Technical Memorandum

To:	Karyn Lewis, Project Manager Lupin Project	From:	Alvin Tong
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File:	Lupin Gold Project - 129500081	Date:	November 13, 2019

Reference: 2 AM-LUP Technical Meeting Commitment Number 12 Response – Risk Assessment on Two Dams in the Lupin Tailings Containment Area

Lupin Mine Incorporated (LMI), a wholly owned subsidiary of Mandalay Resources Corporation is requesting the renewal and amendment of their existing Type "A" Water License No: 2AM-LUP1520 (License), to allow for Final Closure and Reclamation of the Lupin Mine Project (Lupin). The Nunavut Water Board (NWB or Board) Water License Application No. 2AM-LUP1520 Technical Meeting was held June 6-7, 2019 in Kugluktuk, Nunavut. Appendix D of the June 18, 2018 Pre-Hearing Conference Decision Report outlines the agreed upon List of Commitments (Commitments). Stantec Consulting Ltd. (Stantec) was retained by LMI to support the responses to select commitments and this technical memorandum provides the responses to fulfill Commitment No. 12, shown below, which relates to conducting a risk assessment on select dams at the Lupin Tailings Containment Area (TCA).

12	LMI	ECCC	Risk assessment of the two dams selected under item #11, based on the results of the thermal modelling provided on October 15, 2019, and representing both perimeter and internal dam types.	15-Nov-19	Technical Memo

The two dams selected for risk assessment in the response to Commitment No. 11 (Stantec 2019a) are Dam 3D and Dam 4, representing both perimeter and internal dam types. The risk assessment is based on the geotechnical stability results from Commitment No. 6. (Stantec 2019b), surface geophysical results from Commitment No. 11, and potential thawing of the frozen material in the TCA dams under multiple climate warming scenarios from the thermal modelling completed for Commitment No. 13 (Stantec 2019c). This technical memorandum will summarize risk on the dams in terms of geotechnical stability and the potential for impact to downstream water quality due to seepage from the Lupin TCA, based on the current thermal modeling results.

CURRENT CONDITIONS

Geophysical surveys were carried out on Dam 3D and Dam 4 in response the Commitment No. 11. The survey indicated that frozen material was encountered at a depth of approximately 2.5m within the dams. This depth corresponds to sub-zero temperature readings from the existing thermistors in the dams. Both the survey and the thermistor readings indicated that the TCA dams contain a continuous frozen core as licensed, which is intended to control seepage from the TCA cells. The geotechnical stability evaluation done in response to Comment No. 6 concluded that Dam 3D and Dam 4 meet the stability criteria shown in Table 1.

Table 1: Summary of Stability Criteria

Failure Mode	Condition	Factor of Safety (Limit-Equilibrium)
Local	Static	1.3
Global		1.5
Global	Seismic	1.1

Overall, the survey results, thermistor readings, and the stability evaluation all indicate that the dams are currently performing as licensed.

RISK ASSESSMENT

To complete the risk assessment, the current dam conditions were used as a starting point and the results of the thermal modeling were applied to evaluate potential changing dam conditions outlined in the climate scenario. The thermal modeling completed in response to Comment No. 13 (Stantec 2019c) was completed using the low emission scenario (LES) and the high emission scenario (HES). The LES model results suggested only a partial thaw of the frozen core and some degradation of the permafrost, while in contrast the HES model results suggested a complete thaw of the frozen core and significant degradation of the permafrost. As such, this risk assessment will focus on the HES scenario as it is more conservative and will be the critical potential failure mode.

GEOTECHNICAL STABILITY

Stability analyses were completed in the same manner as the work completed in response to Comment No. 6. The only difference is the frozen core was replaced with thawed material, and a phreatic surface was assumed between the top of tailings adjacent to the upstream side of the dam to the downstream toe of the dam. This assumed phreatic surface is more conservative than the expected condition during HES thawing. Realistically, as the frozen core recedes downwards to lower elevations according to the HES model, the phreatic surface is expected to drop accordingly within the dam and recede upstream into the tailings deposit, resulting in a more gradual gradient over a minimum 30m distance in to the tailings (Holubec, 2006) than the assumed phreatic surface next the upstream dam face. Figure 1 shows the typical seepage section for the TCA dams (Holubec, 2006).

Reference: 2 AM-LUP Technical Meeting Commitment Number 12 Response – Risk Assessment on Two Dams in the Lupin Tailings Containment Area

Figure 1: Schematic of Seepage Analyses Results (Holubec 2006)

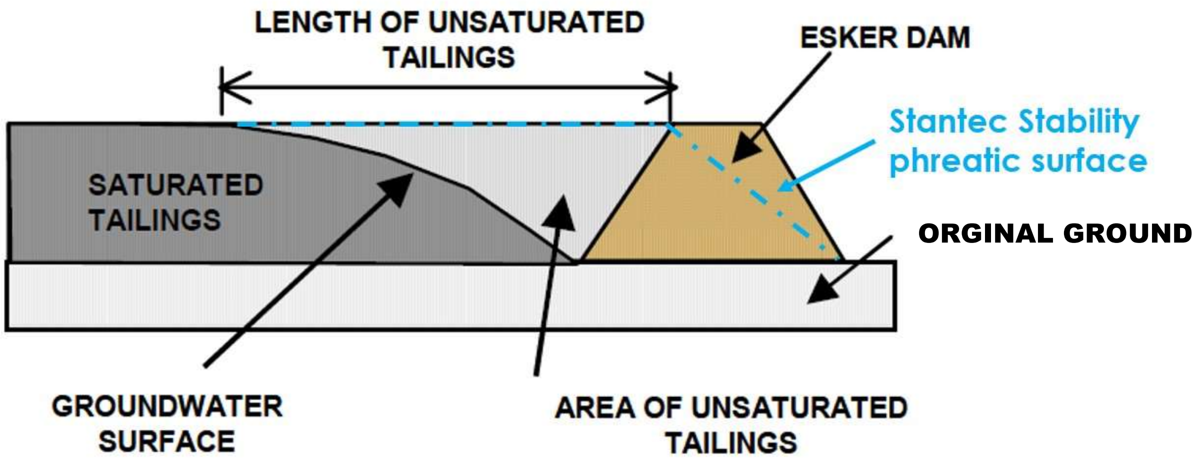

Table 2 shows the material properties used in the analyses and the Figure 1 shows the locations of the stability sections.

Table 2: Material Properties

Material	Unit Weight (kN/m^3)	Effective Stress Parameters
Esker (dam and cover fill)	30	c' = 0, φ' = 35°
Gravelly Sand	30	c' = 0, φ' = 35°
Rockfill	20	c' = 0, φ' = 39°
Tailings (Drained)	18	c' = 0, φ' = 30°
Tailings (Undrained)	18	Minimum strength: 20 kPa, Su/σ'v = 0.24
Till	18	c' = 0, φ' = 30°
Bedrock	Impenetrable	

Reference: 2 AM-LUP Technical Meeting Commitment Number 12 Response – Risk Assessment on Two Dams in the Lupin Tailings Containment Area

Figure 2: Tailings Containment Area Stability Section Locations

The results of the stability analyses are shown in Table 3 and provided in Appendix A. The factor of safety of the dams with the unfrozen core under the HES meet the closure criteria.

Table 3: Summary of Stability Analyses Results

Cross-section	Configuration	Scenario		
		Thawed Condition		Seismic
		Local	Global	Global
3D	As-built	1.3	3.6	3.2
4	As-built	2.9	5.9	4.7

POTENTIAL IMPACT ON THE WATER QUALITY DUE TO SEEPAGE

The potential impact on downstream water quality in the receiving environment due to seepage from the TCA in the scenario where the frozen core of the dam is thawed has been analyzed in previous geotechnical, seepage and water balance studies (Holubec 2006; EcoMetrix 2006). In general, the studies concluded that the current TCA closure plan provides adequate water quality protection in post-thaw conditions. More specifically, the studies concluded the following:

- *If permafrost thaws in the future, the unsaturated tailings adjacent to the dams will continue to retain high degrees of water saturation. The fine-grained nature of the tailings, enhanced infiltration and prevention of the evaporation associated with the esker cover will likely keep the saturation of the tailings high.*
- *Majority of the tailings areas beyond the small unsaturated areas adjacent to the dams will remain fully saturated and thereby exhibit similar very low to negligible oxidation rates that occur under current saturated conditions.*

To further mitigate the seepage risks, the existing perimeter dam, including Dam 4, incorporate a geosynthetic liner to provide additional seepage control.

CONCLUSION

Based on the existing instrumentation and survey data, the dams have a continuous frozen core and are deemed to be performing as licensed. Further evaluation indicated that in the event of the HES scenario where the frozen cores would thaw due to climate change, the dams will remain geotechnically stable. Based on previous work completed (Holubec 2006 and EcoMetrix 2006) as part of the TCA closure plan, the potential water quality impacts to the downstream receiving environment due to TCA seepage was generally estimated to be low, as the predicted increase in concentration in the discharge is estimated to be very low based on small unsaturated areas and the overall runoff dilution. The overall risks to Dam 3D and 4 associated with the HES thermal model are deemed low, and in turn, the risks associated with the LES thermal model are deemed very low.

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Attachment: Appendix A - Stability Results Figures

Reference

Reference: 2 AM-LUP Technical Meeting Commitment Number 12 Response – Risk Assessment on Two Dams in the Lupin Tailings Containment Area

Stantec Consulting Ltd., 2019 (Stantec 2019a). 2AM-LUP Technical Meeting Commitment Number 11 Response – Geophysical Survey Lupin Mine Tailings Containment Area Dams, Technical Memorandum submitted to Lupin Mine Incorporated, October 15, 2019.

Stantec Consulting Ltd., 2019 (Stantec 2019b). 2AM-LUP Technical Meeting Commitment Number 6 Response – Geotechnical Review on the Long-Term Stability of the TCA Dams, Technical Memorandum submitted to Lupin Mine Incorporated, November 15, 2019.

Stantec Consulting Ltd., 2019 (Stantec 2019c). 2AM-LUP Technical Meeting Commitment Number 11 Response – Lupin Mine Tailings Containment Area Dam Thermal Modelling Results, Technical Memorandum submitted to Lupin Mine Incorporated, October 15, 2019.

Holubec Consulting Inc., 2006 (Holubec 2006). Volume 1 and 2 of Geotechnical, Seepage and Water Balance for Reclaimed Tailings Containment Area, Lupin Operation, reports submitted to Kinross Gold Corporation, March 2006.

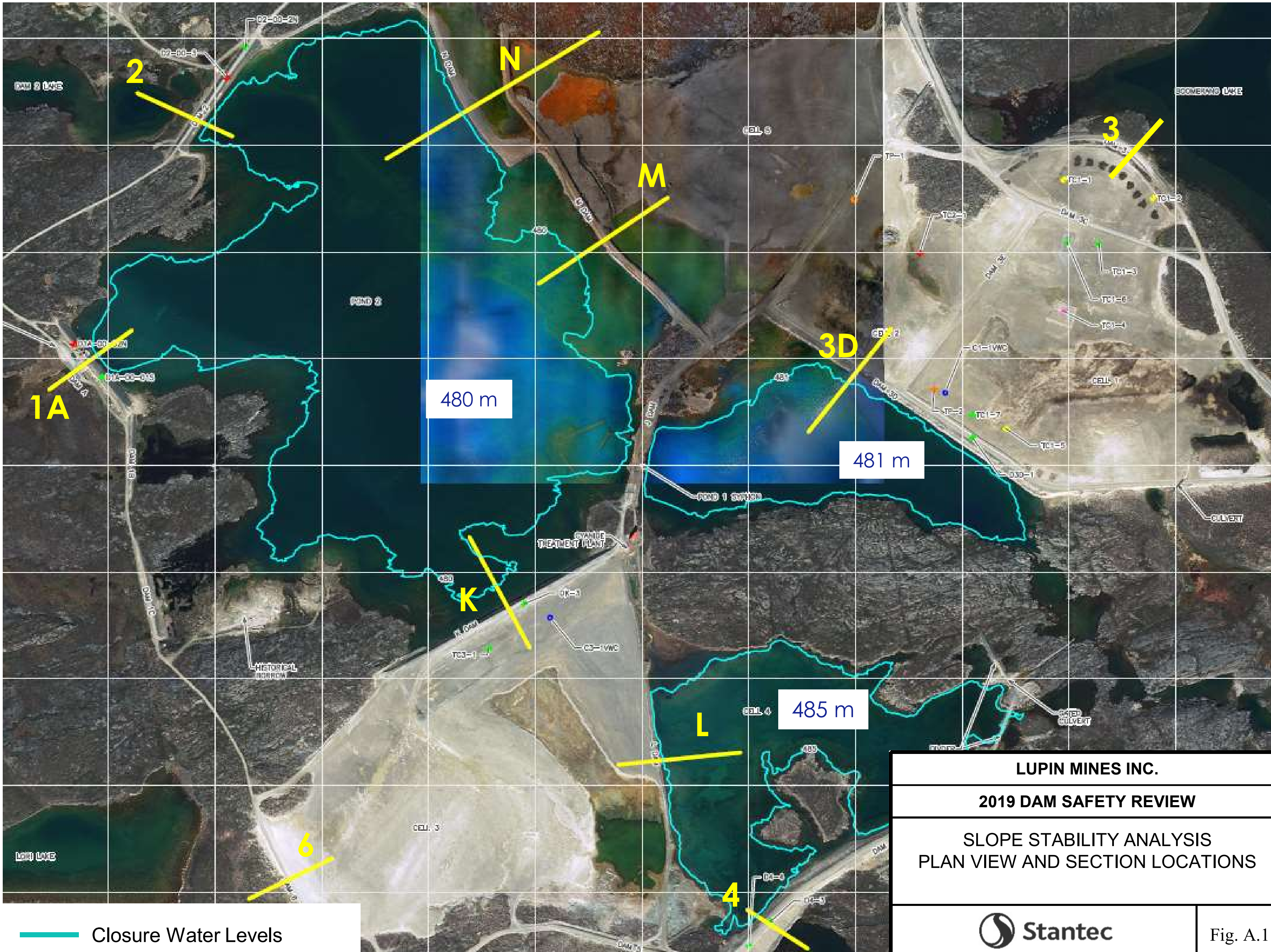
EcoMetrix Incorporated., 2006 (EcoMetrix 2006). Geochemistry and Water Quality, Volume 3 of Seepage and water Quality for Reclaimed Tailings Containment Area, Lupin Operation, report submitted to Kinross Gold Corporation, April, 2006.

Appendix A

Lupin Mines Inc.
2019 Dam Safety Review
Tailings Containment Area

Slope Stability Analysis
Thawed Scenario
(Rev 0)

November 13, 2019



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2019 DAM SAFETY REVIEW

SLOPE STABILITY ANALYSIS
PLAN VIEW AND SECTION LOCATIONS

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Fig. A.1

Fig. A1	Plan View Section Locations
Fig. A2	List of Analyses
Fig. A3	Section 3D - Thawed Scenario, Static Case – Local Failure
Fig. A4	Section 3D - Thawed Scenario, Static Case – Global Failure
Fig. A5	Section 3D - Thawed Scenario, Pseudo-Static Case – Global Failure
Fig. A6	Section 4 - Thawed Scenario, Static Case – Local Failure
Fig. A7	Section 4 - Thawed Scenario, Static Case – Local Failure
Fig. A8	Section 4 - Thawed Scenario, Pseudo-Static Case – Global Failure

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SLOPE STABILITY ANALYSIS
LIST OF ANALYSES
THAWED SCENARIO

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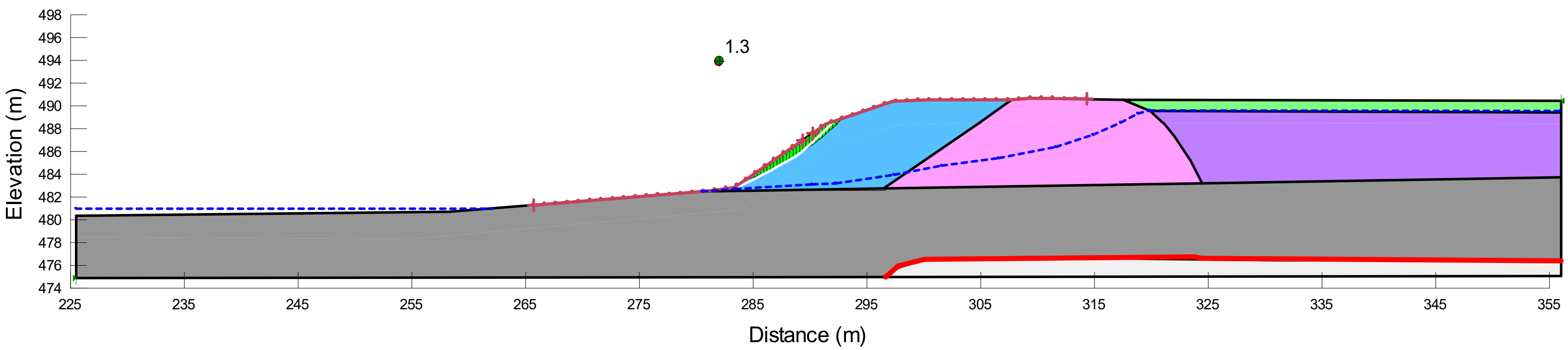
Fig. A.2

Details:
Thawed Scenario: based on High-Emissions Scenario where permafrost is present at depth 14m below ground surface

Material	Unit Weight (kN/m^3)	Drained Parameters		Undrained Parameters	
		Friction Angle (°)	Cohesion (kPa)	Minimum Strength (kPa)	Tau/Sigma Ratio
Esker	30	35°	0	N/A	
Gravelly Sand	30	35°	0	N/A	
Rockfill	20	39°	0	N/A	
Tailings (Drained)	18	30°	0	N/A	
Tailings (Undrained)	18	N/A		20	0.24
Till	18	30°	0	N/A	
Bedrock	Impenetrable				
Permafrost	N/A				
Geotechnical Liner	N/A				



Notes:
1. FOS is for optimized slip surface using Spencer method in SLOPE/W (GeoStudio 2018, version 9.0.4).

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SLOPE STABILITY ANALYSIS
SECTION 3D – THAWED SCENARIO
STATIC CASE – LOCAL FAILURE

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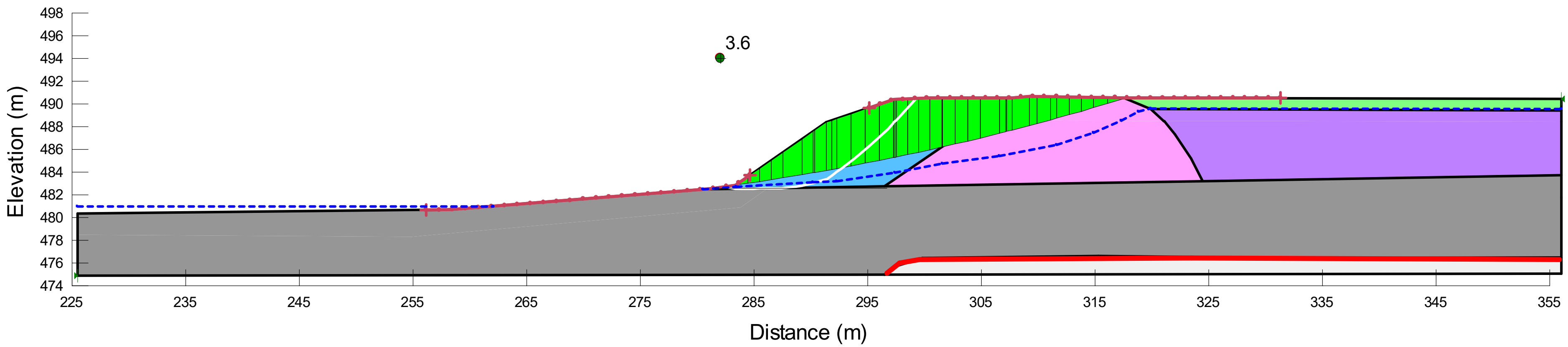
Fig. A.3

Details:
Thawed Scenario: based on High-Emissions Scenario where permafrost is present at depth 14m below ground surface

Material	Unit Weight (kN/m³)	Drained Parameters		Undrained Parameters	
		Friction Angle (°)	Cohesion (kPa)	Minimum Strength (kPa)	Tau/Sigma Ratio
Esker	30	35°	0	N/A	
Gravelly Sand	30	35°	0	N/A	
Rockfill	20	39°	0	N/A	
Tailings (Drained)	18	30°	0	N/A	
Tailings (Undrained)	18	N/A		20	0.24
Till	18	30°	0	N/A	
Bedrock	Impenetrable				
Permafrost	N/A				
Geotechnical Liner	N/A				



Notes:
1. FOS is for global failure that breaches the dam using Spencer method in SLOPE/W (GeoStudio 2018, version 9.0.4).

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SLOPE STABILITY ANALYSIS
SECTION 3D – THAWED SCENARIO
STATIC CASE – GLOBAL FAILURE

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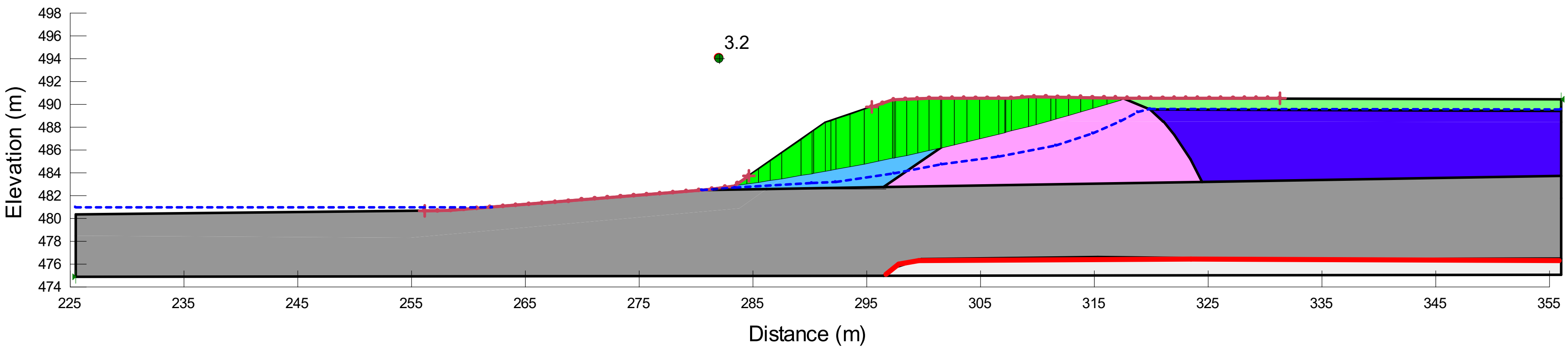
Fig. A.4

Details:
Thawed Scenario: based on High-Emissions Scenario where permafrost is present at depth 14m below ground surface

Material	Unit Weight (kN/m³)	Drained Parameters		Undrained Parameters	
		Friction Angle (°)	Cohesion (kPa)	Minimum Strength (kPa)	Tau/Sigma Ratio
Esker	30	35°	0	N/A	
Gravelly Sand	30	35°	0	N/A	
Rockfill	20	39°	0	N/A	
Tailings (Drained)	18	30°	0	N/A	
Tailings (Undrained)	18	N/A		20	0.24
Till	18	30°	0	N/A	
Bedrock	Impenetrable				
Permafrost	N/A				
Geotechnical Liner	N/A				



Notes:
1. FOS is for global failure that breaches the dam using Spencer method in SLOPE/W (GeoStudio 2018, version 9.0.4).

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SLOPE STABILITY ANALYSIS
SECTION 3D – THAWED SCENARIO
PSEUDO-STATIC CASE – GLOBAL FAILURE

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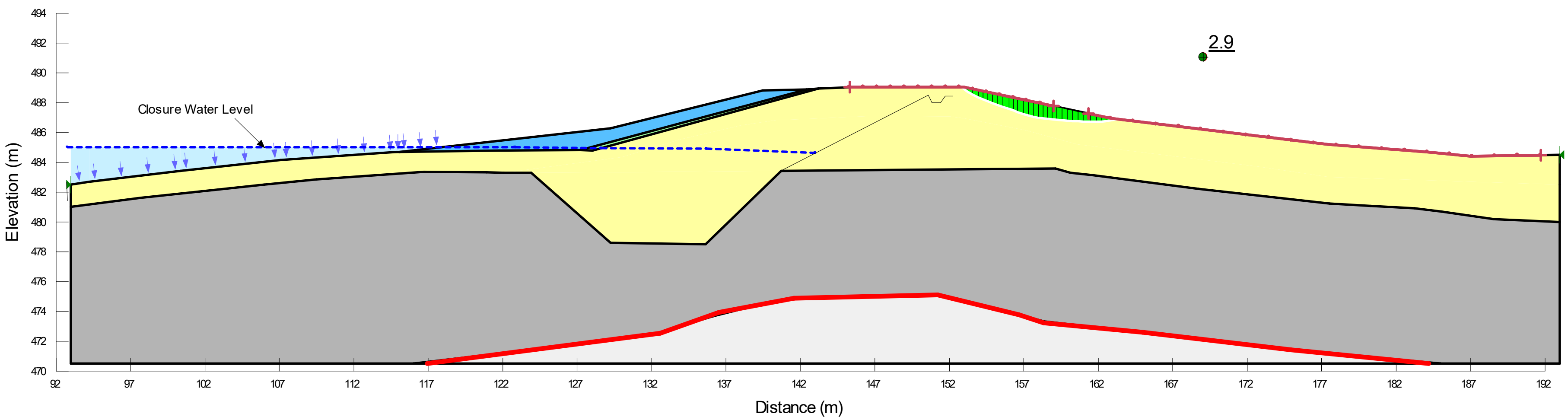
Fig. A.5

Details:
Thawed Scenario: based on High-Emissions Scenario where permafrost is present at depth 14m below ground surface

Material		Unit Weight (kN/m^3)	Drained Parameters		Undrained Parameters	
			Friction Angle (°)	Cohesion (kPa)	Minimum Strength (kPa)	Tau/Sigma Ratio
	Esker	30	35°	0	N/A	
	Gravelly Sand	30	35°	0	N/A	
	Rockfill	20	39°	0	N/A	
	Tailings (Drained)	18	30°	0	N/A	
	Tailings (Undrained)	18	N/A		20	0.24
	Till	18	30°	0	N/A	
	Bedrock	Impenetrable				
	Permafrost	N/A				
	Geotechnical Liner	N/A				



Notes:
1. FOS is for optimized slip surface using Spencer method in SLOPE/W (GeoStudio 2018, version 9.0.4).

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SLOPE STABILITY ANALYSIS
SECTION 4 – THAWED SCENARIO
STATIC CASE – LOCAL FAILURE

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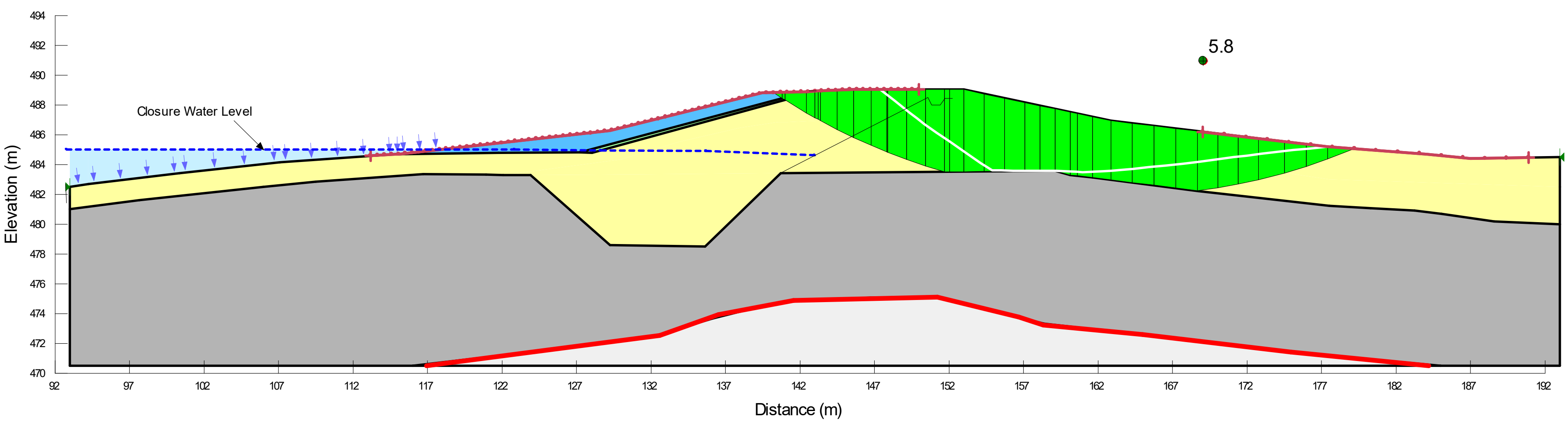
Fig. A.6

Details:
Thawed Scenario: based on High-Emissions Scenario where permafrost is present at depth 14m below ground surface

Material	Unit Weight (kN/m³)	Drained Parameters		Undrained Parameters	
		Friction Angle (°)	Cohesion (kPa)	Minimum Strength (kPa)	Tau/Sigma Ratio
Esker	30	35°	0	N/A	
Gravelly Sand	30	35°	0	N/A	
Rockfill	20	39°	0	N/A	
Tailings (Drained)	18	30°	0	N/A	
Tailings (Undrained)	18	N/A		20	0.24
Till	18	30°	0	N/A	
Bedrock	Impenetrable				
Permafrost	N/A				
Geotechnical Liner	N/A				



Notes:
1. FOS is for global failure that breaches the dam using Spencer method in SLOPE/W (GeoStudio 2018, version 9.0.4).

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SLOPE STABILITY ANALYSIS
SECTION 4 – THAWED SCENARIO
STATIC CASE – GLOBAL FAILURE

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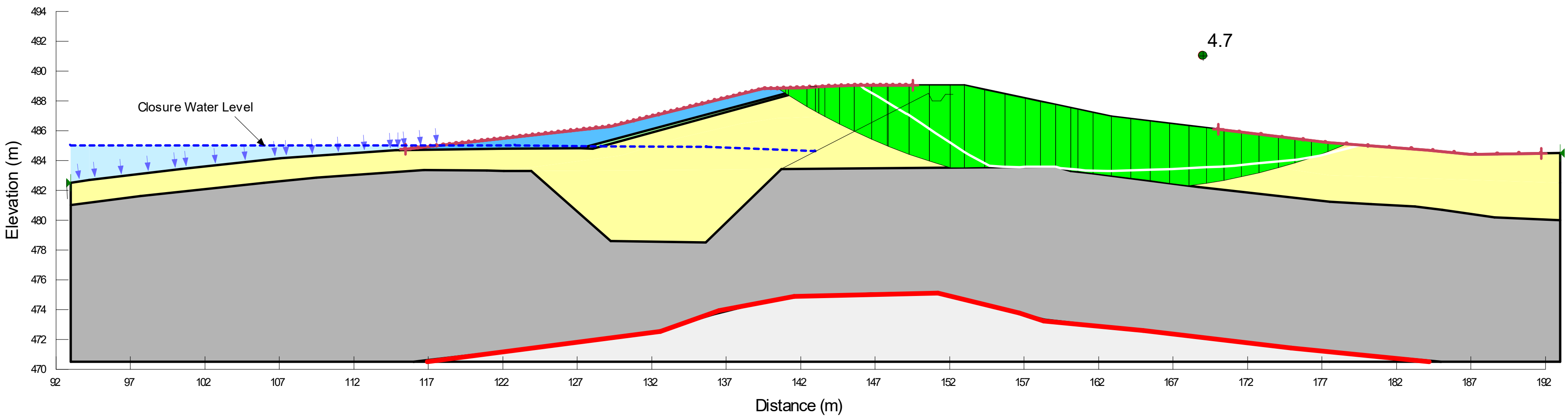
Fig. A.7

Details:
Thawed Scenario: based on High-Emissions Scenario where permafrost is present at depth 14m below ground surface

Material		Unit Weight (kN/m^3)	Drained Parameters		Undrained Parameters	
			Friction Angle (°)	Cohesion (kPa)	Minimum Strength (kPa)	Tau/Sigma Ratio
	Esker	30	35°	0	N/A	
	Gravelly Sand	30	35°	0	N/A	
	Rockfill	20	39°	0	N/A	
	Tailings (Drained)	18	30°	0	N/A	
	Tailings (Undrained)	18	N/A		20	0.24
	Till	18	30°	0	N/A	
	Bedrock	Impenetrable				
	Permafrost	N/A				
	Geotechnical Liner	N/A				



Notes:
1. FOS is for global failure that breaches the dam using Spencer method in SLOPE/W (GeoStudio 2018, version 9.0.4).

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SLOPE STABILITY ANALYSIS
SECTION 4 – THAWED SCENARIO
PSEUDO-STATIC CASE – GLOBAL FAILURE

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Fig. A.8