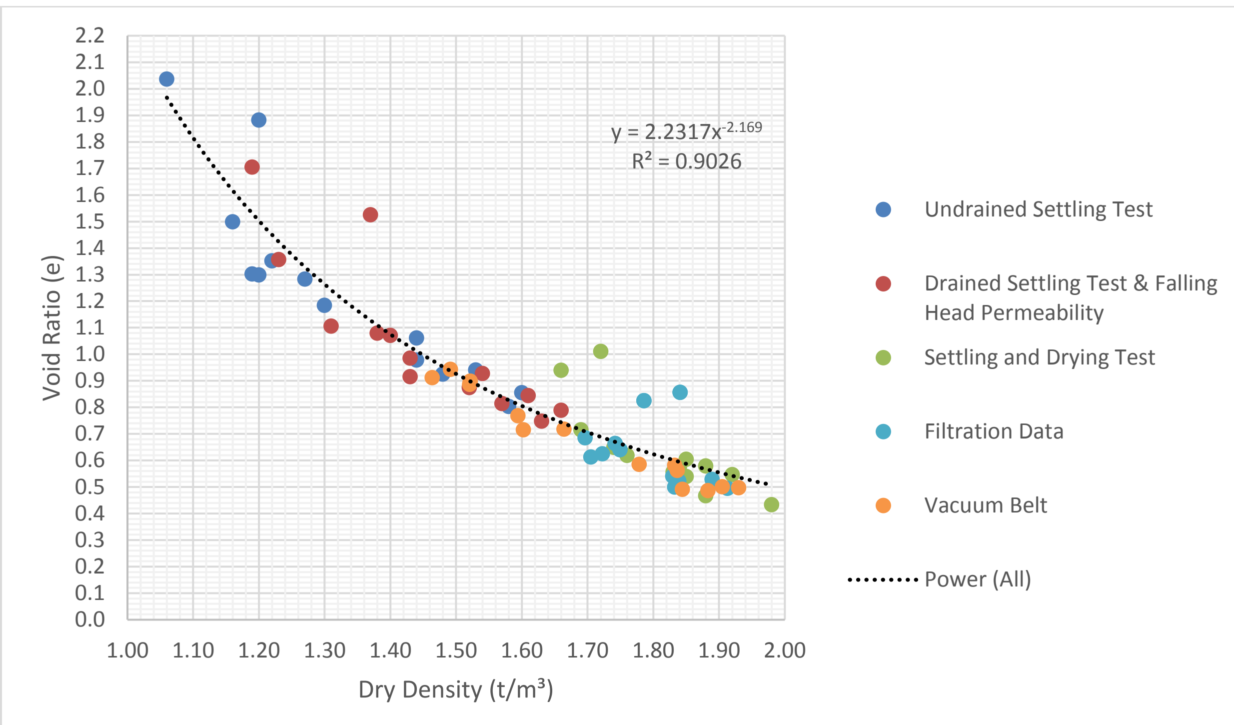

Figure 1: Measured Dry Density versus Void Ratio

Figure 2 and Figure 3 demonstrate the observed relationship between dry density and gravimetric moisture content, and gravimetric moisture content and void ratio, respectively. It can be observed that the obtained final results from the settling and drying tests are not consistent with the otherwise observed trends in the data. This is consistent with our expectations, as the settling and drying tests evaluate the maximum amount of water that can be drained and evaporated from the tailings samples, which can result in an appropriately low moisture content. The data from the settling and drying tests has been included on Figure 2, and Figure 3 in the interest of reporting all available data.

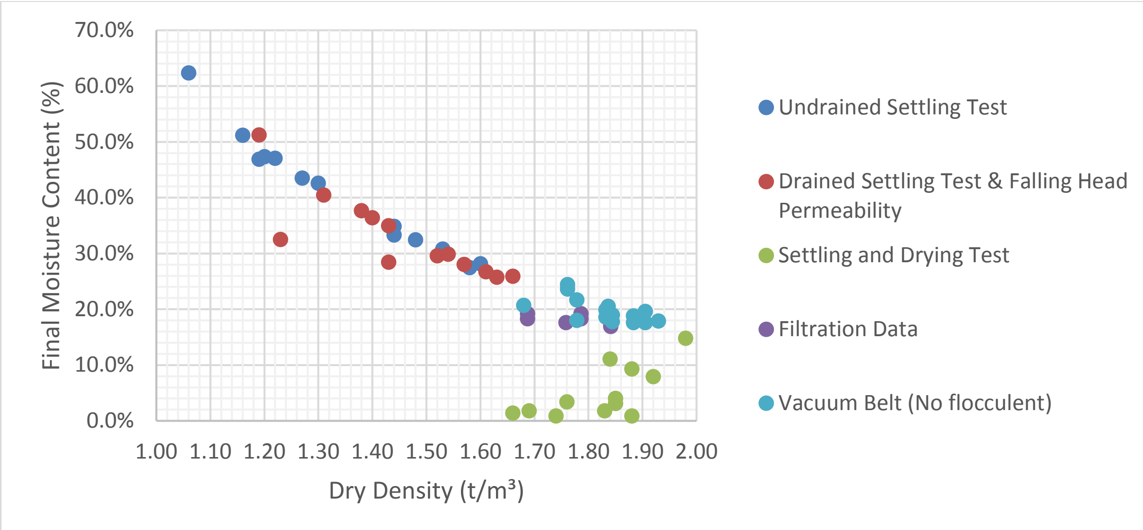

Figure 2: Measured Dry Density versus Measured Moisture Content (Final)

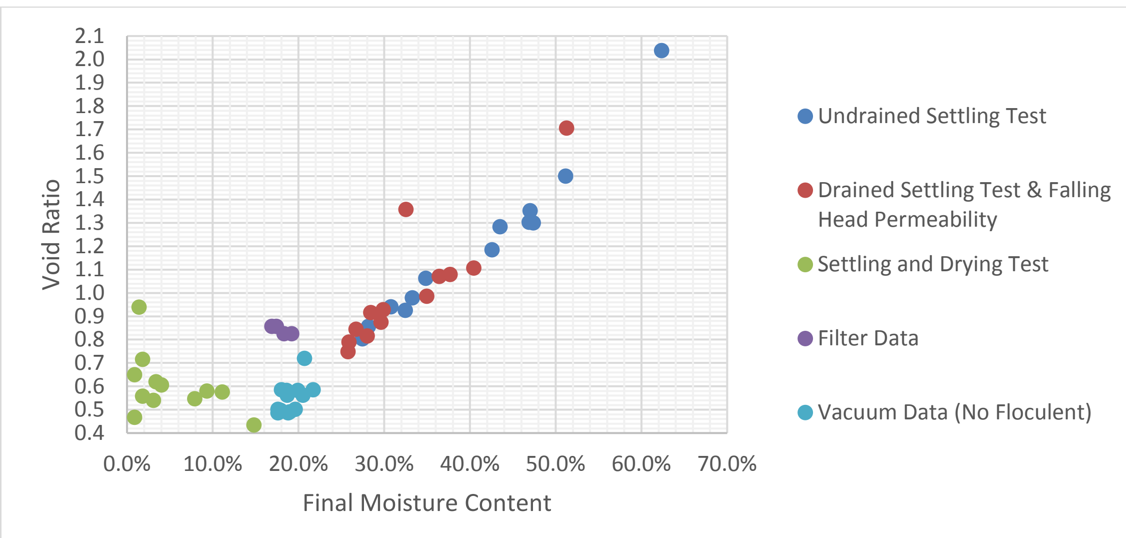

Figure 3: Measured Final Moisture Content versus Void Ratio

5 Summary

As previously stated, the deposited tailings density is dependent on both the specific gravity of the particles and the void ratio of the resulting deposited material. Based on a the average specific gravity of 2.85 (Table 5), and a void ratio of 1.2 (Vick 1990), the resulting dry density is 1.3 t/m^3, which is consistent with the observed average dry density for the tailings from the undrained settling tests (Table 12), and the observed relationship in Figure 1. Therefore, an average dry density of placed tailings equal to 1.3 t/m^3 is appropriate for the Project tailings.

Similarly, the dry density of the drystack tailings is recommended to be 1.8 t/m^3, with a void ratio of 0.6, and a gravimetric water content of 20.5%. These values are representative of the tailings testing in laboratory conditions and appropriately conservative for use as design parameters. Under operational conditions the void ratio may change significantly due to active compaction, resulting in increased density and lower moisture content. Further testing will be required to determine the maximum density and the optimum moisture content.

An internal angle of friction of 43 degrees may be considered high for these tailings; therefore, an angle of 40 degrees has been used in stability modelling to date. Also, the measured value for cohesion is low (1 kPa), and its effectiveness in supporting the soil structure is highly dependent on how the stress path for failure is mobilized. Therefore, cohesion is not considered in stability analysis.

Based on the geotechnical testing results, and the design understanding, the values as presented in Table 16 are recommended to be used on a go-forward basis.

Table 17: Summarized Tailings Geotechnical Properties

Parameter	Value	Source
Specific gravity	2.85	Average of lab testing (Table 5)
% Fines (<0.075 mm)	65%	Average of lab testing (Table 6)
% Silt	52%	Average of lab testing (Table 6)
% Clay	13%	Average of lab testing (Table 6)
Void ratio (e) – slurried tailings	1.2	Assumed & supported with available data (Figure 1)
Void ratio (e) – drystack tailings	0.6	Assumed & supported with available data (Figure 1)
Deposited dry density (tonnes/m^3) – slurried tailings	1.30	Based on void ratio of 1.2 and SG of 2.85, correlates with available data (Figure 1).
Deposited dry density (tonnes/m^3) – drystack tailings	1.8	Based on void ratio of 0.6 and SG of 2.85, correlates with available data (Table 15).
Internal angle of friction (degrees)	40	Engineering judgement based on available data (Table 11)
Cohesion (kPa)	0	Engineering judgement based on available data (Table 11)

Parameter	Value	Source
Gravimetric moisture content (%) – slurried tailings	42.6%	Average based on undrained settling tests (Table 12) (Note: a gravimetric moisture content of 42.6% results in a degree of saturation > 100%)
Gravimetric moisture content (%) – drystack tailings	20.5%	Based on observed relationships in Figure 2 and Figure 3. (Note: a gravimetric moisture content of 20.5% results in a degree of saturation equal to 100%)
Hydraulic conductivity (m/s)	1.3×10^{-7}	Average (Table 10)

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

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Appendix F – Hope Bay Project: Phase 2 Tailings Impoundment Area North Dam Freeboard Hydraulic Assessment

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Memo

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From:	Samantha Barnes, EIT Victor Muñoz, PEng	**Project No:**	1CT022.004.610
Reviewed By:	Maritz Rykaart, PhD, PEng	**Date:**	December 13, 2016
Subject:	Hope Bay Project - North Dam Freeboard Hydraulic Assessment		

1 Introduction

The Hope Bay Project (the Project) is a gold mining and milling undertaking of TMAC Resources Inc. The Project is located 705 km northeast of Yellowknife and 153 km southwest of Cambridge Bay (Iqaluktuttiaq) in Nunavut Territory, and is situated east of Bathurst Inlet (Qingaut). The Project comprises of three distinct areas of known mineralization plus extensive exploration potential and targets. The three areas that host mineral resources are Doris, Madrid, and Boston.

The Project consists of two phases; Phase 1 (Doris project), which is currently being carried out under an existing Water Licence, and Phase 2 which is in the environmental assessment stage. Phase 1 includes mining and infrastructure at Doris only, while Phase 2 includes mining and infrastructure at Madrid and Boston located approximately 10 and 60 km, respectively due south from Doris.

Phase 1 tailings are deposited sub-aerially in the Doris tailings impoundment Area (TIA), formerly Tail Lake, located approximately 5 km from the Doris mill. Containment is provided by three retention structures; a water retaining frozen core dam (North Dam), a frozen foundation tailings containment dam (South Dam), and an Interim Dike situated at approximately the midpoint of the facility. Tailings would be deposited sub-aerially between South Dam and Interim Dike, and the Reclaim Pond will be contained between the Interim Dike and the North Dam. The North Dam was constructed over two winters (2011 and 2012) and has impounded water since 2011. The South Dam and Interim Dike are scheduled for construction in 2017.

Phase 2 tailings deposition would include a continuation of the Doris TIA with raising of the South Dam and construction of a new West Dam (SRK, 2016a). Under the current tailings management plan, all flotation tailings from Doris, Madrid, and Boston would be deposited in the TIA, with cyanide leach tailings being detoxified and used as structural backfill in the underground workings. Tailings would be deposited sub-aerially starting at spigot points along the crest of the raised South Dam and the West Dam, as well as additional spigot points along the eastern perimeter.

The deposition plan makes it such that final tailings surface will create a contiguous beach draining consistently to the north at a 1% slope starting at the South Dam, while the South and West dams will not be retaining any water with the Reclaim Pond developing against the North Dam. As tailings are deposited, the surface of the Reclaim Pond is gradually decreasing. The calculations of the freeboard presented here were completed for the smallest Reclaim Pond footprint at the end of tailings deposition, this being the most conservative scenario.

This memo summarizes the inflow design flood (IDF) and hydraulic freeboard calculations for the North Dam.

2 Methodology

2.1 Supporting Information

Topographical information for the Project site consists of LiDAR, provided by TMAC. The dam alignment and proposed tailings surface bathymetry was used to estimate fetch length and average water depth across the Reclaim Pond.

Required hydrological inputs such as rainfall depth, snow pack, wind speed and spring freshet were obtained from SRK (2016b). The month with the highest snowmelt is June, and this is incorporated into the spring probable maximum flood (PMF) estimation. The IDF table from the SRK (2016b) report was also used in the spring Probable Maximum Precipitation (PMP) calculation.

2.2 Approach

A wind and wave analysis was performed to ensure that the crest of the dam is protected against the most critical of the following two cases (CDA, 2007, updated 2013):

- Normal freeboard: no overtopping by 95% of the waves caused by the most critical wind with a frequency of 1 in 1,000 year when the reservoir is at its full supply level (FSL); and
- Minimum freeboard: no overtopping by 95% of the waves caused by the most critical wind associated with the annual exceedance probability (AEP) event, when the reservoir is at its maximum extreme level during the occurrence of the IDF.

In accordance with the most recent Canadian Dam Safety Association Guidelines (CDA, 2014) the possibility of high water level occurring at the same time of the storm and high wind events must also be considered. Therefore a third scenario was analysed, combining the normal and the minimum freeboard values described above.

The following sections describe the estimations for the IDF, the normal freeboard and the minimum freeboard, as well as the results of the combined freeboard scenario.

3 Inflow Design Flood

3.1 Method

For a dam with a HIGH consequence classification, the IDF is defined to be 1/3 between the 1,000-year event and the PMF (CDA, 2014). The TIA was however designed without a spillway, thus requiring the retention of the full PMF event. The IDF was therefore increased to account for the PMF, which corresponds to a dam with an EXTREME consequence classification.

Both scenarios described above were modelled in HEC-HMS, developed by the U.S. Army Corps of Engineers (USACE, 2015). Additional inputs for the model included the TIA catchment area and associated lag time, and a Curve Number to account for rainfall losses. The results of the model were a range of total flood volumes (Section 3.3).

3.2 Hydrologic Definitions

3.2.1 Probable Maximum Flood

The PMF is considered the most severe flood event that may reasonably be expected at the Project site. It is generated by the PMP, which is the maximum precipitation that may reasonably occur at the Project site, plus snowmelt.

Two PMF cases were considered, based on guidance from the Canadian Dam Association (CDA, 2007 updated 2013):

1) Summer PMF, which is generated by the summer PMP; and

2) Spring PMF, which is defined as the maximum of the following two cases:

   a. Rainfall dominated event: PMF computed with the spring PMP and snowmelt from a 1/100-year snow accumulation; and

   b. Snowmelt dominated event: PMF computed with the 1/100-year rainfall and the snowmelt from the probable maximum snow accumulation.

The probable maximum snow accumulation can be simplified as two times the 100-year snowpack, (Alberta Transportation, 2004).

The snowmelt in each case is calculated by applying a 1/100-year temperature sequence to the design snow depth for an appropriate duration. Since the North Dam will not have a spillway, the selected duration was the full snowmelt period to ensure the dam does not overtop. This simplified the snowmelt calculations to a total snowpack calculation, in snow-water-equivalent (SWE).

3.2.2 1/1,000-Year Flood

The 1/1,000-year flood is the flood resulting from the larger of two events, similar to the PMF, as defined by CDA:

1. Summer 1/1,000-year rainfall; and
2. Spring 1/1,000-flood, which is defined as the maximum of two cases:
    a. Rainfall dominated event: A 1/1,000-year spring rainfall event combined with average snowmelt; and
    b. Snowmelt dominated event: A 1/1,000-year snowmelt combined with an average spring rainfall event.

The snowmelt in this case is also simplified to the total snowpack of each frequency, in SWE.

3.3 Modelled Flow Conditions

Based on the definitions above, a total of five hydrologic conditions were prepared in the HEC-HMS model, which are outlined below:

1) Summer PMF: generated by the summer PMP event;
2) Spring PMF Rainfall-Dominated: generated by the 100-year SWE and the spring PMP event;
3) Spring PMF Snowmelt-Dominated: generated by the 100-year spring rainfall and the probable maximum snow accumulation SWE.
4) 1/1,000-year Summer Flood: generated by the summer 1/1,000 rainfall event;
5) 1/1,000-year Rainfall-Dominated Spring Flood: generated by the spring 1/1,000 rainfall event and the average spring snowmelt; and
6) 1/1,000-year Snowmelt-Dominated Spring Flood: generated by the 1/1,000 SWE and the average spring 24-hour rainfall.

Inputs to the five hydrologic conditions are summarized in Table 1 and defined in SRK (2016b). The total precipitation is equal to the sum of the snowmelt and the rainfall, under each case.

Table 1: IDF Hydrologic Calculation Inputs

Hydrologic Condition	Rainfall (mm)	Snowmelt, in SWE (mm)	Total Precipitation (mm)
1. Summer PMF	180	0	180
2. Spring PMF: Rainfall-Dominated	115	126	241
3. Spring PMF: Snowmelt-Dominated	49	252	301
4. 1/1,000 Summer Flood	118	0	118
5. 1/1,000 Rainfall-Dominated Spring Flood	75	56	131
6. 1/1,000 Snowmelt-Dominated Spring Flood	7	202	209

3.4 Hydrologic Model

3.4.1 Catchment Delineation

The TIA catchment was delineated in Global Mapper™ (Blue Marble, 2016) using site topography, and was divided into three categories: tailings beach, Reclaim Pond, and undisturbed (i.e. natural catchment) area (Table 2).

3.4.2 Transformation

The SCS Unit Hydrograph method was used to transform precipitation into an outflow hydrograph for each sub-area. HEC-HMS uses a single input parameter, the lag time (T_{lag}), defined as the time between the centroid of precipitation mass to the peak for the resulting hydrograph. The lag time for each catchment was calculated using the National Resource Conservation Service (NRCS) transformation from time of concentration. The NRCS transformation is $T_{lag} = 0.6*Tc$. Time of concentration and resulting lag times are relatively short (<15 minutes). This results in peak discharges near the time of the storm peak. The time of concentration was estimated with the methods cited in (Li *et al*., 2008). A minimum time of concentration of ten minutes was applied to all catchments. Each catchment's lag time is presented in Table 2.

To best approximate the storm type, the geographical region closest to the Project site should be used to estimate the storm characteristics. The Type 1 rainfall distribution is typical across Alaska (Chow *et al*. 1988) and because of the close weather similarities between Alaska and the Project site, based on Peel MC *et al.* (2007), the SCS Type I rainfall distribution was selected for use in the HEC-HMS model. This distribution approximates an intense, short-duration storm event.

3.4.3 Curve Number Selection

The SCS Curve Number (CN) for the tailings beach was estimated based on typical tables, based on hydrologic group A, for sands, and an Antecedent Moisture Condition 3 (AMC III) which assumes the soil is saturated. For the Reclaim Pond area, no losses are expected and a CN of 100 was used.

The CN for the undisturbed (i.e. natural catchment) area was calibrated using the 1/100 year flow event for the nearby hydrometric station 10TF001 Freshwater Creek near Cambridge Bay (EC, 2015). The lag time and catchment area were modelled in HEC-HMS, and the CN was adjusted until the modelled peak flow matched the historically estimated 1/100 year peak flow. The final CN for the undisturbed areas was calibrated to be 72. A factor of 1.2 was applied to the CN value to convert it from AMC II to AMC III, giving a CN value of 86 for undisturbed areas.

A summary of catchment CNs and other characteristics are presented in Table 2.

Table 2: Catchment Characteristics

Catchment Description	Catchment Area (km²)	Curve Number	Lag Time (min)	Source
Tailings Beach Area	1.33	80	6	Natural desert landscaping (pervious area only), Group A, AMC III
Reclaim Pond Area	0.43	100	6	Pond surface – no losses
Undisturbed (i.e. Natural Catchment) Area	2.54	86	6	Calibrated by SRK, AMC III

3.5 Hydrologic Model Results

Using the input parameters listed in Table 1 and Table 2, the results presented in Table 3 were determined.

Table 3: Hydrologic Model Results

Hydrologic Condition	Rainfall Volume (m³)	Snowmelt Volume (m³)	Total Volume (m³)
1. Summer PMF	588,600	-	588,600
2. Spring PMF: Rainfall-Dominated	401,037	439,863	840,900
3. Spring PMF: Snowmelt-Dominated	178,718	915,382	1,094,100
4. 1/1,000 Summer Flood	339,000	-	339,000
5.1/1,000 Rainfall-Dominated Spring Flood	223,454	166,846	390,300
6. 1/1,000 Snowmelt-Dominated Spring Flood	23,720	684,480	708,200

Based on the results presented in Table 3, the critical storm for the PMF was found to be Condition No. 3, the snowmelt-dominated Spring PMF, and the critical hydrologic condition for the 1/1,000-year event was found to be Condition No. 5, i.e. the Snowmelt-Dominated Spring Flood.

These results were subsequently used to calculate the IDF volume for both the HIGH and EXTREME consequence classifications (Table 4). The HIGH consequence classification is based on an interpolation between the critical 1/1,000-year event and the critical PMF (CDA, 2014).

Table 4: IDF Volume Results for Dam Classifications High and Extreme

Dam Consequence Classification	Corresponding IDF	Critical Hydrologic Condition	Rainfall Volume (m^3)	Snowmelt Volume (m^3)	Total IDF Volume (m^3)
HIGH	1/3 between 1/1,000-year event and the PMF	3, 6	75,386	761,448	836,833
EXTREME	PMF	2	178,718	915,382	1,094,100

At the end of the mine life, when the Reclaim Pond is at its smallest, the IDF's listed in Table 2 translates to water level increases over the design FSL of 33.5 m for the HIGH and EXTREME consequence classifications of 1.7 m (35.2 m) and 2.1 m (35.6 m) respectively.

4 Freeboard

4.1 Input Parameters and Design Criteria

Inputs for calculating the normal and minimum freeboard for the North Dam include wind speed, initial water level, average Reclaim Pond water depth, and fetch length as presented in Table 5. Fetch length was updated based on the initial water level.

Table 5: Freeboard Design Criteria and Input Parameters

Parameter	Normal Freeboard		Minimum Freeboard HIGH Consequence Classification		Minimum Freeboard EXTREME Consequence Classification	
	Design Criteria	Value	Design Criteria	Value	Design Criteria	Value
IDF	n/a		1/3 between 1/1,000-year event and the PMF		PMF	
Wind Speed (m/s)	1/1,000 year event	35.3	1/2 year event	25.6	1/2 year event	25.6
Initial Water Level (masl)	FSL	33.5	FSL + IDF	35.2	FSL + IDF	35.6
Average Water Depth (m)	FSL	4.4	FSL + IDF	6.1	FSL + IDF	6.5
Fetch Length (m)	FSL	950	FSL + IDF	1,100	FSL + IDF	1,160
Corrected Wind Speed Over Water[1](m/s)	Correction Factor = 1.09	38.5	Correction Factor = 1.10	28.3	Correction Factor = 1.11	28.4
Significant Wave Height (m)[2]	m	0.80	m	0.75	m	0.75
Specific Wave Height (m)	5% exceeding specific wave height[4]	1.12	5% exceeding specific wave height	1.05	5% exceeding specific wave height	1.05
Run-up Ratio[3]	6:1 (H:V)	0.95	6:1 (H:V)	0.95	6:1 (H:V)	0.95

Note:
1. Correction factors are based on fetch length (USACE 1997). See Appendix A-3.
2. The significant wave height was estimated based on the maximum of: wave height figures presented by SANCOLD (1990) in Appendix A-1 and A-2, and the Design Standards No. 13 for Embankment Dams, USBR (2012).
3. Run-up ratio is based on a relationship between the wave height, the embankment slope and the embankment protection (SANCOLD, 1990). Appendix A-4.
4. Average wave height of the highest 5% of waves in a given spectrum, based on Design Standards No. 13 for Embankment Dams, USBR (2012).

4.2 Normal Freeboard

4.2.1 Definition

Normal freeboard is the sum of the wind set-up and the wave run-up, based on the design parameters listed in Table 5. Figure 1 illustrates the parameters contributing to the normal freeboard calculation.

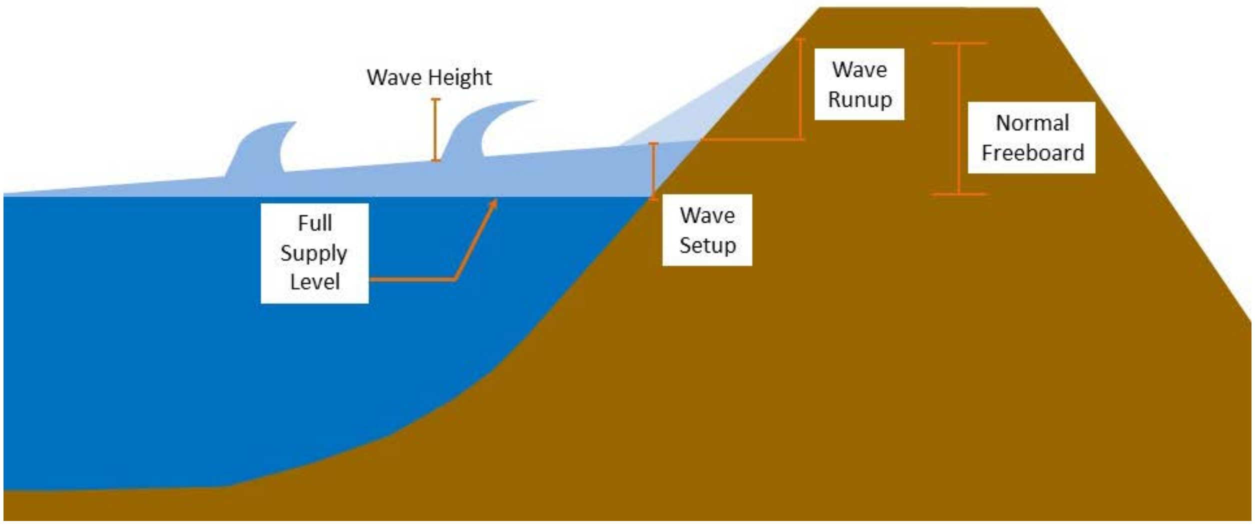

Figure 1: Normal Freeboard Schematic

4.2.2 Wind Setup

Wind set-up is defined as the vertical water height above the static water level which may result from wind stress over the water surface. The US Army Corps of Engineers (USACE, 1989) estimates the wind setup relative to the supply water level (SWL) (which for the purpose of these calculations is equivalent to the FSL) using the following expression:

$$S = \frac{U^2 F}{1400d} \qquad \text{(Eq. 1)}$$

Where:

S is the wind setup relative to the SWL (ft);
U is the wind speed over water (mph);
F is the effective fetch length (miles); and
d is the average water depth over the fetch (ft).

Based on the input parameters presented in Table 5, the resultant wind setup for the normal freeboard is 0.07 m.

4.2.3 Wave Run-up

Wave run-up is defined as the maximum vertical extent of a wave uprush on a beach or structure. The estimation of the wave run-up requires the estimation of the wave height. This analysis was based on the method presented by the South African National Committee on Large Dams (SANCOLD, 1990). SANCOLD (1990) presents a relationship between the wave height, the embankment slope and the embankment protection. The wave run-up is calculated using Equation 2 below.

$$Wave\ Runup = Wave\ Height\ \times Runup\ Ratio \qquad \text{(Eq. 2)}$$

Based on the 6 to 1 slope (horizontal to vertical), and a combination of rough stone and riprap, the run-up ratio was approximated to be 0.95 (Table 5) while the wave run-up for the 1/1,000 wind event was calculated to be 1.06 (Equation 2).

This value and methodology was compared with the methodology presented by USBR (2012); this reference suggests slightly lower values than SANCOLD (1990). As a conservative approach, the values selected utilize the SANCOLD (1990) methodology.

4.2.4 Normal Freeboard Estimate

The normal freeboard for the North Dam was subsequently determined to be 1.13 m (wind setup of 0.07 m + wave run-up of 1.06 m).

4.3 Minimum Freeboard

4.3.1 Definition

Minimum freeboard is described as the required freeboard to protect against the IDF and the wave run-up from a 1 in 2-year wind storm event. This is schematically illustrated in Figure 2, based on the design parameters listed in Table 5.

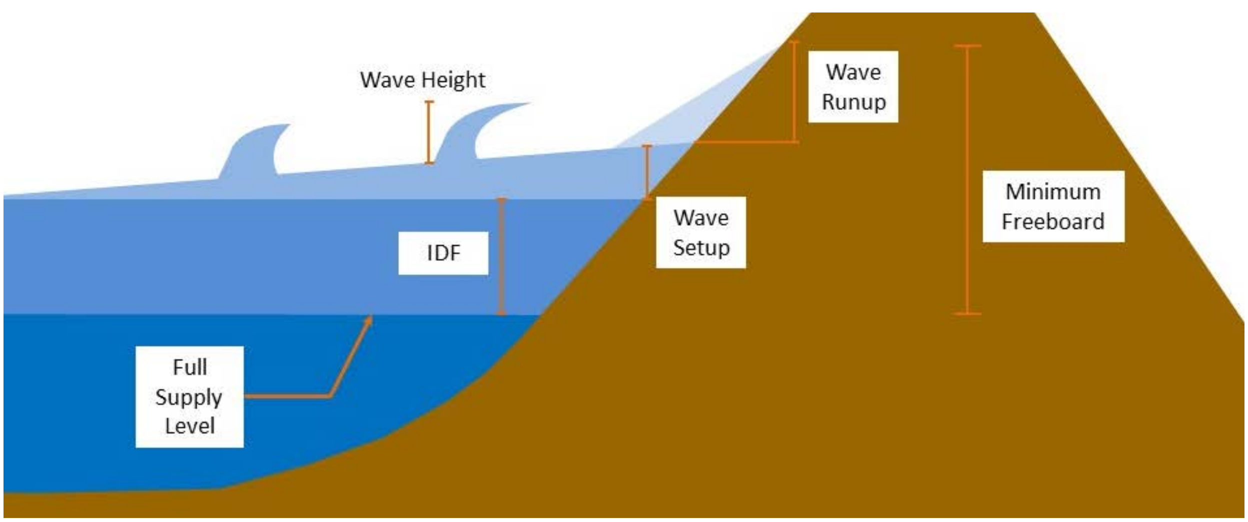

Figure 2: Minimum Freeboard Schematic

4.3.2 Wind Setup

Based on Equation 1 and the input parameters presented in Table 5, the wind setup for the minimum freeboard was calculated to be 0.03 m for both the HIGH and EXTREME consequence classification.

4.3.3 Wave Run-up

Based on the input parameters in Table 5, and Equation 2, the wave run-up for the minimum freeboard was calculated to be 1.00 m for both the HIGH and EXTREME consequence classification.

4.3.4 Minimum Freeboard Estimate

Subsequently the minimum freeboard for the North Dam is 1.03 m, irrespective of the consequence classification.

4.4 Combined Freeboard

4.4.1 Definition

The combined freeboard is the required freeboard to protect against the IDF and the wave run-up from a 1 in 1,000 year wind storm event. This is essentially a combination of the normal freeboard and minimum freeboard criteria for the EXTREME dam classification, where an extreme pond level and high wind are considered, based on the design parameters listed in Table 5.

4.4.2 IDF

As described in Section 3.5, at the end of the mine life when the Reclaim Pond is at its smallest, the IDF's listed in Table 2 translates to 2.1 m water level increases over the design FSL of 33.5 m.

4.4.3 Wind Setup

Based on Equation 1 and the input parameters presented in Table 5, the wind setup for the combined freeboard was calculated to be 0.06 m.

4.4.4 Wave Run-up

Based on the input parameters in Table 5, and Equation 2, the wave run-up for the combined freeboard was calculated to be 1.16.

4.4.5 Combined Freeboard Estimate

Subsequently the combined freeboard for the North Dam is 3.3 m (IDF of 2.1 m + wind setup of 0.06 m + wave run-up of 1.16 m), designed to retain the IDF without the need for a spillway and withstand the wave action resulting from strong winds.

5 Results

The normal and minimum freeboard results for the North Dam are presented in Table 6.

Table 6: Freeboard Results

Freeboard Condition	Initial Water Level (m)	Wind Setup (m)	Wave Run-up (m)	Freeboard (m)	Final Freeboard Elevation (m)
Normal Freeboard	33.5	0.07	1.06	1.13	34.6
Minimum Freeboard HIGH Consequence Classification	35.2	0.03	1.00	1.03	36.2
Minimum Freeboard EXTREME Classification	35.6	0.03	1.00	1.03	36.6
Combined Freeboard EXTREME Classification	35.6	0.06	1.16	1.22	36.8

These freeboard results are consistent with typical values suggested by USBR (2012) where for a fetch smaller than 1,600 m (1 mile) a normal freeboard of 1.2 m (4 ft.) and minimum freeboard of 0.9 m (3 ft.) should be expected.

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6 References

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Appendix A: Reference Material