Tantalum Mining Corporation of Canada – Bernic Lake Mine

West TMA Tailings Pond Dam Raise and Control Structure Replacement Project Notice of Alteration (2023)

Date:

March 6, 2023

Tantalum Mining Corporation of Canada, Limited
Bernic Lake
Box 2000
Lac du Bonnet, Manitoba
MB R0E 1A0
Canada

March 6, 2023

Ms. Jennifer Winsor
Environmental Approvals Branch
Department of Sustainable Development
1007 Century Street
Winnipeg, MB.
R3H 0W4

Dear Ms. Winsor:

Re: Tantalum Mining Corporation of Canada Bernic Lake Mine – West TMA Tailings Pond Dam Raise and Control Structure Replacement Project Notice of Alteration (2023)

Tantalum Mining Corporation of Canada (TANCO) is submitting this report describing proposed changes to West Tailings Management Area (TMA) Tailings Pond at the Bernic Lake Mine (BLM). The proposed alteration includes raising the Tailings Pond Main Dam and the five peripheral dykes to a design elevation of 321.6 MASL from their current crest elevations of 320.1 MASL to provide the necessary storage capacity for forecasted site development.

Please find enclosed, the information required for the alteration regulatory process that details TANCO's proposed plan. There will be some minor potential effects observed onsite associated with the construction of new infrastructure but the effects will be negligible as construction and operation of the Tailings Pond will be almost entirely contained within the current boundaries of the West TMA. Please note it is anticipated that the potential environmental effects from these alterations will be minor and it is believed that the alterations can be implemented within the limits, terms and the conditions of the current Environmental Licence (No. 973).

If you have any questions, or require further information on the report, please do not hesitate to contact me.

Sincerely,

[redacted] Date: March 6, 2023

Joey Champagne
Facility General Manager
Tantalum Mining Corporation of Canada Limited

TANCO Bernic Lake Mine
West TMA Tailings Pond Dam Raise and
Control Structure Replacement Project
Notice of Alteration (2023)

Prepared and reviewed by:

[redacted]

______________________________ Date: March 6, 2023

Jerry White, M.Sc.
Environmental Specialist
Tantalum Mining Corporation of Canada

Disclaimer

The information presented in this document with respect to the West TMA Tailings Pond Dam Raise and Control Structure Replacement Project Description was derived from a conceptual design drawings and information provided to TANCO by the consulting engineers at the time the report was drafted. There may be modifications to the design of the substation during project development but if any design changes affect the overall impact of the proposed alteration in this assessment, then a notice will be sent to Manitoba Sustainable Development detailing those effects.

Executive Summary

This alteration notification is intended to notify the Director of proposed alterations to the design and operation of the Tailings Pond in the West TMA at the TANCO BLM as required under the Environment Act (S.14(1)). This document also contains sufficient information for the Director to determine the significance of the environmental effects associated with these proposed alterations to determine the appropriate approval process for the alteration.

The proposed changes include raising the Main Dam and 5 peripheral dams (PD-01 to PD-05) from their current elevation of 320.1 Metres Above Sea Level (MASL) to a design height of 321.6 MASL. The project also includes the construction of a new decant control structure as the current structure cannot be raised to accommodate the increase in storage levels in the Tailings Pond following the dam raises.

The Canadian Dam Association (CDA) Guidelines have been selected as the design and construction standard for all aspects of the proposed dam raises and installation of a new water control structure in the Tailings Pond. The general construction will also conform to the National Building Code of Canada while material (Structural Steel, Concrete, and Geomembrane Liner) specific construction standards will also be met. Environmental and safety controls currently used at the facility will be implemented in the construction and operational phases of the new infrastructure to control potential risks associated with the proposed development.

Environmental effects associated with the physical environment, emissions, water resources and ecological aspects remain virtually unchanged as the proposed changes to the Tailings Pond are almost entirely contained within the West TMA's current footprint and current measures used at the facility are sufficient to control any additional environmental effects. No anticipated increases in environmental effects are expected with regard to surface water quality in the receiving environment due to the proposed changes.

The proposed alterations to the Tailings Pond at the TANCO BLM are expected to be minor as most potential negative environmental and human health effects resulting from the alteration can be mitigated through TANCO's environmental and health and safety policies currently in place.

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1. Introduction

1.1 Objectives

TANCO's vision is to be a prosperous mining, milling and chemical processing facility through the development of our people, our resources and our community. Site objectives focus on strategic priorities of building strong foundations, striving for operational excellence and development of our site resources. There is currently a strong global market demand for both cesium and lithium products which TANCO believes provides a unique opportunity for growth and development that aligns with our company's vision and site objectives.

This Notice of Alteration (NoA) is intended to notify the Director of proposed alterations to *Environmental Act* Licence No. 973 for the TANCO BLM as required under the *Environment Ac*t (S.14(1); Government of Manitoba 1988). This NoA provides details for the design basis for proposed dam raises and the replacement of the water control structure in the West TMA Tailings Pond. The objective of this report is to provide the Director and Environmental Approvals Branch with sufficient information to determine the significance of environmental effects associated with the proposed development. Once the level of significance is determined by the Director, the appropriate approval process can be identified for the proposed development.

This report describes the physical changes at the Mine as a result of the dam raises and the installation of the new water control structure. It also quantifies the anticipated change in environmental effects at the Mine as compared to pre-alteration levels which includes an environmental assessment resulting from the alteration on the environment.

1.2 Environmental Assessment Criteria

Environmental significance is commonly considered in the context of its magnitude, geographic extent, duration, frequency, degree of reversibility and possibility of occurrence or any combination of these factors.

The significance criteria used in this analysis of the Tailings Pond alteration is defined in Table 1, as well as a description of the significance level (I to III) for each criterion. Although presented as distinct levels in Table 1, significance can be a gradient between not significant (Level I) to potentially significant (Level II) to very significant (Level III).

Table 1-1 Significance Criteria and Levels of Significance.

Significance Level	Context		Magnitude / Geographic Extent	Duration / Frequency	Likelihood of Occurrence	Reversibility
	Ecological / Biophysical	Socio-Cultural				
I	No meaningful adverse biophysical effects	No meaningful adverse effects to socio-economic interests	Magnitude and/or geographical extent of impact(s) considered to be minor, and primarily or solely confined to Mine site	Construction phase of Mine, or during closure phase(s)	Unlikely to Occur	Readily reversible
II	Adverse effects involve commonplace species or communities	Adverse effects would involve meaningful inconvenience to local residents or land users	Magnitude and/or geographical extent of impact(s) have the potential to meaningfully affect off-property residents, lands or receiving waters	Life of Mine	Could reasonably be expected to occur	Can be reversed with difficulty
III	Adverse effects involve locally or regionally important species or communities	Adverse effects to livelihoods and/or property values	Magnitude and/or geographical extent of impact(s) expected to meaningfully affect off-property residents, lands or receiving waters	Extends beyond life of Mine	Will occur, or is likely to occur	Not reversible

2. Proposed Alterations

2.1 Physical Alterations

The alteration includes raising the Main Dam and five peripheral dams used to enclose the Tailings Pond in the West TMA (Figure 2-1). The Main Dam and peripheral dams PD01 to PD04 were constructed in 1996 and have been raised 4 times with the last raise to 320.1 MASL occurring in 2008. Peripheral dam PD05 was constructed in 2005 and has been raised once to its current elevation of 320.1 MASL in 2008. At the current crest elevation, the Tailings Pond has the capacity to store 3.73 million tonnes of tailings with 3.00 million tonnes of tailings already stored in the West TMA.

The dams enclosing the Tailings Pond at the BLM are rockfilled dams with a PVC liner installed upstream above approximately 317.0 MASL (Table 2-1). The PVC liner is tied into clay till below approximately 217.0 MASL.

All six dams enclosing the Tailings Pond in the West TMA will be raised to 321.6 MASL, 1.5 m above their current crest elevations (Table 2-2; Hatch 2022a). The dams were previously downstream raised and it is assumed at this stage of the project that the dams will be downstream raised again. Dam crest widths are assumed to be a minimum of 5 m and upstream slopes are planned to be 2.5H:1V, while the downstream slopes of the dams are planned to be 2H:1V. Final slope geometry will be confirmed with a stability assessment after foundation material has been identified. There will be a new geomembrane liner tied into the existing liner using hot wedge welding equipment above its current height and field seams will tested throughout the installation process to ensure the liners integrity. The overall safety associated with the raise of the Main Dam will improve as inclinometers and surface monitoring monuments will be installed on the new dam to improve monitoring so that any movement of the new infrastructure can be detected earlier.

The downstream design method was selected for the dam raises as it is generally more stable and has reduced risks associated with its design compared to the upstream design method (ICOLD and UNEP 2001). The only negative aspect of the downstream method of dam design is that as the centerline of the dam shifts downstream of the starter dam, the toe moves outward from the base of the dam requiring more space. This will result in the expansion of the West TMA in the area of PD01 to PD04 by an additional 5,600 m^2 and in the area of PD05 by an additional 2,000 m^2 (Figure 2-2; Figure 2-3; Hatch 2022b, 2022c, 2022d). The downstream footprint of the Main Dam will increase by 5,500 m^2 but this area is already part of the Polishing Pond of the West TMA (Figure 2-3; Hatch 2022e). The additional land required for the raises which totals less than 1 ha is entirely contained with the current surface leases of the Mine except for a small area on the extreme downstream edge of PD05 that will encroach on mining claim BRP 20. TANCO currently has this mining claim staked but are in the process of gaining the surface lease for the land for the proposed alteration. Rock used to complete the dam raises will be quarried from the sites located in the West TMA that were used for the previous dam raises in 2008 (Figure 2-1).

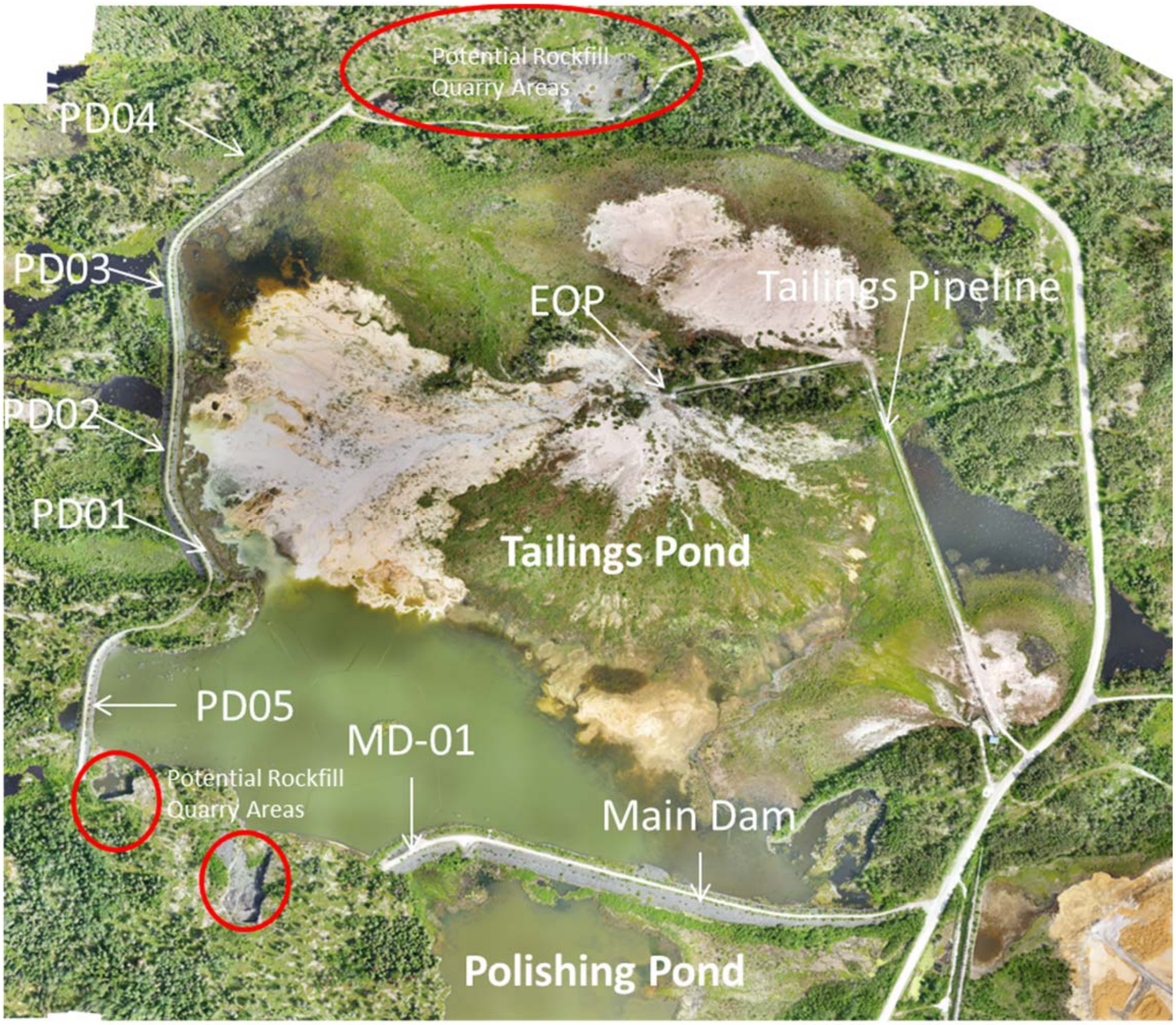


Figure 2-1 TANCO BLM West TMA site plan.

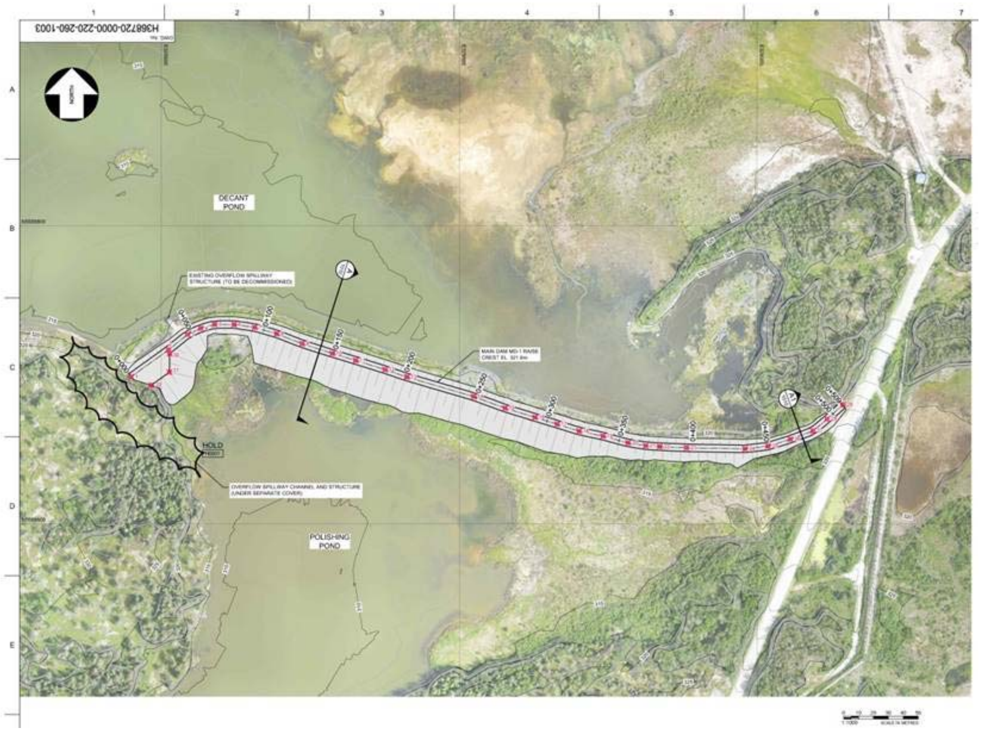
Table 2-1 Current dam configuration in Tailings Pond in the West TMA of the BLM (Hatch 2022a).

Dam	Construction Method/ Type	Crest Ele. (MASL)	Max. Dam Height (m)	Dam Length (m)	Crest Width (m)	Upstream Slope	Downstream Slope
Main Dam	Downstream Raised / Rockfill dam with upstream PVC liner above El. ~317 m, Clay Till Upstream Liner Below El. ~317 m	320.1	12.2	500	5.2	2.0 to 3.0H:1V	2.1 to 2.5H:1V
PD01		320.1	7.5	100	5.2	2.1 to 2.4H:1V	1.7 to 2.1H:1V
PD02		320.1	7.3	150	4.7	2.3 to 2.7H:1V	1.7 to 1.9H:1V
PD03		320.1	7	162	5.2	2.3 to 2.9H:1V	1.8 to 2.5H:1V
PD04		320.1	4.2	108	4.9	2.4 to 2.6H:1V	2.1 to 2.8H:1V
PD05		320.1	5.5	150	4.6	2.3 to 2.7H:1V	1.9 to 2.4H:1V

Table 2-2 Proposed dam raise geometry (Hatch 2022a).

Parameter	Value	Notes
Dam Crest Elevation (MASL)	321.6	1.5 m above the existing dam crest elevation of 320.1 m.
Dam Crest Width (m)	5	Assumed minimum.
Dam Raise Height (m)	1.5	Proposed dam crest increase.
Upstream Slope	2.5H:1V	To allow for geomembrane liner installation. Slope to be validated with a stability assessment based on design and encountered foundation material.
Downstream Slope	2H:1V	Based on closure slopes. Slope to be validated with a stability assessment based on design and encountered foundation material.

Figure 2-2 Proposed downstream expansion of PD01 and PD02 (Top-panel) and PD03 and PD04 (bottom panel)(Hatch 2022b, 2022c).



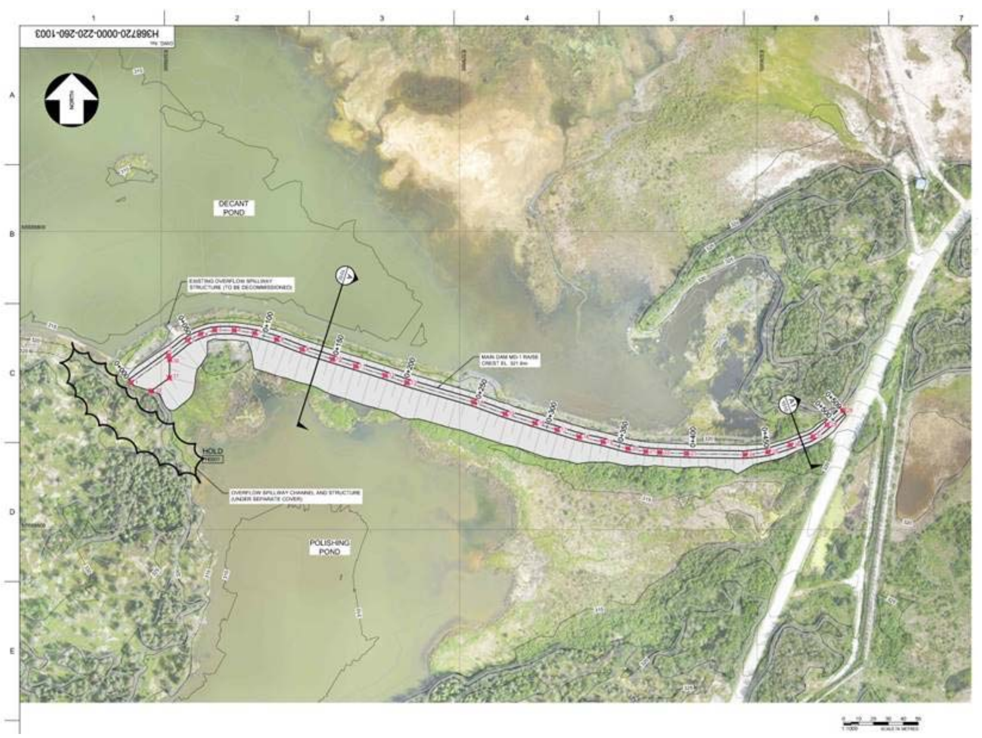


Figure 2-3 Proposed downstream expansion of PD05 (Top-panel) and the Main Dam (bottom panel)(Hatch 2022d, 2022e).

Upgrades to the Tailings Pond in the West TMA also includes replacement of the water control structure as the current structure cannot be raised any further to accommodate the new operating levels that would be encountered in the Tailings Pond after the dams have been raised. There has been some deterioration of culvert in the current water control structure which was identified in November 2021 that requires repair in the near future. The proposed alteration also addresses this problem as the existing structure can be decommissioned after the new water control structure is operational.

A trade-off study was completed to determine the best location and design of the new water control structure (Hatch 2022f; Appendix B). The study indicated that an overflow spillway cut into bedrock in the bedrock embankment at the west end of the Main Dam was the most advantageous location as it would avoid excavating through the embankment of the existing Main Dam and the geometry in this area of the dam would allow for the smallest cofferdam to be constructed (Figure 2-4; Figure 2-5; Hatch 2023a). Its location in bedrock would also minimize settlement of the new structure as well as minimize excavation, backfilling and concrete volumes.

Throughout the construction phase, water will continue to be managed through the existing control structure (MD-1) until the new spillway channel/ control structure is complete. Once the new structure is complete, MD-1 will be decommissioned by backfilling the structure along with the culvert with mass concrete to seal it permanently (Figure 2-6; Hatch 2023b).

Design and construction of the dam raises and new water control structure will follow CDA Guidelines and construction will follow the following standards:

General

- National Building Code of Canada

Structural Steel

- Design: CAN/CSA-S16
- Materials: CAN/CSA-G40.20/G40.21
- Welding: W47.1, W59

Reinforced Concrete

- Design: CSA A23.3, ACI Report 224R
- Materials: CAN/CSA-A23.1 [Ref. 49], CAN/CSA-G30.18, CSA A23.4
- Testing CAN/ CSA-A23.2

Rigorous design, installation and testing requirements have been outlined for the technical specifications of the geomembrane liner on the dams to ensure that the installed liner meets current standards (Hatch 2023c).

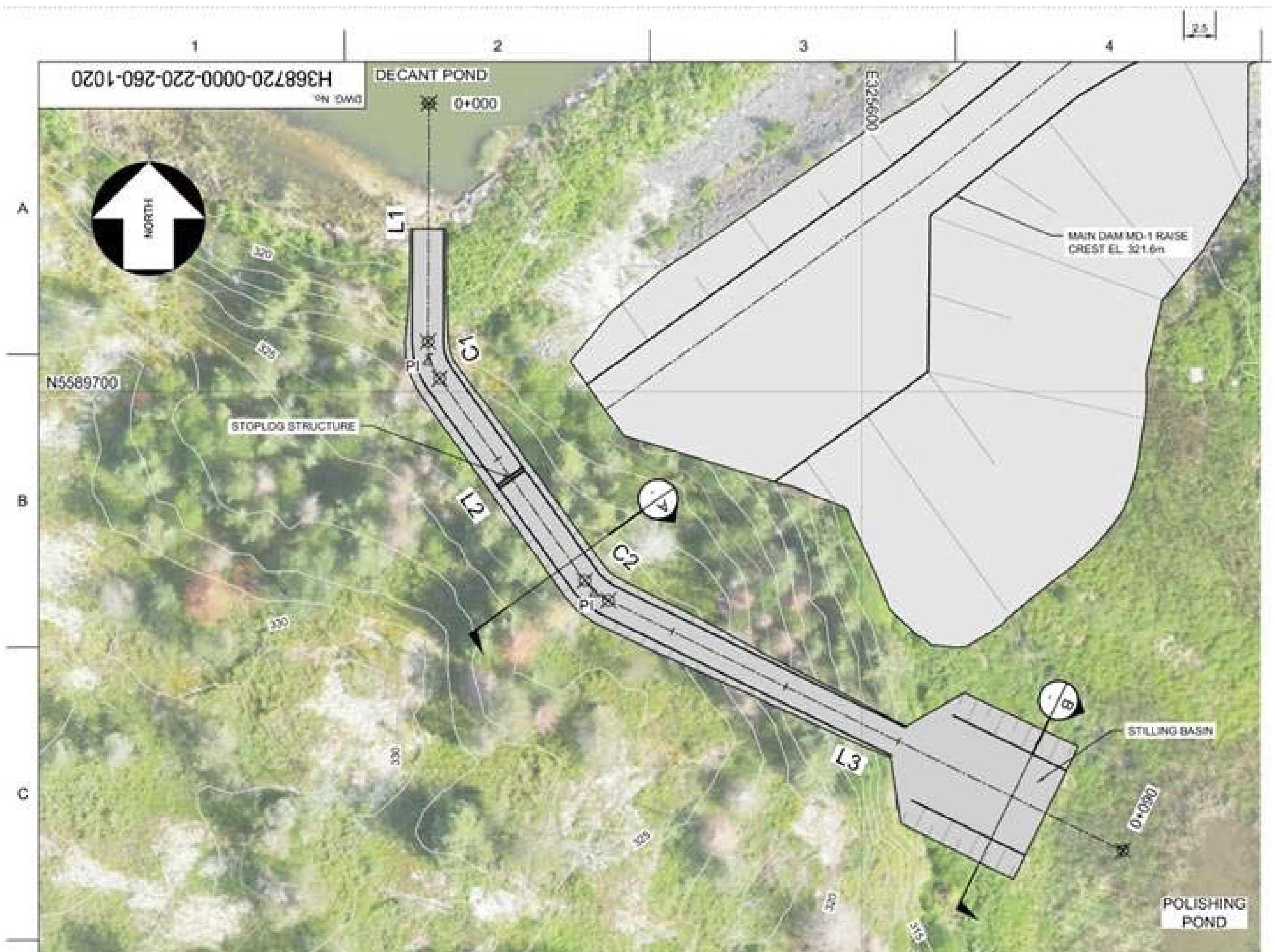


Figure 2-4 Tailings Pond spillway design (Hatch 2023a).

Figure 2-5 Proposed Tailings Pond spillway location.

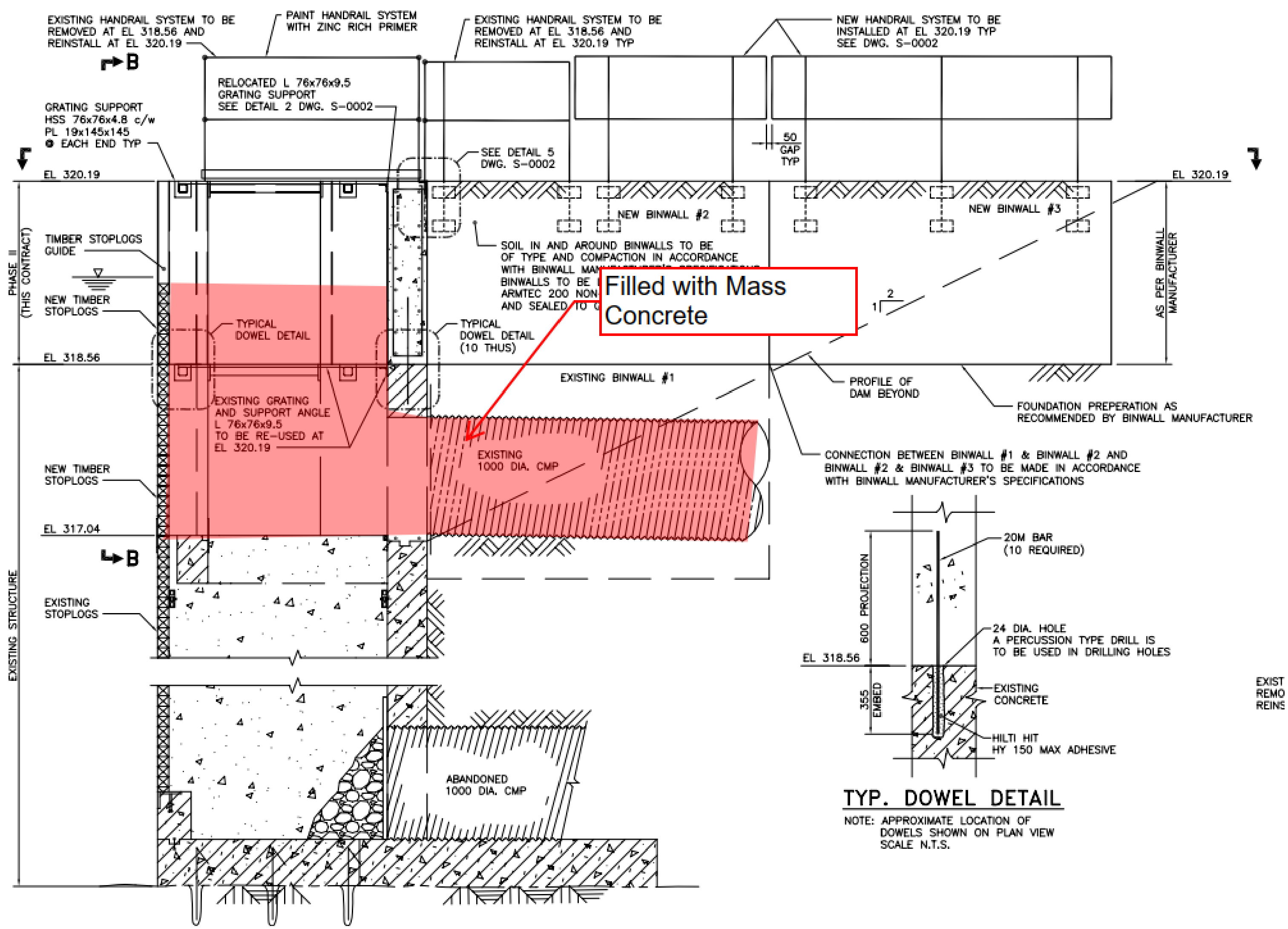


Figure 2-6 Preliminary plan for the decommissioning of the current Tailings Pond water control structure (MD-1; Hatch 2023b).

All regulatory safety regulations along with TANCO's site safety policy will be strictly adhered to through the construction phase for the project.

Construction environmental risks will be mitigated through the following protocols:

- Cofferdam construction in the West TMA at the proposed overflow spillway location to prevent uncontrolled release of water to the environment.
- Erosion and sedimentation control measures will be implemented for dam foundation excavation activities. They will comply with Department of Fisheries & Oceans Canada (DFO) and Manitoba provincial requirements.
- Groundwater and surface water collected in excavations will be managed through a series of perimeter ditches/pump sumps and discharged accordingly as per regulatory requirements.
- Spill kits will be provided for each piece of construction equipment.

2.1 Process Alterations

There are currently no alterations to processes at the Mine associated with the proposed alteration.

2.2 Environmental Assessment

2.2.1 Physical Environment

Topography

The proposed alteration will almost be entirely contained within the current surface leases of the Mine. Small areas at the toe each perimeter dam will need to be cleared and excavated to complete the dam raises but total increase in the boundary of the West TMA will be approximately 0.76 ha. Since, the areas required for the proposed alteration are small and almost completely within the boundaries of the current surface leases of the mine, it is anticipated that there will be a minor change in environmental effects from current conditions with respect to site topography associated the proposed alteration (Table 2). Therefore, the level of significance associated with the project with respect to topography is deemed to be no higher than Level I. Accordingly, the summary evaluation for this potential impact is deemed to be not significant.

Soils

The risk of soil contamination during the construction of the new substation will be similar to other construction projects at the site. The risk of soil contamination during the operation and maintenance of the upgrade Tailings Pond is negligible. Existing Spill Response Protocols and Best Management Practices for Materials Handling at the facility are sufficient mitigation measures for dealing with the potential environmental effects (Table 2). Therefore, a Level I level of significance (not significant) is assigned to the potential environmental effects on soil associated with the proposed alterations.

Table 2-3 Summary of potential effects associated with the proposed Tailings Pond alteration at the TANCO Bernic Lake Mine.

Classification of Potential Effect	Alteration Phase	Potential Effect	Magnitude of Effect	Direction of Effect	Duration of Effect	Frequency of Effect	Scope of Effect	Mitigation Measures	Residual Effects	Reversibility	Significance
Physical											
Topography	Construction	Modification in topography	Minor within current surface leases	Negative	Long Term	One-time	Project Site	Dam raises will almost be entirely within the Mine's surface leases and only requires clearing and excavating a small area (0.76 ha) for the infrastructure.	Negligible	Reversible	Not significant
Soils	Construction	Soil contamination	Negligible	Negative	Long Term	Rare	Project Site	Clean up any hydrocarbon or chemical spills immediately during construction of the Tailings Pond upgrades.	Negligible	Reversible	Not significant
	Operation	Soil contamination	Negligible	Negative	Long Term	Rare	Project Site	Use current best practices in material handling and appropriate containment measures.	Negligible	Reversible	Not significant
Geology	Construction	Bedrock excavation	Negligible	Negative	Long Term	One-time	Project Site	Dam raises require excavation down to bedrock at a maximum. Bedrock outcropping at west end of Main Dam will be modified to install new spillway but is within current footprint of the West TMA. Rock for backfill will be quarried from existing areas within West TMA.	Negligible	Reversible	Not significant
Emissions											
Air Quality	Construction	Dust	Minor within current surface leases	Negative	Short Term	Intermittent	Project Site	Use current Best Management Practices for Control of Fugitive Dust/ Minimize disturbed areas and use dust suppression if required.	Negligible	Reversible	Not significant
	Construction	Noise	Minor within current surface leases	Negative	Short Term	Intermittent	Project Site	Construction activities short-term and noise will be generally limited to project area/Remote location limits socio-cultural effects.	Negligible	Reversible	Not significant
	Operation	Dust	Negligible	Negative	Long Term	None	Project Site	No additional dust will be emitted through the operation of the upgraded Tailings Pond.	Negligible	Reversible	Not significant
	Operation	Noise	Negligible	Negative	Long Term	None	Project Site	No noise associated with the operation of the new infrastructure.	Negligible	Reversible	Not significant
	Operation	GHG Emissions	Negligible	Negative	Long Term	None	Global	No GHG emitted from the operation of the new infrastructure.	Negligible	Reversible	Not significant
Water Resources											
Groundwater	Construction	Groundwater Drawdown/Quality	Minor within current surface leases	Negative	Short Term	None	Project Site	Excavation limited to contact with bedrock at a maximum for dam raises. All water collected during excavation will be collected and pumped back into the TMA for treatment. Alteration to bedrock outcropping for spillway is largely above grade and will not intercept groundwater flows. Spill Response Protocols will be used to limit exposure to groundwater.	Negligible	Reversible	Not significant
	Operation	Groundwater Quality	Negligible	Negative	Long Term	None	Project Site	No changes in groundwater quality are expected with operations after the upgrade to the Tailings Pond is completed.	Negligible	Reversible	Not significant
Surface Water	Construction	Surface Runoff	Minor within current surface leases	Negative	Short Term	Intermittent	Project Site	Control surface water runoff during construction phase.	Negligible	Reversible	Not significant
	Operation	Surface Runoff	Negligible	Negative	Long Term	None	Project Site	Surface water outside the footprint of the TMA will not come in contact with mining operations and will not affect surface water quality. Project area will be allowed to drain along natural flow paths. Water falling within the boundaries of the TMA will be treated prior to its release into the environment through the FDP.	Negligible	Reversible	Not significant
	Operation	Surface water usage	Negligible	Negative	Long Term	None	Project Site	No water required during the construction of the project.	Negligible	Reversible	Not significant
	Operation	Surface water quality	Negligible	Negative	Long Term	None	Project Site	No additional water required for the operation of the Tailings Pond after the upgrades.	Negligible	Reversible	Not significant

Table 2 (cont'd) **Summary of potential environmental effects associated with the proposed Tailings Pond alteration at the TANCO Bernic Lake Mine.**

Classification of Potential Effect	Alteration Phase	Potential Effect	Magnitude of Effect	Direction of Effect	Duration of Effect	Frequency of Effect	Scope of Effect	Mitigation Measures	Residual Effects	Reversibility	Significance
Ecological											
Flora and Fauna	Construction/ Operation	Habitat disturbance	Minor within current surface leases	Negative	Long Term	Continuous	Project Site	Project requires clearing of a small area (0.76 ha) almost entirely within the boundary of the Mine's surface lease that may cause some habitat disturbance but the area is immediately adjacent to the current boundaries of the Tailings Pond.	Negligible	Not applicable	Not significant
	Construction/ Operation	Noise	Negligible	Negative	Long Term	Intermittent or continuous	Project Site	Construction will be short-term and increased noise levels will be generally limited to within project boundaries. The should be no noise associated with the operation of the upgraded infrastructure	Negligible	Not applicable	Not significant
	Transportation	Habitat disturbance	Negligible	Negative	Short to long term	Rare	Project Site/Local Highways	Small increase in traffic along transportation routes during the construction phase to bring in equipment and workers.	Negligible to Major	Reversible depending on incident	Not significant
Sociological											
Employment	Construction	Increased Employment	Minor	Positive	Short Term	Continuous	Project Site	Recruit from the local workforce for construction, if possible	Minor	Not applicable	Significant
	Operation	Increased Employment	Negligible	Positive	Long Term	None	Project Site	No additional staff required for the operation phase of the Tailings Pond.	Negligible	Not applicable	Not significant
Health and Safety	Construction/ Operation	Safety of workers	Negligible to Major	Negative	Short to long term	Rare	Project Site	All work conducted in accordance to Manitoba's *Workplace Safety and Health Act*/ All workers receive appropriate training/ Workers must wear appropriate PPE at all times and follow all TANCO Health and Safety guidelines associated with proposed alteration during construction and operation.	Negligible to Major	Reversible depending on incident	Not significant
	Transportation	Safety of workers and community	Negligible to Major	Negative	Short term	Rare	Project Site/Local Highways	Small increase in traffic along transportation routes during the construction phase to bring in equipment and workers.	Negligible to Major	Reversible depending on incident	Not significant

Geology

Construction activities with respect to dam raises will almost be entirely limited to areas within current surface leases and excavation will limited to the depth of bedrock. Rockfill used in the dam raises will be quarried from areas previous used as quarry sites for dam raises which are located within the boundaries of the West TMA. The bedrock outcrop at the west abutment of the Main Dam will be modified to create the new spillway/ water control structure but the modifications will generally occur at or near the surface and within the current boundary of the West TMA. Therefore, a Level I significance is assigned to the potential environmental effects on bedrock and is deemed not significant (Table 2).

2.2.2 Emissions

Air Quality

Short-term intermittent increases in hydrocarbon, dust and noise emissions may be observed during construction of dams and water control structure; however, these emissions will be limited to the project area. TANCO will employ Best Management Practices for Control of Fugitive Dust, minimize the size of disturbed areas and use dust suppression, if necessary, during construction as mitigation measures. Noise emissions will increase for the short-term during construction due to the use of heavy equipment and power tools but given the remote location of the facility, it is not anticipated to have any socio-cultural effects and any ecological effects would be short in duration.

No increases in hydrocarbon, dust or noise emissions are anticipated during the operational phase of the project.

Construction is short-term and mitigation measures should control dust emissions during this period. Increased noise during construction will also be short-term and generally limited to within projects boundaries. Therefore, it is deemed that the proposed alteration is insignificant with respect to air quality and assigned Level I significance (Table 2).

2.2.3 Water Resources

Groundwater

Any spills during construction will be contained immediately by the Environmental Department and reported to the proper authorities as required. Groundwater collected in excavations will be managed through a series of perimeter ditches/pump sumps and discharged into the West TMA for treatment prior release into the environment. No effects are anticipated in groundwater quality during the operational phase of the project. Existing Spill Response Protocols and Best Management Practices for Materials Handling at the facility are sufficient mitigation measures for dealing with the potential environmental effects related to groundwater contamination.

As there is no change in the risk to groundwater sources above current levels during construction or operation of the Tailings Pond alteration, a significance Level I is assigned with respect to potential environmental effects to groundwater and has been deemed not significant (Table 2).

Surface Water

Surface water coming in contact with construction activities will be collected and pumped back into the West TMA for treatment prior to its release into the environment. Existing Spill Response Protocols and Best Management Practices for Materials Handling at the facility are sufficient mitigation measures for dealing with the potential environmental effects related to surface water contamination during construction. Following the completion of construction phase, no effect is anticipated in surface water quality due to the operation of the Tailings Pond. No potential environmental effects are anticipated with respect to surface water runoff at the site as the topography in the area will remain relatively unchanged and site runoff should continue to follow current drainage paths.

Because potential environmental affects to surface water quality and runoff are expected to be negligible with respect to the proposed alteration, a Level I significance has been assigned and the potential effects have been deemed not significant (Table 2).

2.2.4 Ecological

Environmental effects with regard to flora and fauna due to habitat disturbance and fragmentation are expected to be minor as the construction and operation of the proposed alteration will occur within the boundaries of the Mine's surface leases and the area to be cleared for the project will be small. The increase in noise anticipated during construction will be short-term and mostly limited to the project area. Noise in this area of the proposed alteration will be minor and less than the noise emitted by other equipment used in mining activities.

Because the effect on habitat is expected to minor and noise levels will be lower than pre-alteration levels, it is deemed that the alterations are insignificant with respect to ecological environmental effects and assigned Level I significance (Table 2).

3. Conclusions

A detailed review of the environmental effects associated with alterations to the Tailings Pond in the West TMA at the BLM has indicated that the proposed amendments have been deemed as not significant when compared to existing conditions at the Facility.

Effects associated with the physical environment, emissions, water resources and ecological and sociological (health and safety) aspects remain virtually unchanged as the proposed upgrades are almost entirely contained within the Mine's surface leases and measures currently used at the facility are sufficient to mitigate any long-term adverse effects. No anticipated increases in environmental effects are expected with regard to water usage or surface water quality in the receiving environment due to the alteration.

The proposed alteration at the TANCO Bernic Lake Mine is expected to be insignificant as most potential negative environmental and human health effects resulting from the alteration can be mitigated through TANCO's environmental and health and safety policies currently in place at the Mine.

4. References

Government of Manitoba. 1988. *The Environment Act*, C.C.S.M. c. E125. Available from https://web2.gov.mb.ca/laws/statutes/ccsm/_pdf.php?cap=e125 .

Hatch. 2022a. Design Basis – West TMA Perimeter Dam Raises (H368720-0000-22A-210-0001. Prepared for TANCO. 30 pp.

Hatch. 2022b. Peripheral Dykes PD-1 and PD-2 Raise Plan (H368720-0000-220-1004). Prepared for TANCO. 1 p.

Hatch. 2022c. Peripheral Dykes PD-3 and PD-4 Raise Plan (H368720-0000-220-1004). Prepared for TANCO. 1 p.

Hatch. 2022d. Peripheral Dyke PD-5 Raise Plan (H368720-0000-220-1006). Prepared for TANCO. 1 p.

Hatch. 2022e. Main Dam MD-1 Raise Plan (H368720-0000-220-1003). Prepared for TANCO. 1 p.

Hatch. 2022f. West TMA Perimeter Dam Raise Replacement Outflow Structure – Trade-off Study (H368720-0000-280-146-0001. Prepared for TANCO. 18 pp.

Hatch. 2023a. Water Control and Emergency Spillway Design - Draft (H36720-0000-220-1020). Prepared for TANCO. 1 p.

Hatch. 2023ba. Preliminary MD-1 Decommissioning Plan. Prepared for TANCO. 1 p.

Hatch. 2023c. Technical Specification – Geomembrane Material Supply and Installation (H368720-0000-220-242-0002. Prepared for TANCO. 19 pp.

ICOLD and UNEP (2001). Bulletin 121: Tailings Dams - Risk of Dangerous Occurrences, Lessons learnt from practical experiences. Paris.144

Appendix A

Design Basis: West TMA Perimeter Dam Raises (Hatch 2022a)

Design Basis

West TMA Perimeter Dam Raises

H368720-0000-22A-210-0001

			[redacted]	[redacted]	[redacted]	
2022-08-15	A	Client Review	S. Grieve D. Zaborniak	R. Wong	R. Wong	J. Champagne
DATE	REV.	STATUS	PREPARED BY	CHECKED BY	APPROVED BY	APPROVED BY
				Discipline Lead	Functional Manager	Client

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IMPORTANT NOTICE TO READER

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This document contains the expression of the professional opinion of Hatch, based upon information available at the time of preparation. The quality of the information, conclusions and estimates contained herein is consistent with the intended level of accuracy for such a document, as well as the circumstances and constraints under which this document was prepared.

However, this document is a Design Basis and, accordingly, all estimates and projections contained herein are based on limited and incomplete data. Therefore, while the work, results, estimates and projections herein may be considered to be generally indicative of the study progress and development, they are not definitive. No representations or predictions are intended as to the results of future work, nor can there be any promises that the estimates and projections in this report will be sustained in future work.

1. Introduction

The Tantalum Mining Corporation of Canada Ltd. (Tanco) is a wholly owned subsidiary of Sinomine Resource Group Co. Ltd. (Sinomine). Tanco is planning to raise the West Tailings Management Area (TMA) dams at the Tanco mine site located in eastern Manitoba, Canada.

Hatch Ltd. (Hatch) has been retained by Tanco to complete the detailed design of raising the West TMA perimeter dams. The perimeter dams comprise of the Main Dam (MD) and five peripheral dykes (PD01 to PD05). The dam raise design also includes the replacement of the existing decant outflow structure on the Main Dam. The purpose of the decant outflow structure is to manage water levels within the West TMA and transport excess water to the downstream Polishing Pond.

This document presents the design basis and assumptions for the West TMA perimeter dam raise detailed design.

2. Site Description

2.1 Project Location

The Tanco Bernic Lake Mine (N50º25’42”, W95º27’10”) is located approximately 160 km by road northeast of Winnipeg, Manitoba on the northwest shore of Bernic Lake, Manitoba (Figure 2-1). The mine is located approximately nine kilometres north of Manitoba’s Eastman Region northern boundary, adjacent to the Rural Municipality of Alexander. Access to the mine site is by a 10 km long gravel road (Tanco Mine Road), maintained by Tanco, which connects the mine site to Highway 315.

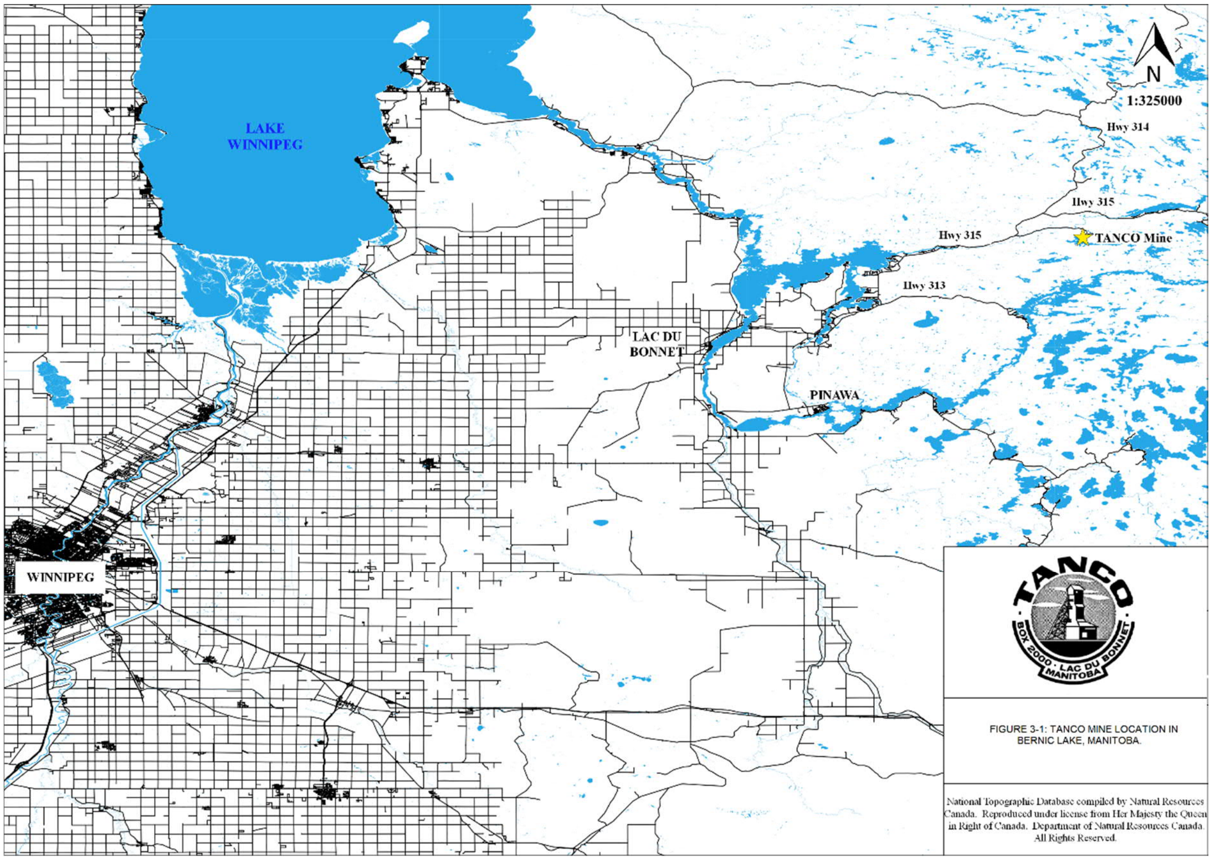


Figure 2-1: Project Location

2.2 Mine Description

The Tanco mine property contains an underground mine, mill and cesium processing facility. The mine is a primary global source of pollucite, which is used in the production of cesium chemicals. In addition to the cesium contained in the Tanco orebody, there are also significant quantities of lithium, in the form of amblygonite and spodumene, as well as tantalum. The mine has been operating for approximately 50 years and recently has been producing a lithium concentrate from mined ores.

2.3 Existing Tailings Management Areas

There are two TMA's at the Tanco mine site. They are listed below along with their main components:

- East Tailings Management Area (East TMA) - Includes two containment cells and two ponds (Recharge Pond and Groundwater Pond).
- West Tailings Management Area (West TMA) - Includes the Tailings Pond (cell), Polishing Pond and Water Management Control Structures (West Discharge and Main Dam).

Figure 2-2 presents the general arrangement of the TMA's and related infrastructure at the Tanco mine site. The East TMA is at capacity for the long-term storage of tantalum and spodumene tailings. Cesium (CPF) residue is still deposited in the two containment cells where solids are allowed to settle out. The leftover residue solids after dewatering are dry stacked on top of old tailings in the north end of the facility. The TMA covers approximately 32 hectares and contains approximately 3 million tonnes of spodumene and tantalum tailings. The estimated quantity of cesium residue material stacked on top of the old tailings to date is approximately 700,000 cubic metres. The estimated amount at mine closure based on current reserves and projected mining rates is approximately 1.2 million cubic metres. Water from the containment cells is decanted and recycled back into the CPF for reuse in the process.

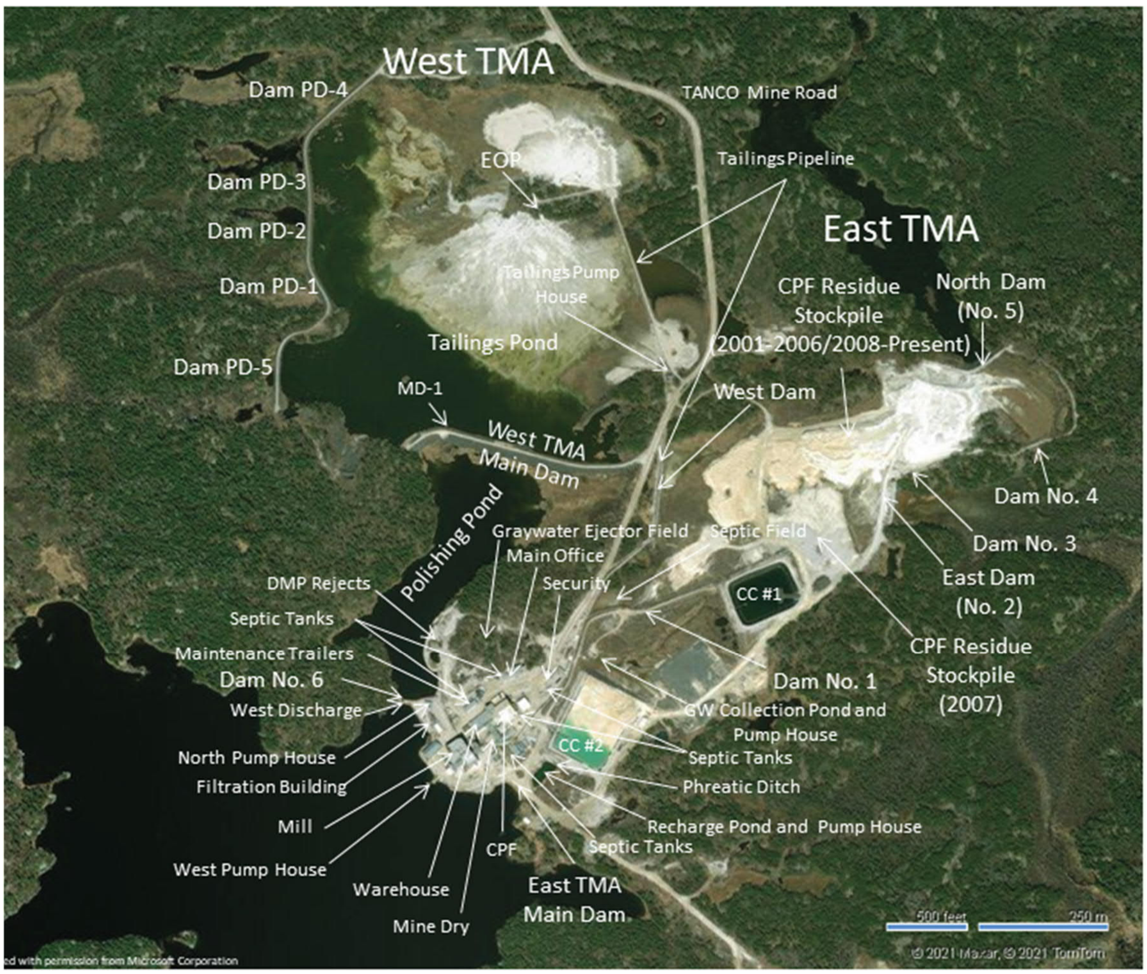


Figure 2-2: Existing TMA Infrastructure General Arrangement

The West TMA is an active facility at site and provides long-term storage of tantalum and spodumene tailings. The Tailings Pond receives the tailings slurry from the mill along with water collected in the underground mine sumps and the groundwater collection and recharge ponds in the East TMA. The Tailings Pond in the West TMA also receives water collected in various sumps around the property used to control surface water drainage and on occasion has received excess water transferred from the Containment Cells in the East TMA. Tailings from the Mill are spigotted into the north end of the Tailings Pond which flow south across the surface of old tailings until they reach the Main Dam where the water is retained and solids continue to settle out. Water is transferred from the Tailings Pond into the Polishing Pond via a control structure in the Main Dam (MD-1). The Polishing Pond provides additional time for solids to settle out of the effluent prior to its discharge into Bernic Lake through a control structure known as the "West Discharge" located in the Polishing Pond Dam.

The Main Dam (MD) and 5 Peripheral Dams (PD01 to PD05) enclose the Tailings Pond in the West TMA. The MD and PD01 to PD04 were constructed in 1996 and have been raised four times, with the last raise occurring in 2008 to the current dam elevation of 320.1 m. PD05 was constructed in 2005 and raised in 2008 to the same elevation of the MD and PD01 to PD04 (El. 320.1 m). At the current dam elevation of 320.1 m, the West TMA has the capacity to store 3.73 million tonnes of tailings with an estimated 3.00 million tonnes currently stored within the facility. Table 2-1 shows a summary of the existing dam configurations at the West TMA (Tanco, 2020 and Acres, 2009).

Table 2-1: Summary of West TMA Dam Configurations

Dam	Construction Method /Type	Crest El. (m)	Max. Dam Height (m)	Dam Length (m)	Crest Width (m)	Upstream Slope	Downstream Slope
Main Dam (MD)	Downstream Raised / Rockfill dam with upstream PVC liner above El. ~317 m, Clay Till Upstream Liner Below El. ~317 m	320.1	12.2	500	5.2	2.0 to 3.0H:1V	2.1 to 2.5H:1V
PD-1		320.1	7.5	100	5.2	2.1 to 2.4H:1V	1.7 to 2.1H:1V
PD-2		320.1	7.3	150	4.7	2.3 to 2.7H:1V	1.7 to 1.9H:1V
PD-3		320.1	7.0	162	5.2	2.3 to 2.9H:1V	1.8 to 2.5H:1V
PD-4		320.1	4.2	108	4.9	2.4 to 2.6H:1V	2.1 to 2.8H:1V
PD-5		320.1	5.5	150	4.6	2.3 to 2.7H:1V	1.9 to 2.4H:1V

3. Site Conditions

3.1 Topography and Subsurface Conditions

The Tanco mine site is located in the Winnipeg watershed immediately adjacent to Bernic Lake which is the receiver of effluent discharged from the site. The topography of the site is undulating with moderate local relief usually less than 15 m. The vegetation in the area consists of moderate bush cover including jack pine, poplar, and spruce. Smaller spruce and tag alder marsh cover numerous low lying and marshy areas at site. Bedrock outcrops are common in the area and the is mainly categorized as metamorphosed volcanic rock. The bedrock is typically covered by thin mantles of sandy to clay till; however, peat is generally found in low-lying areas covering compact silty sand and gravel or silty clay on top of bedrock.

Several geotechnical investigations have been completed at the West TMA to characterize the foundation conditions over the years with the last one completed in 2008. A new geotechnical investigation is currently planned for the summer of 2022 to obtain new information and verify past data. The information from the past geotechnical investigations and the planned new one will provide the basis for the detailed design of the West TMA perimeter dam raises, including the new decant overflow structure. Previous geotechnical investigation campaigns completed that are of interest are the following:

- 1996 geotechnical investigation comprising of a series of boreholes and test pits by Trow to characterize the native subsurface along the Main Dam and Peripheral Dam alignments prior to the development of the West TMA (Trow, 1996).
- 2008 geotechnical investigation by Acres to characterize the native subsurface conditions in the eastern side of the TMA adjacent to the site access road (Acres, 2009).

3.2 Regional Geology and Hydrogeology

The Tanco mine site is underlain by the Bernic Lake pegmatite group within the Bird River greenstone belt in the Archean Superior Province of the Canadian Shield in southeastern Manitoba. It comprises metavolcanic and metasedimentary rocks and associated synvolcanic intrusions, which are bounded to the north by the English River Domain and to the south by the Winnipeg River Domain. The bedrock geology at the Tanco site consists primarily of gabbro and diorite as shown on Figure 3-1.

Groundwater flow within the West TMA is generally south towards Bernic Lake. Due to the tight bedrock conditions, it is anticipated groundwater flows would primarily be along the soil bedrock interface and the only significant infiltration into bedrock would occur through faults and joints.

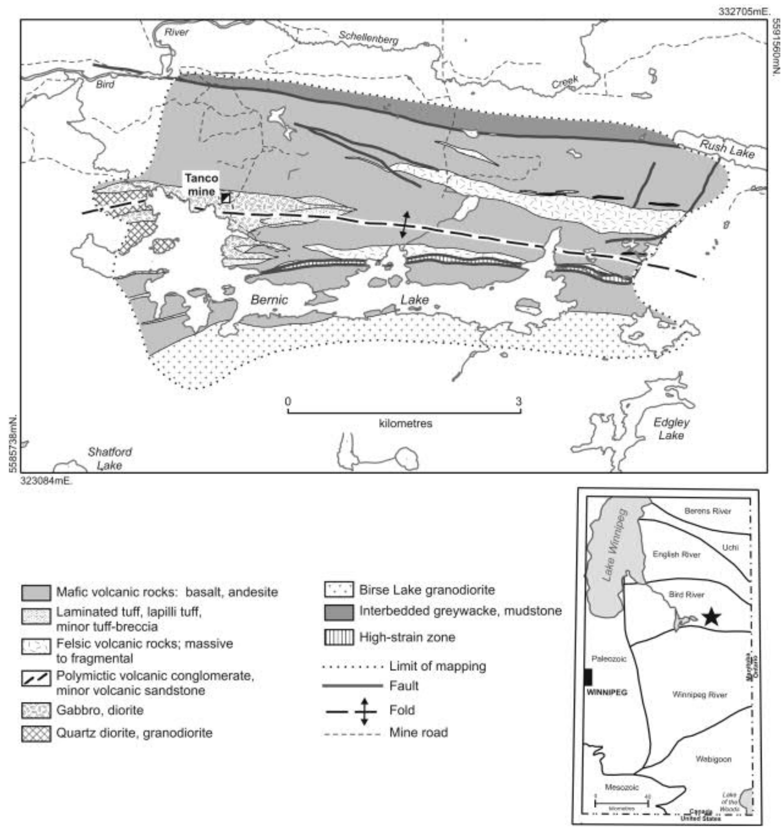


Figure GS-18-1: Preliminary map of the Bernic Lake area around the Tanco mine, Bird River greenstone belt, southeastern Manitoba PMAP2006-9 (Kremer and Lin, 2006).

Figure 3-1: Tanco Mine Site Geological Map

3.3 Climatic Data

No on-site climatic station exists at the Tanco mine site. Based on feedback received during the July 26 site visit by Hatch, Tanco uses information from the Environment and Climate Change Canada (ECCC) station in Pinawa, Manitoba. Two climate stations exist at the same location in Pinawa: Pinawa (ID 503B1ER) and Pinawa WNRE (ID 5032162). The two stations are the closest ECCC stations to the Tanco mine site and are located approximately 52 km southeast of the site. Historical temperature and precipitation data were available from Pinawa Station from 1996 through July 2022, while Climate Normals[1] were available from Pinawa WNRE from 1981 to 2010.

Another ECCC station, Bisset Station (ID 5030282), was used to characterize climate conditions in the Tanco, Bernic Lake Mine, Tailings and Wastewater Operation, Maintenance, and Surveillance Manual (Tanco, 2020). Intensity-duration-frequency (IDF) data was

[1] Climate Normals are used to summarize average climatic conditions of a climate station. At the completion of each decade, Environment and Climate Change Canada updates its Climate Normals for as many climate characteristics as possible based on data collected in the previous 30 years.

available for Bisset Station and was factored to develop IDF data for Pinawa Station. The Bisset Station is located approximately 69 km northeast of the Tanco site.

Evaporation at the Tanco site was estimated based on evaporation data from Climate Normals datasets from four nearby climatic stations.

Figure 3-2 shows the location of all climate stations used in this study relative to the Tanco site. Table 3-1 presents general information for the climatic stations used in this study.

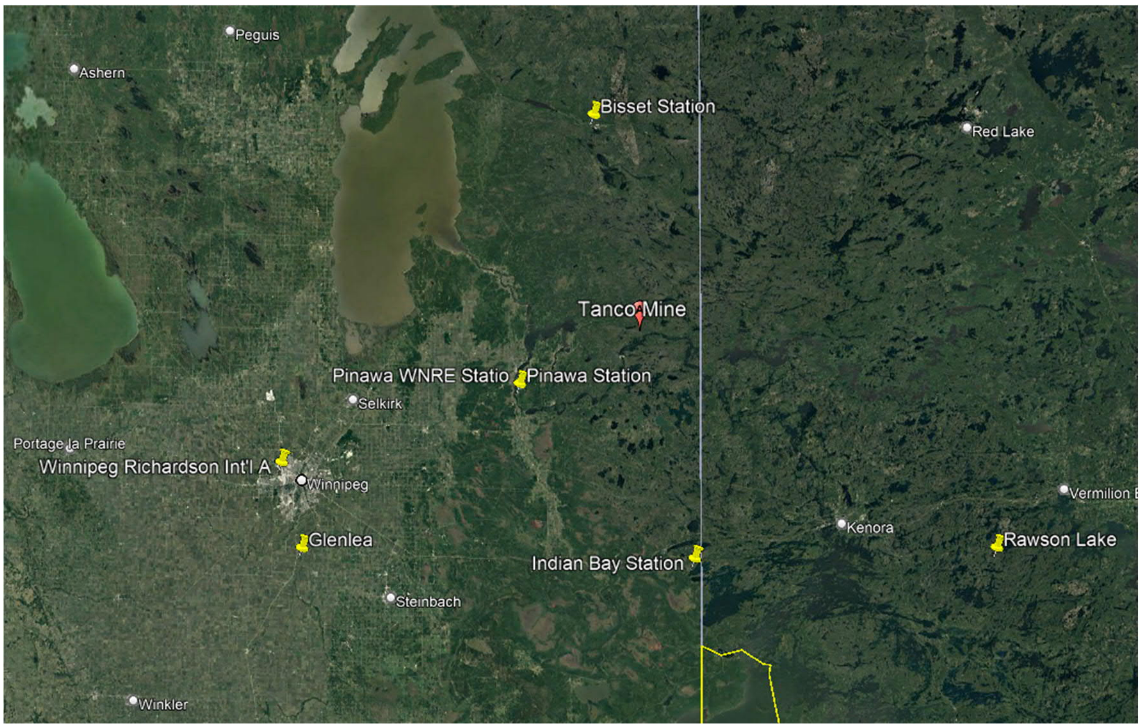


Figure 3-2: Locations of Nearest Climatic Stations (ECCC)

Table 3-1: Regional Climatic Stations

Station	Station ID	Latitude	Longitude	Elevation	Data Type	Record Period	Distance to Site
Pinawa	503B1ER	N 50.18	W 96.06	259.1	Temperature, Precipitation, Wind	1996 to 2022	52 km
Pinawa WNRE	5032162	N 50.18	W 96.06	266.7	Climate Normals	1981 to 2010	52 km
Bisset	5030282	N 51.03	W 95.70	259.0	IDF	1969 to 1984	69 km
Indian Bay	5031320	N 49.62	W 95.20	326.7	Climate Normals (Evaporation)	1981 to 2010	91.8 km
Winnipeg Richardson Int'l A	5023222	N 49.92	W 97.23	238.7	Climate Normals (Evaporation)	1981 to 2010	137.3 km
Glenlea	5021054	N 49.65	W 97.12	234.4	Climate Normals (Evaporation)	1981 to 2010	145.5 km
Rawson Lake	6036904	N 49.65	W 93.72	358.1	Climate Normals (Evaporation)	1981 to 2010	152.8 km

3.3.1 Air Temperature

Table 3-2 presents average daily, mean daily maximum, mean daily minimum, and extreme temperatures from the Climate Normals dataset at the Pinawa WNRE station. The mean annual temperature is estimated to be 2.8˚C, with a summer mean high of 19.3˚C in July and a winter mean low of -16.6˚C in January.

Table 3-2: Air Temperatures at the Pinawa WNRE Station

Month	Average Daily (°C)	Mean Daily Maximum (°C)	Mean Daily Minimum (°C)	Extreme Maximum (°C)	Extreme Minimum (°C)
January	-16.6	-11.1	-22.1	9.5	-44.0
February	-13.2	-7.3	-19.0	12.0	-47.8
March	-5.7	0.2	-11.6	20.0	-40.5
April	3.9	10.3	-2.5	32.5	-28.9
May	11.2	17.7	4.6	34.5	-13.9
June	16.4	22.5	10.3	37.5	-3.9
July	19.3	25.2	13.2	37.0	-0.6
August	18.2	24.3	12.0	36.0	-1.5
September	12.3	18.0	6.7	36.0	-6.7
October	5.1	9.7	0.4	28.5	-15.5
November	-4.5	-0.7	-8.3	23.3	-34.5
December	-13.1	-8.5	-17.6	10.0	-40.0
Annual	2.8	8.4	-2.8	37.5	-47.8
	(average annual)	(average annual)	(average annual)	(record highest)	(record lowest)
Source: Climate Normals (1981 to 2010) from Pinawa WNRE Station (Environment and Climate Change Canada).					

3.3.2 Precipitation

Table 3-3 presents precipitation, rainfall, and snowfall data from the Climate Normals dataset at the Pinawa WNRE station. The mean annual precipitation is estimated at 578.3 mm with approximately 80% falling as rain and 20% falling as snow (in snow water equivalent). The maximum daily precipitation of 168.4 mm was recorded on June 14, 1973.

Table 3-3: Precipitation, Rainfall, and Snowfall at Pinawa WNRE Station

Month	Rainfall (mm)	Snowfall (in water equivalent) (mm)	Total Precipitation (Rainfall + Snowfall) (mm)	Max Daily Precipitation (mm)
January	0.3	21.4	21.7	23.9
February	2.1	14.6	16.7	26.0
March	11.0	14.9	25.8	44.4
April	19.7	9.4	29.1	48.0
May	64.5	2.1	66.6	65.0
June	98.8	0.0	98.8	168.4
July	89.1	0.0	89.1	63.5
August	65.3	0.0	65.3	77.2
September	61.4	0.5	61.9	75.2
October	40.3	7.9	48.2	56.5
November	10.3	19.2	29.5	21.2
December	1.6	24.0	25.6	35.0
Annual	464.3	113.9	578.3	168.4
Source: Climate Normals (1981 to 2010) from Pinawa WNRE Station (Environment and Climate Change Canada).				

3.3.3 Evaporation

Evaporation was estimated based on data collected from four regional climatic stations near the Tanco site (see Figure and Table 3-1). The Climate Normals data for each of the stations included daily lake evaporation estimates for the period from 1981 to 2010. Given that the four stations are all within approximately 150 km from the site, and within an elevation range of +/- 80 m from the elevation of the West TMA dams, an average of the Climate Normals evaporation data was used to represent evaporation at the Tanco site.

Table 3-4 summarizes the data collected from the four regional climatic stations and resulting average lake evaporation to be adopted for this study.

Table 3-4: Summary of Lake Evaporation Data

Month	Average Daily Evaporation (mm/day)				
	Indian Bay	Winnipeg Richardson Int'l A	Glenlea	Rawson Lake	Average Adopted for Tanco Site
January	0	0	0	0	0
February	0	0	0	0	0
March	0	0	0	0	0
April	0	0	0	0	0
May	3.2	4.7	4.0	3.7	3.9
June	3.9	4.9	4.5	4.1	4.4
July	4.0	4.7	4.5	4.1	4.3
August	3.4	4.5	4.3	3.5	3.9
September	2.1	2.9	2.8	2.1	2.5
October	1.4	1.4	0	0	1.4
November	0	0	0	0	0
December	0	0	0	0	0
Source: Climate Normals (1981 to 2010) from regional climatic stations (Environment and Climate Change Canada).					

3.3.4 *Statistical Rainfall and Rain-on-Snowmelt*

Statistical rainfall and rain-on-snowmelt data were collected from ECCC stations in Bisset and Pinawa. Short-duration (i.e., from 5 minutes to 24 hours) data was available from Bisset Station, whereas only longer duration (i.e., 1-day to 30-day) data was available for Pinawa Station. The short-duration rainfall depth-duration-frequency (DDF) data for Bisset Station was developed using the historical maximum daily rainfall records from 1969 to 1984; no recent data was available at this station. Therefore, short-duration rainfall DDF distribution for Bisset Station was factored for Pinawa using the 1:100-year 1-day rainfall depth at Pinawa extracted from the ECCC longer duration rainfall DDF. The 1:100-year 1-day rainfall event at Pinawa Station is 121.3 mm, developed based on historical records at Pinawa from 1996 to 2016. Table 3-5 presents the resulting rainfall DDF for Pinawa Station.

Table 3-5: Rainfall Depth-Duration-Frequency Data for Pinawa Station

Duration	Return Period (years)					
	2	5	10	25	50	100
(min)	Rainfall Depth (mm)					
5	6.6	8.6	9.9	11.4	12.7	13.9
10	10.1	12.3	13.8	15.7	17.0	18.4
15	12.8	16.1	18.4	21.2	23.3	25.4
30	16.8	21.9	25.3	29.5	32.7	35.8
60	20.3	26.1	30.0	34.9	38.6	42.2
120	24.6	33.1	38.7	45.7	51.0	56.2
360	33.3	47.1	56.3	67.9	76.5	85.0
720	41.5	60.4	73.0	88.8	100.5	112.1
1440	50.2	69.3	81.8	97.9	109.6	121.3

The statistical 1-day to 30-day rain-on-snowmelt depths at the Pinawa Station for 1-in-2-year to 1-in-100-year return periods were obtained from ECCC and are summarized in Table 3-6.

Table 3-6: Rain-on-Snowmelt Intensity-Duration-Frequency for Pinawa Station

Duration (days)	Return Period (years)					
	2	5	10	25	50	100
	Rain-on-Snowmelt Depth (mm)					
1	22.80	29.71	34.29	40.06	44.35	48.61
2	36.19	43.41	48.19	54.23	58.71	63.16
3	44.08	54.01	60.58	68.88	75.03	81.15
4	50.69	59.73	65.71	73.27	78.87	84.44
5	56.46	67.83	75.36	84.88	91.94	98.95
6	62.50	76.62	85.97	97.78	106.55	115.24
7	65.54	81.08	91.38	104.38	114.03	123.60
8	69.72	84.96	95.05	107.80	117.25	126.64
9	74.27	88.41	97.77	109.60	118.37	127.08
10	78.01	97.55	110.48	126.82	138.94	150.97
15	82.20	107.00	123.42	144.17	159.56	174.84
20	91.95	127.29	150.68	180.25	202.18	223.95
25	95.68	144.29	176.48	217.15	247.32	277.27
30	99.04	152.71	188.25	233.15	266.45	299.52

3.4 Hydrology

Figure 3-3 shows a watershed map of the province of Manitoba downloaded from the Government of Manitoba, Environment, Climate and Parks. The Tanco mine site is in the Winnipeg River watershed at the easternmost edge of the province.

In the Winnipeg River watershed, the Tanco site is located immediately adjacent to Bernic Lake, which receives effluent discharge from Tanco's operations. Bernic Lake is a small second order lake with two basins of approximately equal size. All inflows to the lake are in the eastern basin while the Tanco mine and single outflow are in the western basin. The lake has a maximum depth of 9.17 m and a mean depth of 4.59 m. Bernic Lake outflows to Bernic Creek which flows into the Bird River, through Lac du Bonnet, and eventually to the Winnipeg River. The lake is hydrologically isolated from the Bird River for much of the open-water season except for during spring freshet or extreme rainfall events (Tanco, 2020).

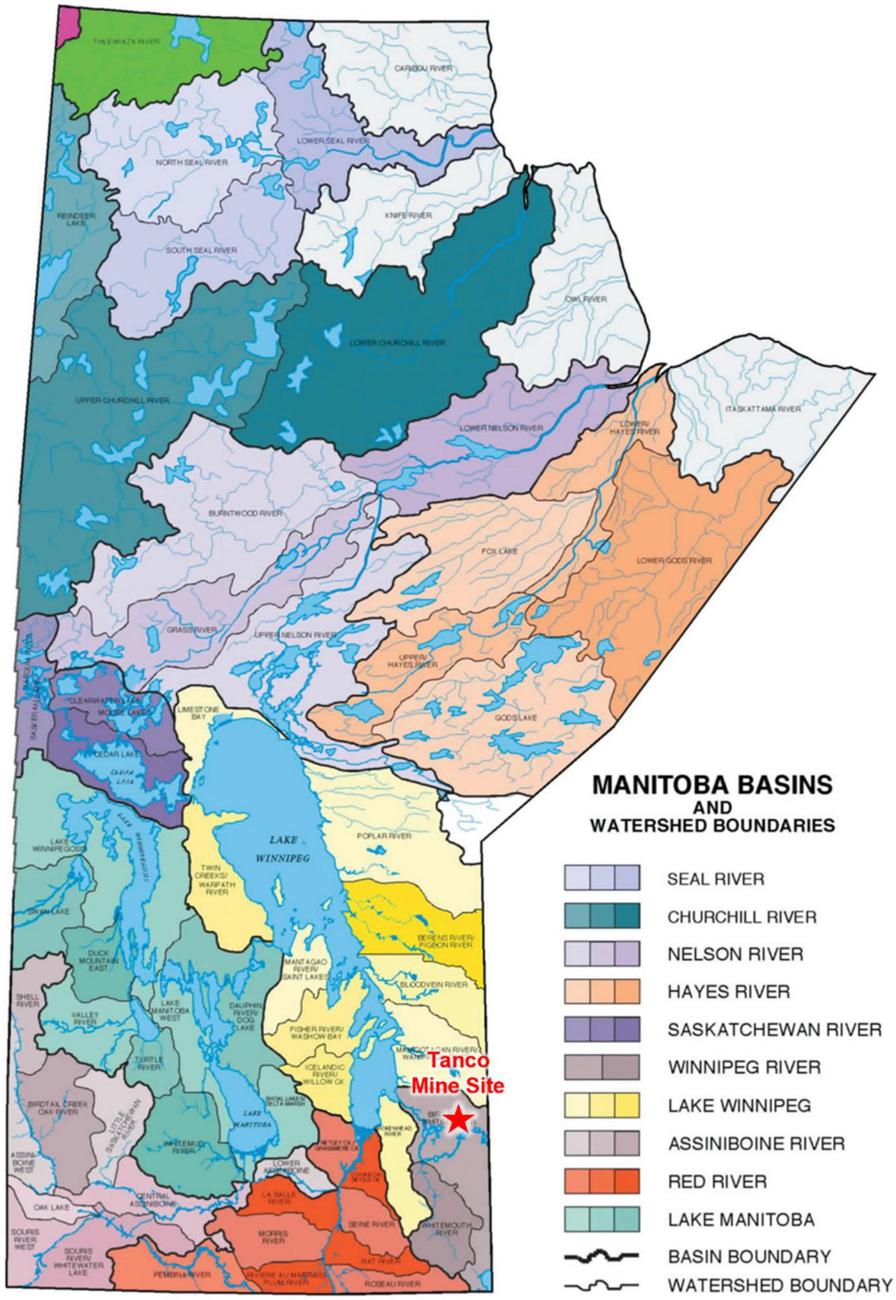
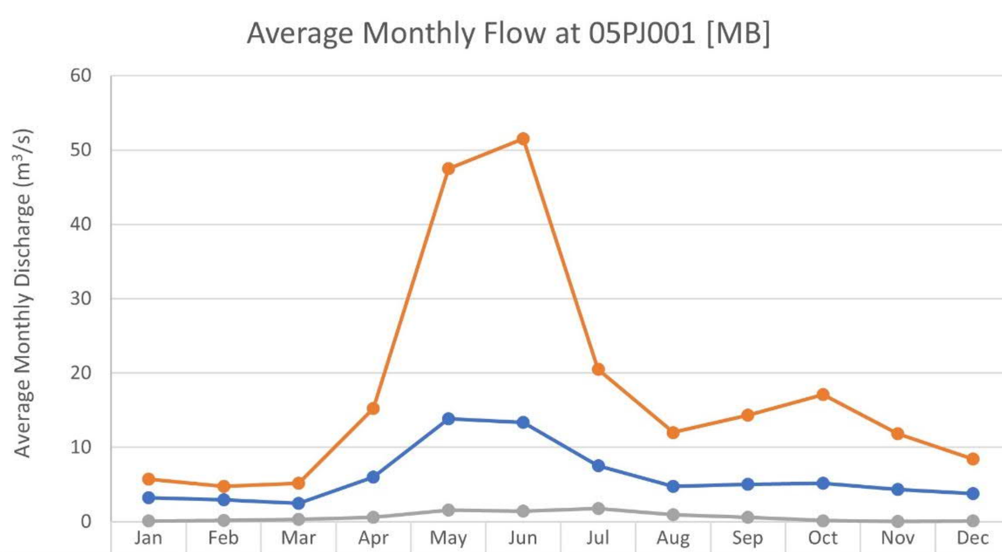


Figure 3-3: Provincial Watershed Map

A regional streamflow station exists northwest of the Tanco mine site at the outflow of Bird Lake (BIRD RIVER AT OUTLET OF BIRD LAKE (05PJ001) [MB]). The location of the station relative to the mine is shown in Figure 3-4.

Figure 3-4: Location of Regional Streamflow Station

Monthly flow data from the Bird River at Outlet of Bird Lake station is available for the period from 1960 to 2020. A summary of the data is presented in Figure 3-5.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	3.21	2.94	2.47	6.03	13.9	13.3	7.56	4.72	5.02	5.19	4.33	3.75
Max	5.74	4.79	5.14	15.2	47.5	51.5	20.5	12.0	14.3	17.1	11.8	8.46
Min	0.11	0.20	0.32	0.59	1.59	1.42	1.78	0.92	0.62	0.14	0.04	0.10

Figure 3-5: Monthly Flow Distribution at Regional Streamflow Station

The Bird River at Outlet of Bird Lake station is unregulated meaning that the data represents natural drainage from the streamflow catchment area. This data will be used to characterize the natural runoff distributions at the Tanco site.

3.5 Seismicity

The Tanco Mine site is in a stable seismic zone. The 2020 National Building Code Seismic Hazard Calculator has been used to estimate median Peak Ground Acceleration (PGA) for firm ground (Soil class C - average shear wave velocity 360 - 750 m/s), and the PGA values are summarized in Table 3-7.

Table 3-7: Tanco Mine - Peak Seismic Ground Acceleration (NBCC, 2020)

Parameter	Unit	Return Period		
		1:475	1:1,000	1:2,475
Peak ground acceleration (PGA)	g	0.012	0.021	0.043

4. Tailings Production Schedule and Properties

The mined tailings production schedule and properties adopted for the West TMA perimeter dam raise is summarized in Table 4-1. Based on existing information, there is estimated to be nearly 3 Mt of tailings currently stored within the West TMA (TetraTech, 2011).

Table 4-1: West TMA Tailings Production Schedule and Properties

Parameter	Unit	Value	Notes
Specific Gravity	-	2.75	Hatch, 2017
Final tailings dry density	t/m^3	1.50	Hatch, 2017. Within existing West TMA and anticipated final density of reprocessed/mine tailings
Total annual mined tailings	t/yr	70,000	Dry Tonnes. Includes Mined Spodumene Ore on the Spodumene Circuit for 5 months (2,000 t/month) and on the Tantalum Circuit for 12 months (5,000 t/month)
	m^3/yr	46,670	Calculated using a density of 1.50 t/m^3
Total allowable mined tailings volume to be stored in West TMA based on raise	m^3	TBD	Will be estimated based on tailings deposition model
Tailings sub-aerial beach slope	%	TBD	Will be estimated from latest site aerial survey
Tailings sub-aqueous beach slope	%	TBD	Will be estimated from latest site bathymetry survey

5. TMA Design Criteria

5.1 Design Guidelines

Presently, there is no specific guidelines for dam design that must be used and followed in the province of Manitoba. As a result of this, Canadian Dam Association (CDA) guidelines (CDA, 2019) have been selected as the design standard for all aspects of the proposed dam raises at the West TMA. The CDA is an industry recognized organization whose guidelines and standards describe best practices for tailings dam design and construction.

5.2 Hazard Potential Classification

Based on the CDA Dam Safety Guidelines (CDA, 2013), the classification of dams is based on potential consequences of dam failure. A dam classification exercise, using the guidelines outlined by CDA, has been conducted to determine the classification of the dams at the West TMA. Table 5-1 is a copy of the Dam Classification Table from the Dam Safety Guidelines (CDA, 2013) with red boxes to highlight the classifications selected for the West TMA. The following is a summary of the hazard potential for each consequence category::

- Population at Risk: Temporary Only - Significant
- Loss of Life: Unspecified – Significant.
- Environmental and Cultural Values Losses – High.
- Infrastructure and Economics – Significant.

The overall dam classification is by aligning the category with the description of the highest potential hazard, whether loss of life, property losses, environmental losses, or cultural-built heritage losses guidelines (CDA, 2019). Since the category of Environmental and Cultural Values Losses has a “High” hazard potential, the Dam Classification based on CDA guidelines is “High” for the West TMA dams.

It should be noted that the Dam Safety Guidelines (CDA, 2019) consider only the economic losses to third parties beyond the limits of the mining lease on which the mining dam is situated, and it is one consideration for the owner in terms of establishing the risk profile for the mining dam. The economic loss within the mining lease limits associated with a failure can also be substantial to a mining company or owner, including the direct financial burden associated with a failure such as clean-up and rehabilitation costs and rebuilding. Additionally, failures of mining dams can result in lost production, have a negative impact on the market capitalization of a company and limit the ability of the company to engage in other mining projects. Therefore, the owner must also consider other consequences that the dam presents to their operation when establishing the risk profile. This may not change the classification; however, the risk profile could have a bearing on the surveillance activities and design criteria (CDA, 2013).

Table 5-1: CDA Dam Consequence Classification (CDA, 2013)

Dam Class	Population at Risk	Incremental Losses		
		Loss of Life	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 or deterioration 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	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).

Notes:

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 unforeseeable misadventure.

   Temporary – People are only temporarily in 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.

5.3 Hydrotechnical Criteria

According to the CDA guidelines, the West TMA is to be designed to withstand:

- An Inflow Design Flood (IDF) without overtopping the dam embankments; and
- An Environmental Design Flood (EDF) without the release of untreated water to the environment.

For a dam classification of "High", CDA defines the annual exceedance probability of the IDF as "1/3 between 1/1000 year and PMF". As a conservative approach, a flood resulting from a 24-hour Probable Maximum Precipitation (PMP) event will be used. This design basis exceeds the minimum CDA requirements.

The EDF is the most severe flood that is to be contained without release of untreated water to the environment. The selection of return period and duration of the EDF considers the water quality being stored, regulatory requirements, frequency, rate, and duration of overflow events, environmental conditions downstream, and public perception.

Table 5-2 summarizes the hydrotechnical design criteria to be adopted in the design of the West TMA.

Table 5-2: Hydrotechnical Design Criteria

Parameter	Unit	Value	Note	Source
Inflow Design Flood (IDF)	mm	420.4	24-hour Probable Maximum Precipitation (PMP) to be released via spillway	ECCC. 1-Day to 30-Day Precipitation Depth-Duration-Frequency Values at Pinawa Station.
Environmental Design Flood (EDF)	mm	299.5	1:100 year, 30-day Storm (rainfall plus ice/snow melt) to be stored	Table 3-6
Minimum Freeboard	mm	To be calculated (Note 2)	Minimum vertical distance between the maximum still pond level and the dam crest	CDA, 2013

Notes:

1. The PMF is selected as the design IDF storm event for conservative consideration. This design basis exceeds the minimum CDA requirements for a facility with a “High” hazard potential dam classification, which is defined as “1/3 between 1/1000 year and PMF”.
2. Based on CDA (2013), the minimum freeboard required for “High” hazard potential embankment dams should be sufficient to meet all of the following criteria:
   a. No overtopping by 95% of the waves caused by the most critical wind with a frequency of 1/1000 year when the reservoir is at its maximum normal elevation.
   b. No overtopping by 95% of the waves caused by the most critical wind when the reservoir is at its maximum extreme level during the passage of the IDF. The most critical wind for the latter case depends on the consequence class of the dam. A suggested AEP value of 1/2 of wind frequency is to be used for calculation of freeboard during IDF for a “High” consequence dam.
   c. The maximum still-water level of the reservoir should be maintained at all times below.
   d. the top of the impervious core, unless analysis can demonstrate that temporary exceedance of the top of the core does not endanger the dam. The thickness of the material covering the impervious core of the dam or dyke should be sufficient to prevent freezing of the core in winter.

To the extent possible, non-contact water from undisturbed (i.e., natural) catchments will be diverted away from the TMF. This will reduce the amount of water passing through the TMF and the size of hydraulic structures required for contact water management. The non-contact water diversion works (i.e., channels, culverts, stilling basins, etc.) will be designed to convey a 1-in-100-year storm event without overflow into the TMF footprint.

5.4 Geotechnical Stability Criteria

Following the CDA Guidelines, the seismic data and factors of safety under various loading conditions required for the stability analysis of the West TMA dams are presented in Table 5-3 and Table 5-4, respectively.

Table 5-3: Seismic Parameters

Item	Unit	Value	Note	Source
Return Period	-	1:2,475 year	For a "High" consequence classification dam	CDA, 2019
Peak Horizontal Ground Acceleration (PHGA)	g	0.043	2,475-year return period	National Research Council of Canada (NRCC), 2020

Table 5-4: Recommended Guideline Factor of Safety (CDA, 2019)

Condition	Factor of Safety	Slope
End of Construction (before filling of impoundment)	1.3	Upstream and Downstream
Long Term	1.5	Downstream
Full or Partial Rapid Drawdown	1.2 to 1.3	Upstream
Pseudo-static	1.0	Upstream and Downstream
Post-Earthquake	1.2	Upstream and Downstream

6. TMA Design Basis and Assumptions

6.1 Dam Raise Geometry

The proposed overall slopes and internal zoning and alignment of the perimeter dam (Main dam and peripheral dams) raises at the West TMA will be confirmed during the design phase of the project. Key dam geometries which will be used as a starting basis for designs are presented in Table 6-1. It is assumed that the perimeter dams will be downstream raised at this stage of the project and that there are no issues with regards to accommodating the raise within the property limits of the mine.

Table 6-1: Dam Raise Typical Geometry

Parameter	Unit	Value	Notes
Dam Crest Elevation	m	321.6 m	1.5 m above the existing dam crest elevation of 320.1 m.
Dam Crest Width	m	5	Assumed minimum
Dam Raise Height	m	1.5	Maximum permitted dam elevation is 321.6 m, 1.5 m higher than current dam elevation.
Upstream Slope	-	2.5H:1V	To allow for geomembrane liner installation. Slope to be validated with a stability assessment based on design and encountered foundation materials.
Downstream Slope	-	2H:1V	Based on closure slopes. Slope to be validated with a stability assessment based on design and encountered foundation materials.

6.2 Dam Foundations

The downstream raises to the perimeter dams will need to be founded on competent dense till or bedrock. Foundation preparation for the downstream footprint areas of the dam raises will consist of excavating and removing any vegetation, organics and soft soil layers until dense till or bedrock is found. The amount of subgrade preparation on dense till or bedrock will depend on the construction application and be detailed during the design.

7. Structure Stability Design Criteria

7.1 Basic Design Data

In general, concrete structures should be analyzed for the most unfavorable possible combination of the following loads:

- Dead Loads (self weight)
- Loads Due to Water, Earth, and the Environment.
  - hydrostatic water loads
  - uplift
  - soil pressures
  - siltation
  - ice
  - Earthquake Loads.
  - Post-tensioning Forces.
  - Construction Induced Load

7.2 Unit Weights

- Structural Concrete: 23.5 kN/m^3
- Mass Concrete: 22.8 kN/m^3
- Water: 9.81 kN/m^3
- Earth: Based on subsurface investigation (TBD)

7.3 General Loading Conditions

This category includes all loading conditions under which the structure is intended to serve during normal operation. The loading conditions should include:

- gravity (or dead) loads (D),
- water loads due to normal operating levels at the upstream face (H),
- water loads due to normal tailwater levels at the downstream face (T),

- hydrostatic uplift loads (U),
- rock, soil, and siltation (S), and
- ice loads (I).

Upstream water levels shall be based on normal Tailings Pond operating levels. Tailwater levels shall be based on Polishing Pond operating levels. Ice loads are to be considered concurrent with normal winter operating water levels.

7.4 Unusual Loadings

This category should include all loading conditions not intentionally imposed on the structure, but which may reasonably be expected to occur individually.

The Inflow Design Flood (IDF) upstream and downstream water levels will be used in conjunction with other loads, except for ice loads, which should not be considered under this loading condition. The IDF upstream and downstream water levels are to be determined as described in Section 3.

7.5 Extreme Loading – Seismic

This category should include all loads resulting from a seismic event (Q) along with all loads, except that no ice loads should apply. Along with this analysis, a post-earthquake analysis may be required if the seismic event results in a cracked plane. The post-earthquake loading condition should be considered after the ground accelerations have dissipated and full headwater pressure has developed within a crack created by the earthquake. It may be required to perform an iterative calculation to determine the extent of the crack and to confirm the convergence of the crack.

7.6 Extreme Loading – Seismic with Flood Discharge Loading

This category shall include all loads resulting from a seismic event listed above, in combination with flood discharge loading.

7.7 Loading Combinations

The combinations of load conditions described above are summarized in Table 7-1.

Table 7-1: Load Combinations for Stability Analysis of Concrete Structures

Load Case	Load Conditions			Type of Load						
	Normal	Unusual	Extreme	Self-Weight D	Head Water H	Tailwater T	Uplift U	Rock and Soil S	U/S Ice Sheet I	Earthquake Q
Normal Operations										
(i) Normal Summer Level	x			x	x	x	x	x		
(ii) Normal Winter Level*	x			x	x	x	x	x	x	
Flood Conditions										
(i) IDF (< 1:1,000)		x		x	x	x	x	x		
Seismic Event			x	x	x	x	x	x		x

Note:
* Normal winter level assumes the same Tailings Pond and Polishing Pond elevations as normal summer levels with the inclusion of ice loads.

7.8 Limiting Criteria

Table 7-2 shows a summary of the limiting criteria for the stability analysis.

Table 7-2: Limiting Stability Criteria for Concrete Structures

Requirements		Loading Conditions			
		Normal	Unusual	Extreme	Post-EQ
(a)	Location of resultant	Within kern	75% of the base in compression (1)	Within base	Within kern of reduced base in compression
(b)	Minimum sliding factor (2)	1.5	1.3	1.1	1.1
(c)	Maximum base pressure	(3)	(3)	(3)	(3)
(d)	Tensile capacity of concrete/foundation interface	Zero	Zero	Zero	Zero

Notes
(1) Cracked base analysis.
(2) Equals [(V - U)tan φ']/H* Where:
V = sum of vertical forces
H = sum of horizontal forces
φ' = angle of internal friction at horizontal plane under consideration based on available geotechnical soils information
(3) Allowable bearing capacity should be based on available geotechnical information.

8. Structural Design Criteria

The design and construction, should be executed in conformance with the latest edition of the following standards:

- General
  - National Building Code of Canada (NBCC).
- Structural Steel
  - Design: CAN/CSA-S16.
  - Materials: CAN/CSA-G40.20/G40.21.
  - Welding: W47.1, W59.
- Reinforced Concrete
  - Design: CSA A23.3, ACI Report 224R.
  - Materials: CAN/CSA-A23.1 [Ref. 49], CAN/CSA-G30.18, CSA A23.4.
  - Testing: CAN/CSA-A23.2.

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Appendix B

West TMA Perimeter Dam Raise Replacement Outflow Structure – Trade-Off Study (Hatch 2022b)

West TMA Perimeter Dam Raise

Replacement Outflow Structure - Trade-Off Study

H368720-0000-280-146-0001

			[redacted]	[redacted]	[redacted]	
2022-08-12	A	Client Review	D. Zaborniak	S. Grieve	J. Silcox	Client
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				Discipline Lead	Functional Manager	Client

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Disclaimer

This document was prepared by Hatch Ltd. (“Hatch”), for the sole and exclusive benefit of the Tantalum Mining Corporation of Canada (the “Owner”) for the purpose of assisting the Owner in the completion of the detailed design of the West Tailing Management Area (West TMA) perimeter dam raises, and must not be provided to, relied upon or used by any other party. The use of this report by the Owner is subject to the terms of the relevant agreement between Hatch and the Owner.

This report is meant to be read as a whole, and sections should not be read or relied upon out of context. The report includes information provided by the Owner and by certain other parties on behalf of the Owner. Unless specifically stated otherwise, Hatch has not verified such information and does not accept any responsibility or liability in connection with such information.

This report contains the expression of the opinion of Hatch using its professional judgment and reasonable care, based upon information available at the time of preparation. The quality of the information, conclusions and estimates contained in this report is consistent with the intended level of accuracy as set out in this report, as well as the circumstances and constraints under which this report was prepared.

As this report is a trade-off study, all estimates and projections contained in this report are based on limited and incomplete data. Accordingly, while the work, results, estimates and projections in this report may be considered to be generally indicative of the nature and quality of the Project, they are not definitive. No representations or predictions are intended as to become the results of future work, and Hatch does not promise that the estimates and projections in this report will be sustained in future work.

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1. Introduction

The Tantalum Mining Corporation of Canada Ltd. (Tanco) is a wholly owned subsidiary of Sinomine Resource Group C., Ltd. (Sinomine), and owns and operates the Tanco Mine, located about 160km northeast of Winnipeg, near Bernic Lake, Manitoba, Canada. The Tanco mine has produced tantalum, lithium and cesium.

The West Tailings Management Area (TMA) at the Tanco Mine is surrounded by a Main Dam (MD-1) and five perimeter dykes (PD-1 to PD-5). An outflow structure is located at the Main Dam which transports water from the Tailings Pond within the West TMA to the downstream Polishing Pond.

The purpose of the decant outflow structure is to manage water levels within the West TMA and transport excess water to the downstream Polishing Pond. A limitation of the current outflow structure is that it cannot be raised any further to accommodate increased storage levels in the TMA. As such, the outflow structure must be replaced as part of the planned dam raise.

Hatch was retained by Tanco to prepare a trade-off study to evaluate multiple alternatives to replace the existing outflow structure. The following report documents the identification and evaluation of potential replacement options. Different outflow structure types and locations were considered in the evaluation. A discussion is presented for each conceptual alternative with recommendations as to which concept should receive further consideration through detailed design. The outcome of this trade-off study will provide Tanco with sufficient information to select the replacement outflow structure type and location that will best meet their operational needs.

2. Existing Conditions

The existing outflow structure consists of a stoplog controlled drop structure connected to a 1050 mm diameter corrugated steel pipe (CSP) that crosses through the Main Dam and discharges to the Polishing Pond.

The current West TMA dam was last raised in 2008, to a dam crest elevation of 320.1 m (1103 Tanco ft). The West TMA dam crest was previously raised in 2003, whereby the existing concrete outflow structure through the main dam was raised to accommodate the increase in earth embankment height. A new discharge pipe with an invert elevation of 317.04 m (1050 mm diameter corrugate steel pipe, CSP) was added, with the original discharge pipe being abandoned. In agreement with the client at the time of design, the outflow structure had the design limitation of being raised up to elevation 320.1 m, and no further. As such, to raise the main embankment dam further, a new structure is required.

Recently, some deterioration of the existing structure has been identified, including deformation of the CSP and some separation of the joints, Replacement of the CSP was recommended by the inspector.

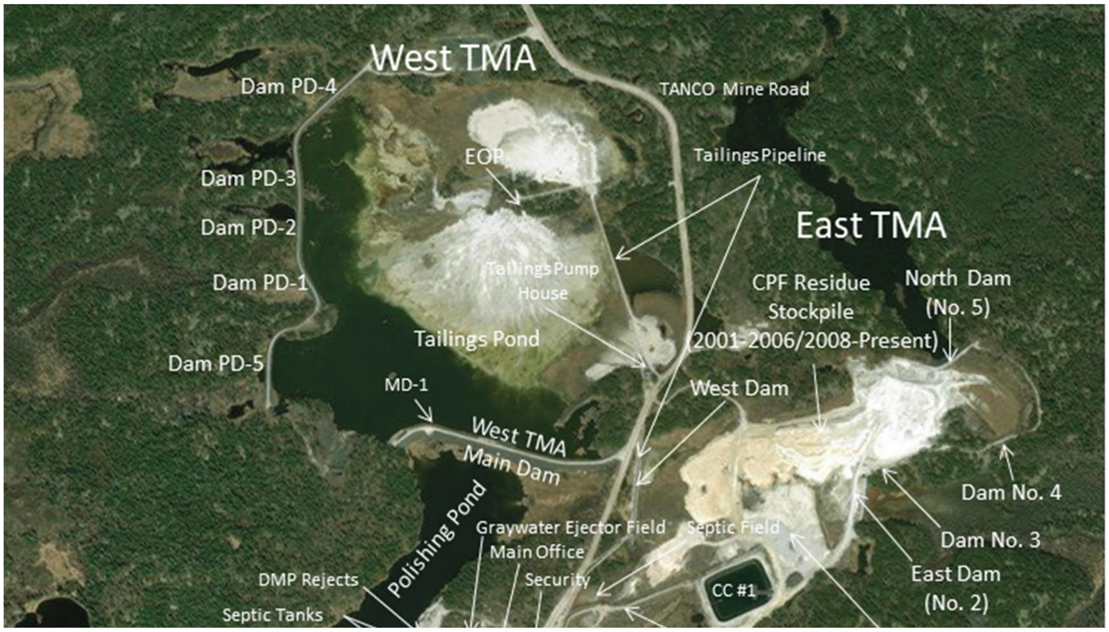

Figure 2-1: Existing Layout of West TMA

3. Outflow Structure Alternatives

As part of this trade-off study, four (4) potential outflow structure types were considered. The concepts presented herein consider different types of structure types placed on specific locations, which were deemed to be the most appropriate for the Tanco site.

The main characteristics for the options are differences in construction, elevation, location, alignment, and the resulting difference in size requirements for the structure. For the purposes of this study, all concepts are assumed to pass the same flow as the original outflow structure.

All options considered will accommodate the progressive installation of stoplogs over their lifespan to raise the dam crest, as tailings material is added to the Tailings Pond. Precast concrete stoplogs will be permanently installed to the structures to ensure that the elevation of the weir is higher than the elevation of the waste material within the Tailings Pond. Following the installation of a stoplog, the ends of the stoplog will be grouted in place to seal the log and prevent localized erosion of the waste material due to stoplog leakage.

Tanco indicated that the new outflow structure must be capable of passing light vehicle traffic, but that load capacity for larger mining equipment was not a requirement. A limitation for options that require a bridge is that heavy mining and construction equipment will be unable to traverse the bridge structure and would need to use the service road on the west side of the TMA.

The proposed outflow structures are described in the following subsections, while alternate locations are described in Section 4.

3.1 Structure Type A – Overflow Spillway

Structure Type A consists of a stoplog controlled reinforced concrete overflow spillway structure with an outlet channel. The invert elevation is expected to be set at approximately elevation 317 m but will be confirmed during detailed design.

The proposed reinforced concrete overflow spillway will be constructed with two parallel vertical retaining walls to retain fill material from the raised dam. Due to the proximity of bedrock, it is assumed this structure will be founded on and keyed into bedrock, to provide stability in the upstream-downstream direction. An outlet channel, lined with concrete or potentially cut directly into bedrock, will connect the downstream end of the overflow spillway at the downstream toe of Main Dam to the Polishing Pond. The outlet channel will discharge directly onto a rip rap slope at the downstream toe of the Main Dam to prevent downstream erosion.

A bridge crossing the top of the structure, between vertical retaining walls, at the dam crest will provide access across the structure as well as to the stoplogs slots. Tanco has indicated that only light vehicular traffic will need to traverse the structure. However, this will limit the size of equipment and vehicles that can cross the bridge.

Refer to the Figure 3-1 below for a general conceptual visualization of this concept.

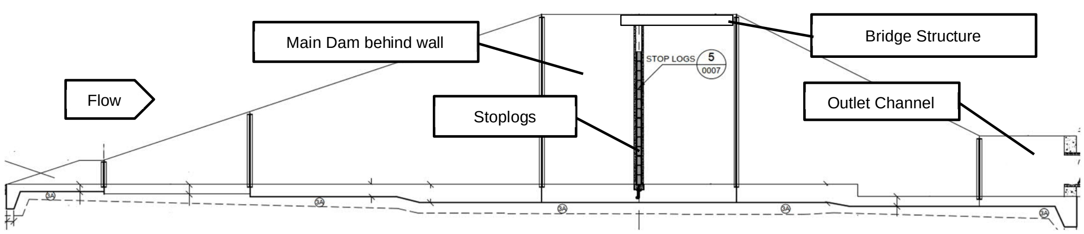

Figure 3-1: Elevation View Showing Section Through Concept of Overflow Spillway Structure

This structure type is commonly used in tailings service, and provides long service life and reliable performance, however, has higher construction costs than some of the other control structure types considered in this evaluation.

3.2 Structure Type B – Overflow Spillway Cut into Bedrock

Structure Type B is similar to Structure Type A, but consists of an inlet channel cut directly into bedrock, a small reinforced concrete structure anchored to the bedrock with reinforcing steel dowels to support and provide a sealing surface for the stoplogs, and a discharge channel cut into the bedrock downstream of the stoplogs to transport the discharge to the Polishing Pond. If the bedrock is competent and free of significant cracks and fissures, the inlet and discharge channels can remain as exposed bedrock. However, if the bedrock along the channels contain significant cracks or fissures, a concrete channel lining must be provided. This will be verified upon completion of the bedrock excavation.

Refer to the sketches below for a conceptual visualization of this concept. Note that this structure type can only be installed where the bedrock is at higher elevation, e.g., in the west abutment. Structure Type B offers the same benefits as Type A but has the potential to be the lowest cost option considered. As an added benefit, the bedrock that is excavated for the channels can be reused during construction of the dam raise.

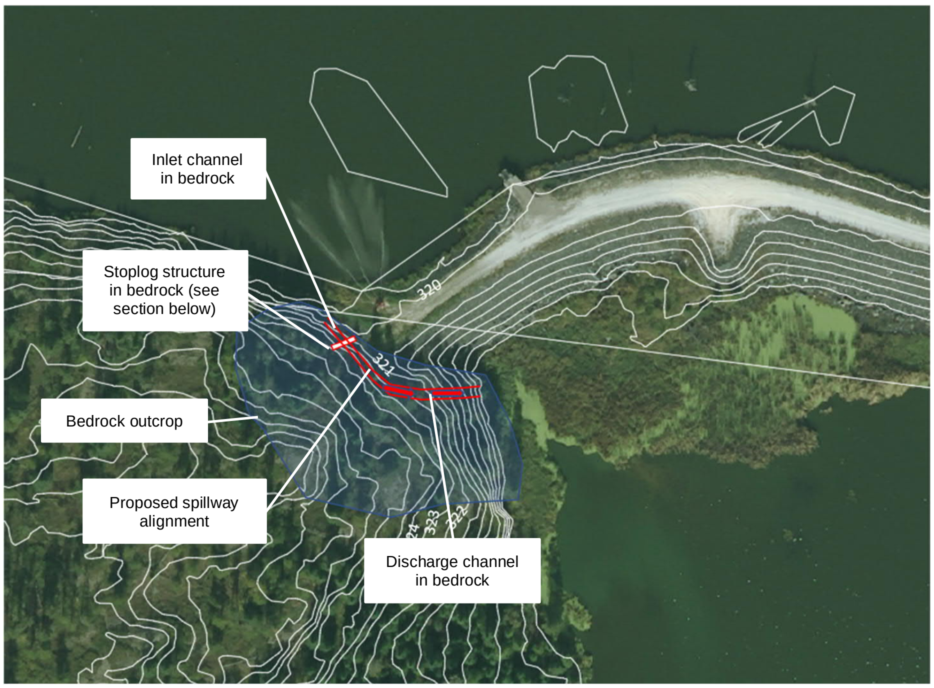

Figure 3-2: Plan Showing the Proposed Structure Type B and Discharge Channel Through the West Abutment Bedrock Outcrop.

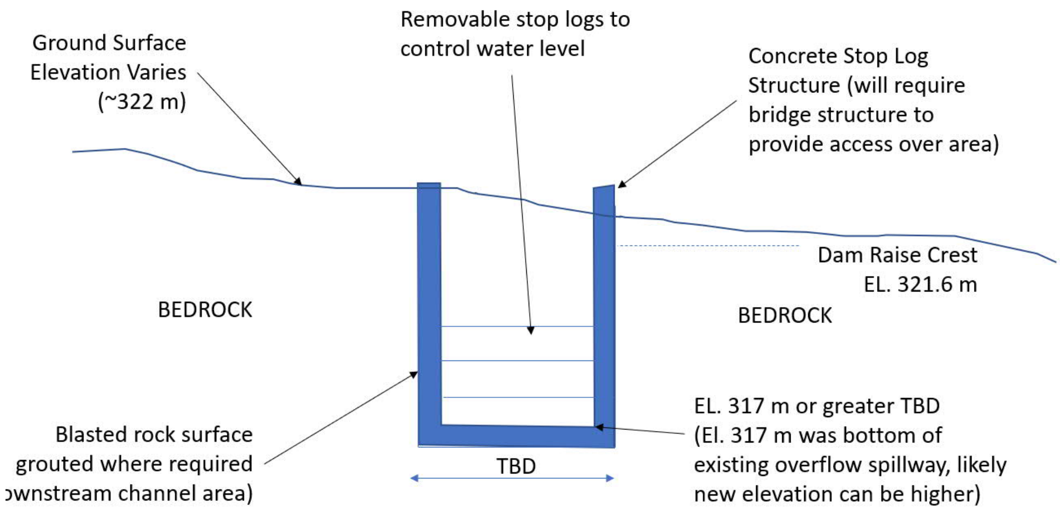

Figure 3-3: Section Through Proposed Overflow Spillway Structure Cut into Bedrock

3.3 Structure Type C – Drop Structure

Structure Type C is similar to the existing control structure in MD-1, consisting of a stoplog controlled drop structure with a reinforced concrete inlet structure featuring parallel vertical retaining walls located within the Tailings Pond. The retaining walls are used to retain the drop structure backfill and create a sluiceway channel to direct flows through the concrete reinforced drop structure to a conduit through the dam. The invert of this inlet structure will be set at approximately elevation 313.4 m. Due to the proximity of bedrock, it is assumed this structure will be founded on bedrock.

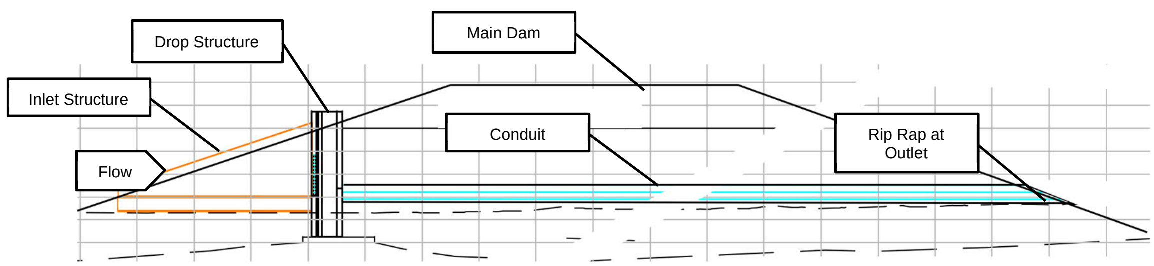

Figure 3-4: Elevation View of Structure Type C through Main Dam

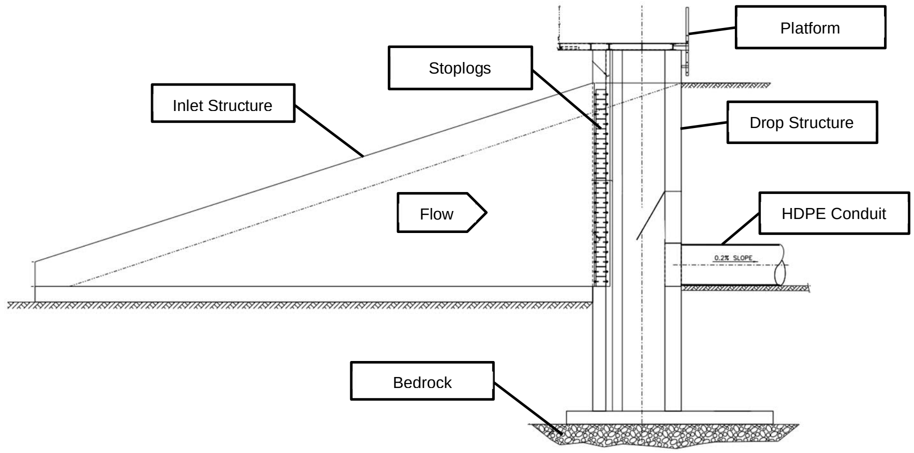

Figure 3-5: Elevation View Showing a Concept of The Proposed Inlet and Drop Structures

The inlet structure is located within the embankment, offset from the centerline of the Main Dam, allowing for vehicle traffic across the dam crest.

A grated steel access platform at the top of the drop structure provides for personnel access during stoplog installation. Removable sections of grating will be provided to access both the stoplog slot and the interior of the drop structure. As this structure is not accessible to the public, there would be no provisions for locking the removable grating sections.

The conduit invert will be sloped at approximately 0.2%. The conduit will discharge directly onto a rip rap slope at the downstream toe of the Main Dam. Unlike the existing control structure that uses a CSP conduit, high-density polyethylene (HDPE) is recommended for the new conduit material for the following reasons:

- Low weight which facilitates shipping and installation.
- Does not corrode.
- Resistant to fatigue, due to its flexibility.
- Long life index, see the figure below.

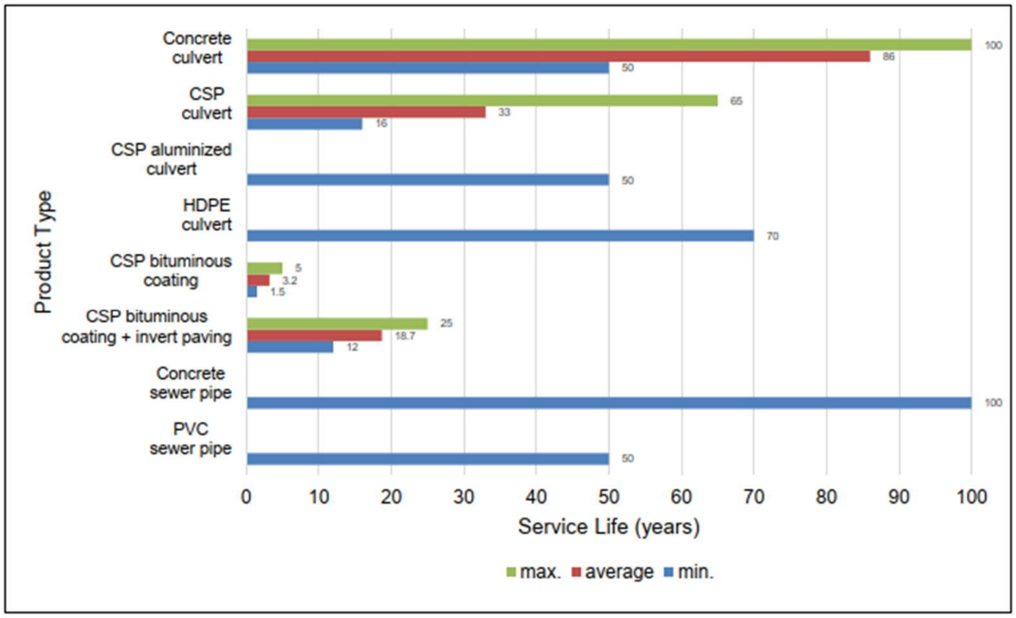

Figure 3-6: A Comparison of Service Life for Various Pipe Types [Ref. 1]

Structure Type C will have the lowest cost in comparison the other structure types constructed above bedrock (Structure Types A, C, and D), as it reduces the volume of the concrete structure by utilizing an HDPE conduit. However, this lower cost comes with an increase in risk; because the conduit will be backfilled beneath the embankment dam, it will be inaccessible and will hinder the ability to complete future repairs, as demonstrated by the existing outflow structure. This risk can be mitigated by founding the structure on bedrock to minimize the potential for differential sediment and considering that the flexibility of HDPE pipe can tolerate small movements. However, having a conduit backfilled within an embankment dam is no longer considered best practice for tailings management.

3.4 Structure Type D – Chute Type Spillway

Structure Type D, a chute type spillway, was considered for this study as it substantially reduces the amount of excavation in comparison to other comparable options. This is particularly advantageous for Locations 2 and 3 described further below that require excavating through the existing Main Dam. A chute type spillway structure will be founded on the Main Dam embankment itself.

Structure Type D consists of a stoplog controlled reinforced concrete chute spillway structure. Due to the relatively small flow requirement through the structure, a narrow chute type spillway could be constructed, with chute walls structurally tied together through the chute slab. The need for an under-slab drainage system can be avoided by ensuring each structural chute section mobilized sufficient backfill to be stable, thus reducing future inspection and maintenance requirements in comparison to typical chute type spillways with under-slab drainage systems. A small stilling basin would likely be required at the downstream toe of the Main Dam to prevent downstream erosion.

A bridge crossing the top of the structure, between vertical chute walls, at the dam crest will provide access across the structure as well as to the stoplogs slots.

Refer to the sketch below for a general conceptual visualization of this concept.

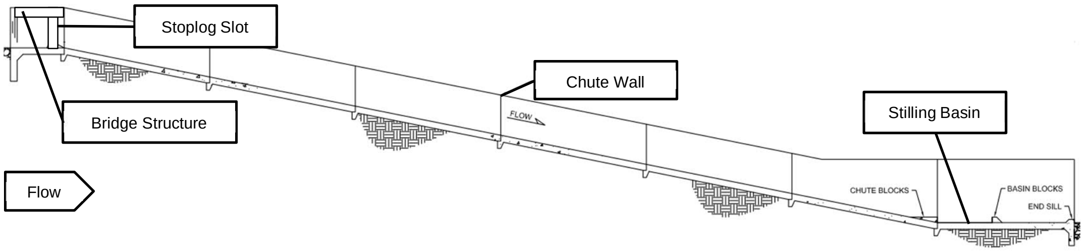

Figure 3-7: Elevation View of a Chute Spillway

4. Location Alternatives

For this study, three (3) potential outflow structure locations were considered, as described in the subsections below. All options consider transporting discharge water from the Tailings Pond to the Polishing Pond.

4.1 Location 1 – West Embankment (Suitable for Structure Type B)

Located at the west end of the Main Dam MD-1, Location 1 routes the outflow structure around the 26-year-old dam (originally constructed in 1996) and through the west abutment in bedrock. This location is advantageous in that it avoids excavating through the embankment of the existing Main Dam. In addition, from visual observations it is understood that this location is a bedrock outcrop, whereby the outflow structure could be cut into the bedrock. As a result, the potential for differential settlement would be minimized. This location is also advantageous in that it would minimize the size of cofferdam, due to the geometry in which the Main Dam intercepts the west abutment. See the figure below for the location, circled in red.

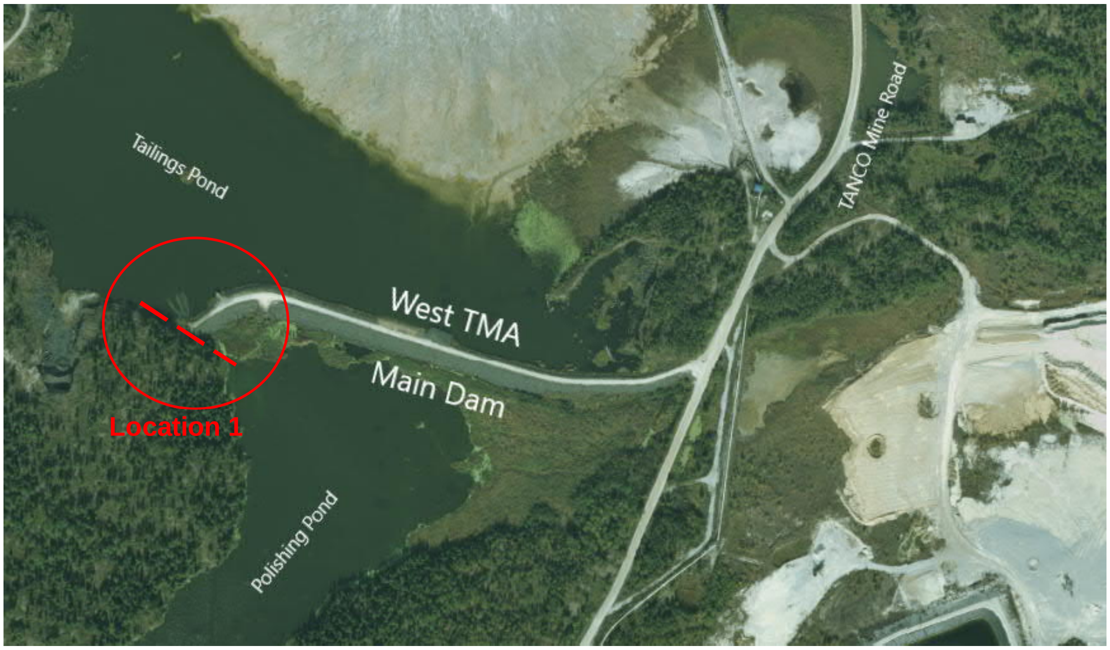

Figure 4-1: Proposed Location 1 Circled in Red

Although any of the proposed control structure types could be installed at Location 1, it is best-suited for Structure Type B – Overflow Spillway Cut into Bedrock. Structure Types A and C would require additional excavation to a deeper elevation, which would then need to be backfilled or replaced with concrete, while Structure Type D offers no additional benefit but with increased cost for concrete. As a result, Structure Type B – Overflow Spillway cut into Bedrock is the recommended option for Location 1.

4.2 Location 2 – Central Embankment (Suitable for Structure Types A, C, and D)

Located centrally on the Main Dam, Location 2 considers an outflow structure routed through the earth embankment, requiring excavation through the Main Dam itself. Structure Types A, C and D could be installed in this location. Due to the geometry of the Main Dam, this location would require the largest sized cofferdam in comparison to the other options considered, increasing project costs. See the figure below for the location, circled in red.

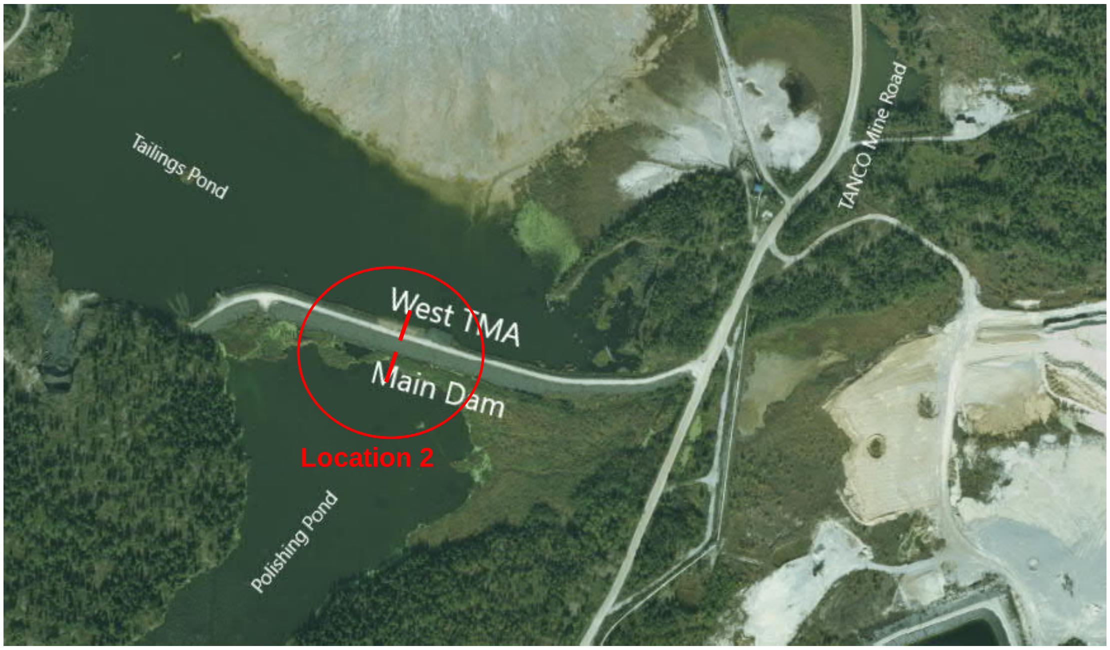

Figure 4-2: Proposed Location 2 Circled in Red

It should be noted that excavating through the Main Dam is highly undesirable, as this could create a potential seepage path through the geomembrane and clay till core which could lead to a piping failure. For this reason, Structure Types A and C are not recommended.

To minimize the volume of excavation through the Main Dam, Structure Type D – Chute Type Spillway is the only option recommended for this location, though it must be noted that this structure type may be subject to differential vertical settlements post-construction, given the potential rebound effects of excavating through a 26-year-old embankment.

4.3 Location 3 – East Embankment (Suitable for Structure Type A, C, and D)

Location 3 is similar to Location 2, in that it a new outflow structure will require excavation through the existing Main Dam embankment. Due to the potential risks associated with excavating through the existing embankment (see Section 4.2) only Structure Type D – Chute Type Spillway is recommended for this location.

Location 3 differs from Location 2 in that it is located at the east end of the Main Dam, which reduces the size of the cofferdam required due to the geometry of the embankment. However, Location 3 is disadvantageous in that the east end of the Main Dam is swampy in nature, which may complicate construction. Refer to the figure below for the location, circled in red.

Figure 4-3: Proposed Location 3 Circled in Red

5. Evaluation of Outflow Structure Alternatives

The hydraulic performance of each concept is considered equivalent and would function equally well. As such, hydraulic performance was not considered as a criterion for evaluation.

The evaluation of each option is summarized in the following subsections.

5.1 Cost

The cost of each concept has been evaluated only at a high-level qualitative basis. Cost estimates for each concept have not been prepared. In evaluating the cost of each structure, the initial capital cost and life cycle cost has been considered.

Structure Type B – Overflow Spillway cut into Bedrock requires the smallest volume of concrete, smallest volume of excavation, and requires no structural backfilling. As such, this structure type is the preferred option in terms of cost.

Structure Type C – Drop Structure requires the second smallest volume of concrete and the shortest cofferdam placement. In addition, HDPE pipe is relatively inexpensive in comparison to concrete conduits or chute structures. However, as noted previously, due to an inability to perform repairs, this structure type is no longer considered best practice.

Structure Types A – Overflow Spillway and Structure Type D – Chute Type Spillway are more complex structures and are inherently more expensive to construct and maintain in comparison to the other structure types considered. Locations 2 and 3 require Structure Type D to minimize excavation and the potential for seepage. It should be noted that Structure

Type A or D in Location 2 is expected to be the most expensive alternative as it requires the largest cofferdam.

5.2 Constructability and Construction Schedule

Due to requiring the smallest volume of concrete, the smallest cofferdam and no requirement for structural backfill, Structure Type B – Overflow Spillway cut into Bedrock offers significant advantages from a constructability and schedule perspective.

Structure Type C - Drop Structure offers some advantage in terms of construction schedule, requiring a shorter construction duration than Types A or D. The HDPE conduit is lightweight and will greatly facilitate a reduced construction duration in comparison to the full concrete of Structure Types A and D.

The bridge structures required for Structure Types A, B, and D add some complexity to the design and will likely necessitate a crane during construction.

Structure Type D - Chute Type Spillway for Locations 2 and 3, needed to minimize excavation through the Main Dam, are more complex and will require a longer construction duration in comparison to the other options.

5.3 Ease of Future Maintenance and Repairs

Options that maintain open channel flow, namely Structure Types A, B and D, are inherently easier to inspect and maintain. As it is cut into bedrock, Structure Type A will likely require the least amount of maintenance over its service life.

Due to being constructed on the Main Dam, Structure Type D will likely require a higher frequency of inspections and a greater level of maintenance due to the potential for vertical movement and differential settlement. More frequent inspections will also be required for Structure Types A, C or D if installed in Locations 2 or 3, checking for evidence of any seepage, which would require immediate rehabilitation. Seepage concerns are viewed as a significant disadvantage to Locations 2 and 3.

Structure Type C – Drop Structure is advantageous in that it does not require a bridge structure, avoiding the inspection and maintenance program associated with that type of structure. HDPE pipe has a long service life when installed correctly. However, there is risk associated with this type of structure, in that maintenance and repairs to the HDPE conduit are not practical.

5.4 Environmental Impacts

Overall, Structure Type B – Overflow Spillway cut into Bedrock requires the least volume of material to be excavated. It also requires the smallest cofferdam. As a result, this option will cause the least disturbance to the surrounding environment.

Structure Type D in Location 3 requires the second smallest cofferdam and the least excavation in the existing embankment and would be the second least impactful to the surrounding environment.

Structure Type D in Location 2 requires the largest cofferdam. Therefore, Structure Type D in Location 2 is the least favourable in terms of environmental impact.

5.5 Extension to the Life of the Structure

Structure Type B – Overflow Spillway cut into Bedrock offers the greatest longevity, as all concrete will be directly anchored to bedrock with the likelihood of movement due to settlement being almost zero.

Structure Types A and D, are full concrete structures. As a result, they will offer an improved extension to service life in comparison to Structure Type C.

Structure Type C has a HDPE conduit that has a reduced service life in comparison to concrete, and limited ability to perform maintenance or repairs.

5.6 Outflow Structure Evaluation Summary

Table 5-1 below presents a summary table comparing the options on the criteria described above. When assigning points for each evaluation criteria, each option was ranked against one another from 1 to 4. The points are then added up, and the option with the fewest points is the highest ranked option.

Table 5-1: Outflow Structure Comparison Matrix

Type	Description	Cost	Constructability and Schedule	Ease of Maintenance and Repairs	Environmental Impacts	Service Life Extension	Total
A	Stoplog controlled overflow spillway structure	3	3	1	3	2	**12**
B	Stoplog controlled overflow spillway structure cut into bedrock	1	1	1	1	1	**5**
C	Stoplog controlled drop structure	2	2	4	3	4	**15***
D	Stoplog controlled chute spillway	4	4	3	2	3	**16**

* Drop structures with pipes routed within embankments are no longer considered best practice

6. Evaluation of Locations

Location 1 – West Embankment is strongly preferred for the construction of a new outflow structure. Location 1 requires the smallest cofferdam and is also advantageous in that founding the outflow structure in bedrock is possible in this location, which will provide a more stable structure and minimize the potential for differential settlements.

Locations 2 and 3 require excavation through the Main Dam which presents an inherent risk with seepage and rebound.

7. Recommendations

As noted previously, Location 1 – West Embankment is the preferred location to construct a new outflow structure. The bedrock outcrop aids in reducing excavation, backfilling, and concrete volumes. Although other structure types may be technically feasible, only a single option – Structure Type B – Overflow Spillway cut into Bedrock – makes good use of this location to reduce cost and increase technical viability.

Through the evaluation process it became readily apparent that Structure Type B – Overflow Spillway cut into the bedrock of Location 1 is the most favourable, and it scored the highest ranking in every evaluation criterion. As such, Structure Type B – Overflow Spillway cut into the Bedrock of Location 1 is recommended for advancement to the detailed design phase.

8. References

1. Institute for Research in Construction – Nation Research Council of Canada, “Durability and Performance of Gravity Pipes: A State-of-the-Art Literature Review”, August 1998.

Appendix C

Technical Specification – Geomembrane Material Supply and Installation (Hatch 2023b)

Tantalum Mining Corporation of Canada Ltd.
West TMF Perimter Dam Raise
H368720

Technical Specification

Geomembrane Material Supply and Installation

			[redacted]	[redacted]	[redacted]	
2023-01-11	A	Client Review	S. Grieve	R. Wong	R. Wong	J. Champagne
Date	**Rev.**	**Status**	**Prepared By**	**Checked By**	**Approved By**	**Approved By**
HATCH						**Client**

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1. General

1.1 Scope of Work

1.1.1 This specification covers the requirements for the supply, installation and testing of the geomembrane lining system of the proposed dam raise for the West Tailings Management Area (TMA) perimeter dams raise at the Tanco mine site located in eastern Manitoba, Canada as indicated on the Construction Drawings. The scope of work is summarized as follows:

- Installation and testing of the lining system extension to the West TMA perimeter dam raises. The liner system consists of 60-mil Polyvinyl Chloride (PVC) geomembrane liner.
- Installation and testing of various wear sheets.
- As-built Drawings and Report documenting the layout and numbering of panels, roll numbers, and destructive sample locations for each element of the project shall be required. As-built Drawings shall be submitted to the Construction Manager and the Engineer within two weeks of the completion of liner installation and quality control/quality assurance testing and inspection. As-built Drawings shall be prepared and submitted in AutoCAD v. 2018 or compatible format. As-built Report shall include all quality certifications of the liner used as well as summary of all field testing completed (both non-destructive and destructive testing).

1.1.2 The work requirements outlined above and as shown on the Construction Drawings include furnishing materials, labour, Quality Control (QC) testing, construction machinery and services for construction of the facility as outlined on the Construction Drawings and in these Specifications.

1.1.3 The Lining Installation Contractor's construction layout drawings shall be submitted for approval and shall specify all components and details required to meet these specifications. The responsibility of the Construction Manager, the Owner, the Earthwork Contractor and the Lining Installation Contractor shall be clearly indicated in the proposed work plan.

1.2 Definition

1.2.1 The following definitions apply to this Technical Specification:

Owner is defined as the Tantalum Mining Corporation of Canada (Tanco).

Engineer is defined as a representative appointed and authorized by the Owner. The Engineer shall be a registered Professional Engineer in the Province of Manitoba. The Engineer must be identified in writing to the Contractor by the Owner.

Contractor is defined as the party or parties identified as such by the Owner and responsible for the Scope of Work.

Lining Installation Contractor is defined as the party or parties identified as such by the Owner and/or Contractor and is responsible for the Scope of Work as identified in the

"Geomembrane Material Supply and Installation" technical specification (H368720-0000-220-242-0002).

Construction Manager is defined as a representative appointed and authorized by the Owner to act as a liaison between the Owner, the Earthwork Contractor, the Lining Installation Contractor, and the Engineer. Depending on staff availability, Tanco may act as the Construction Manager.

Surveyor is defined as the party authorized by the Earthwork Contractor and/or the Owner to provide staking, determinations of geometric characteristics of field conditions and certify the correctness of points, grades, and elevations. If authorized by the Earthwork Contractor the Surveyor shall be a registered Professional Land Surveyor in the Province of Manitoba. The Surveyor must be identified in writing to the Owner by the Contractor.

Contractor's Testing Agency. The qualified testing agency, capable of performing Quality Control (QC) testing in accordance with the requirements of the specifications and drawings retained by the Earthwork Contractor to provide all the testing and (as required) re-testing as outlined in the specifications.

Owner's Testing Agency. The qualified testing agency designated by the Owner to conduct Quality Assurance (QA) testing. In lieu of Quality Assurance testing, the Owner or the Engineer may rely upon review of the Contractor's Testing Agency procedures and results. The Owner's Testing Agency will perform QA observations and testing for the project. Resumes of all inspectors from Owner's Testing Agency shall be submitted to the Owner for approval.

1.3 Qualifications

1.3.1 The Geomembrane Manufacturer shall have at least five (5) years continuous experience in manufacturing polyethylene geomembrane and have manufactured a minimum of 1,200,000 square meters of manufactured polyethylene geomembrane.

1.3.2 The Geomembrane Manufacturer or the Lining Installation Contractor shall submit a complete description of their quality control program, as applicable, for manufacturing, handling, installing, testing, repairing and providing a completed lining in accordance with requirements of these specifications. The description shall include, but not limited to, polymer resin supplier, product identification, acceptance testing, fabrication and production testing. Installation testing, documentation of changes, alterations and repairs, retests and acceptance.

1.3.3 A full time safety representative, nominated by the Lining Installation Contractor, shall be present on site during the work.

1.3.4 Liner installation shall be performed under the constant direction of a liner installation supervisor or liner inspector from the Lining Installation Contractor who shall remain on site and be responsible, throughout the liner installation, for liner layout, seaming, testing, repairs, and all other activities by the Lining Installation Contractor.

1.3.5 The field installation supervisor shall have installed or supervised the installation of a minimum of 250,000 square meters of polyethylene geomembrane.

1.3.6 The Lining Installation Contractor shall submit written certification that the lining system was installed in accordance with the Liner Manufacturer's recommendations, the approved Construction Drawings and Specifications, and approved submittals, to the Engineer and Construction Manager.

1.3.7 Seaming shall be performed under the direction of a master seamer (who may also be the field installation supervisor) who has performed a minimum of 250,000 square meters of polyethylene geomembrane, using the same type of seaming apparatus specified for this project. The field installation supervisor and/or master seamer shall be present whenever seaming is performed.

1.4 Submittals

1.4.1 The Manufacturer shall provide the following documentations:

1.4.1.1 Submittals with Bid Documents:

- Material properties of the geomembrane proposed for this project.
- Manufacturing quality control program.

1.4.1.2 Submittals after Contract Award, prior to liner installation:

- Quality control certificates issued by the resin supplier.
- Quality control certificates for the geomembrane in conformance with Section 1.6.

1.4.2 The Installer shall provide the following written information:

1.4.2.1 Submittals with Bid Documents:

- A list of projects previously completed by the Lining Installation Contractor involving installation of polyethylene geomembrane, totaling a minimum of 250,000 square meters. For each installation, the following information shall be provided:
  - Name and purpose of facility, location, and date of installation.
  - Name of Owner, design engineer, manufacturer, and name and telephone number of contact at the facility who can discuss the project.
  - Thickness and quantity of the installed geosynthetics.

1.4.2.2 Submittals by Successful Bidder Prior to Commencement of Installation:

- Proposed installation panel layout.
- A sample of the proposed material for approval by the Owner.
- Resume of the field installation supervisor and master seamer.

1.4.3 Quality Control Certificate with the requirements of standards and testing methods specified herein shall be submitted for each roll of material prior to delivery. The certificates shall clearly indicate the roll or rolls of each material which they represent. The Geomembrane Manufacturer must satisfy by affidavit to the Lining Installation Contractor, the Engineer and the Construction Manager that the material they offer to furnish will meet, in every respect, the requirements set forth in these specification. The Lining Installation Contractor shall transmit to the Engineer and the Construction Manager the affidavit given by the manufacturer or supplier prior to approval for the furnishing and installing of any such material.

1.4.4 The Lining Installation Contractor shall submit a schedule detailing the liner system fabrication and installation. The scheduling shall be sufficient to allow the Engineer to review mill certificates prior to the materials being shipped to the project. Failure to submit the mill certificates will result in conformance testing that could results in delay. The conformance testing shall be carried out by the Lining Installation Contractor at no additional cost to the Owner.

1.5 Warranty

1.5.1 A written warranty of minimum twenty (20) years shall be provided by the manufacturer for material quality. The Lining Installation Contractor shall provide a minimum warranty of 2 years on labour and workmanship. Terms and conditions of the warranty are to be agreed upon between the Owner and the Lining Installation Contractor.

1.6 Supply

1.6.1 Packaging

1.6.1.1 The PVC geomembrane shall be provided in rolls. Each roll shall be labelled so as to provide the following identifying data:

- Product name and grade.
- Length and width of roll (m/ft).
- Total weight of roll (kg/lb).
- Production lot number and individual roll number.

1.6.2 Delivery

1.6.2.1 Materials shall be delivered to the site after the required submittals have been approved by the Engineer.

1.6.2.2 The Liner Installation Contractor is responsible for liner delivery, unloading and/or storage at the project site. Liner deliveries shall be coordinated between the Liner Installation Contractor and the Construction Managers.

1.6.3 Storage and Handling

1.6.3.1 Storage and Handling of the materials shall conform to the Geomembrane Manufacturer's recommendations and carried out under supervision of the Owner's Testing Agency to prevent damage to any part of the work. The Lining Installation Contractor shall be responsible for unloading, storage and handling of materials. Any unloading and handling performed by the Construction Manager and/or the Owner will be back-charged to the Lining Installation Contractor.

1.6.3.2 Roll goods shall be stored on a flat dry surface, protected from moisture, dust, dirt and debris. All roll goods shall be labelled.

1.6.3.3 No more than two rolls shall be stacked on top of one another.

1.6.3.4 Roll goods shall be handled using a sling or steel bar inserted through the core bar and slings or chains attached to the end of the bar. The core bar shall be suspended from a spreader bar so that the edges of the liner are not damaged by the suspending straps or chains. The diameter of the core bar shall be small enough to allow for easy insertion through the roll core.

1.6.4 Inspection of Sheet/Roll

1.6.4.1 The Lining Installation Contractor shall be responsible for inspection of the sheet goods and rolls of material at the job site. Should rolls show damage from transit, they shall be identified by the Lining Installation Contractor and set aside.

1.6.4.2 During unrolling of the particular material, the Lining Installation Contractor shall carry out visual inspection of the material surface. Any faulty areas shall be marked and repaired by the Lining Installation Contractor in a manner that is acceptable to the Engineer.

1.7 Verification of Areas to Receive Geomembrane Materials

1.7.1 On each work day prior to installation of geomembrane liner, the Lining Installation Contractor, the Owner's Testing Agency and the Construction Manager, shall inspect and verify the conditions of the specified area as adequate for placement of the liner. Following the verification of the surface, the Lining Installation Contractor shall sign an acceptance form and assume full responsibility for the verified areas.

1.7.2 After the supporting soil surface has been approved, it shall be the installer's responsibility to indicate to the Owner's Testing Agency any changes to its condition that may require repair work.

1.7.3 The Earthwork Contractor shall be responsible for any required rework on the subgrade due to precipitation events.

2. Material Specification

2.1 Applicable Test Methods

2.1.1 American Society for Testing and Materials (ASTM)

- ASTM D751 Standard Test Methods for Coated Fabrics
- ASTM D792 Specific gravity (relative density) and density of plastics by displacement
- ASTMF D882 Standard Test Method for Tensile Properties of Thin Plastic Sheeting
- ASTM D1004 Initial tear resistance of plastic sheeting
- ASTM D1203 Standard Test Methods for Volatile Loss from Plastics Using Activated Carbon Methods
- ASTM D1204 Standard Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature
- ASTM D1239 Standard Test Method for Resistance of Plastic Films to Extraction by Chemicals
- ASTM D1790 Standard Test Method for Brittleness Temperature of Plastic Sheeting by Impact
- ASTM D2124 Standard Test Method for Analysis of Components in Poly(Vinyl Chloride) Compounds Using an Infrared Spectrophotometric Technique
- ASTM D4437 Standard Practice for Nondestructive Testing (NDT) for Determining the Integrity of Seams Used in Joining Flexible Polymeric Sheet Geomembranes (Air Lance Testing)
- ASTM D5199 Test method for measuring nominal thickness of geotextiles and geomembrane
- ASTM D7176 Standard Specification for Non-Reinforced Polyvinyl Chloride (PVC) Geomembranes Used in Buried Applications
- ASTM D7177 Standard Specification for Evaluation of Polyvinyl Chloride (PVC) Dual Track Seamed Geomembrane (Air Channel Testing)
- ASTM D7408 Standard Specification for Non-Reinforced PVC (Polyvinyl Chloride) Geomembrane Seams
- ASTM G160 Standard Practice for Evaluating Microbial Susceptibility of Nonmetallic Materials By Laboratory Soil Burial

2.1.2 PVC Geomembrane Institute(PGI)

- PVC Geomembrane Installation Specifications

2.2 Quality Control

2.2.1 The geomembrane shall consist of 60-mil PVC. Tests to be performed and minimum specifications shall include, but not be limited to, those listed in Table 2-1.

Table 2-1: Specification of PVC Geomembrane

Property	Test Method	60-mil PVC
Thickness (min.)	ASTM D5199	1.52 mm +/- 0.08 mm
Tensile Properties (min. ave.):	-	-
- Break Strength	ASTM D882	24 kN/m
- Break elongation	ASTM D882	450%
- 100% Modulus	ASTM D882	10.5 kN/m
Tear Strength (min. ave.)	ASTM D1004	67 N
Dimensional Stability	ASTM D1204	3%
Low Temperature Impact	ASTM D1790	-29 °C
Specific Gravity	ASTM D792	1.2
Water Extraction Loss (max.)	ASTM D1239	0.20
Average Plasticizer Molecular Weight	ASTM D2124	400
Volatility Loss (max.)	ASTM D1203	0.5
Soil Burial (max. change):	-	-
- Break Strength	ASTM G11.260	5%
- Break elongation	ASTM G160	20%
- 100% Modulus	ASTM G160	20%
Hydrostatic Resistance	ASTM D751	1240 kPa
Shear Strength (min.)	ASTM D7408/ASTM D882	20 kN/m (116 lbs/in)
Peal Strength (min.)	ASTM D7408/ASTM D882	2.6 kN/m (15 lbs/in)

2.3 Geomembrane Conformance Testing

2.3.1 Conformance testing shall be conducted by a third party laboratory to statistically measure conformance of the geomembrane roll goods shipped to the project. Conformance testing shall be arranged by the Lining Installation Contractor. Test results shall be submitted to the Owner and approved by the Engineer prior to commencement of installation.

2.3.2 Testing Requirements

2.3.2.1 Table 2-2 lists the minimum required testing which shall be performed as part of the conformance program.

Table 2-2: Geomembrane Conformance Testing

Property	Test Method
Thickness	ASTM D5199
Tensile Properties	ASTM D882

2.3.3 Sampling Procedures

2.3.3.1 Samples shall be taken at a rate of one per lot or one per 100,000 square feet of roll goods shipped to the project, whichever results in the greater number of tests. Rolls shall be selected at random for testing.

2.3.3.2 Samples shall be removed from the roll at a random location, but shall not include any area within the first three (3) lineal feet of the beginning and end and/or edge of the roll.

2.3.3.3 The sample shall be a minimum of one and a half (1.5) feet by three (3) feet in size and shall be marked with an arrow to indicate that machine direction and the Liner Manufacturer's roll and lot identification number shall be included on the sample.

2.3.4 Test Results

2.3.4.1 The Engineer shall review the test results for project compliance and shall provide a written report to the Construction Manager.

2.3.5 Procedures for Conformance Test Failure

2.3.5.1 Should any test results indicate non-conformance with the project specifications, the non-conforming roll number shall be identified and additional conformance testing shall be performed on rolls with adjacent numbers. All non-conforming rolls shall be identified and set aside. The cost for additional conformance testing due to test results which indicate non-conformance shall be borne by the Lining Installation Contractor.

3. Installation

3.1 Method of Placement

3.1.1 The geomembrane shall be laid out and installed by trained technicians in accordance with the Construction Drawings; the layout and details as presented in the approved shop drawings; and in accordance with the Manufacturer's requirements.

3.1.2 The lining layout shall be designed to minimize the number and length of field joints, consistent with proper methods of liner installation.

3.1.3 The liner shall be oriented to minimize stress on the field seams. Liner panels shall be laid out such that the seam is oriented longitudinally with the grade and not along the contours (field seam shall be oriented up and down the slope or grade). Liner seams shall be shingled in the direction of flow (if applicable).

3.1.4 The liner shall be installed such that foot traffic is minimized and no heavy vehicle traffic crosses the liner.

3.1.5 The liner shall have no cuts, nicks, abrasion, holes, tears or insufficient joints which could leak or develop into leaks after installation is complete.

3.1.6 Any holes, tears or suspect material or joints which occur during installation shall be immediately marked and repaired. Repair methods shall be approved by the Engineer. The Lining Installation Contractor shall have sufficient quality control to detect holes, tears, or insufficient joints during installation.

3.1.7 Field seams shall have sufficient overlap for proper seaming. Typical overlap shall be a minimum of 100 mm (4 inches) for double wedge fusion (thermal) welds and 150 mm (6 inches) for chemical seams. All field seams shall be 100% inspected by the Lining Installation Contractor.

3.1.8 Under no circumstances shall the lining be subjected to equipment, or other items being dragged across its surface, nor shall workers and other slide down slopes atop the lining. All scuffed surfaces resulting from abuse of any kind caused by the Lining Installation Contractor in performance of the work shall be repaired at no additional cost to the Owner.

3.1.9 Deployed liner shall be secured from damage due to high winds by using sandbags or alternate ballasting. A sufficient quantity of sandbags shall be placed along unseamed roll and liner edges at intervals no greater than 2 meters. Sand bags shall remain in place on all sheets and edges until the liner is secured.

3.1.10 The Lining Installation Contractor shall be responsible for making any allowances considered necessary to accommodate predictable differential settlements of the subgrade, and/or variations in temperature. In particular, allowances shall be made to accommodate the ultimate thermal movement of the liner during the coldest periods in the region.

3.1.11 Liner shall be placed with sufficient slack to prevent excessive lifting of the liner from the subgrade upon contraction. Compensating seams shall be required to prevent excessive lifting (trampolines).

3.1.12 Liner installation to bedrock shall be by a batten bar connection. The Lining Installation Contractor shall provide the details of the proposed batten bar connection detail to the Engineer for acceptance.

3.2 Weather Conditions

3.2.1 Challenging weather conditions may be present during installation of the liner. The Lining Installation Contractor shall be prepared for low temperatures, high winds and high precipitation conditions.

3.2.2 The Lining Installation Contractor shall not proceed with panel placement and seaming when ambient temperatures are below 2 degrees C or above 40 degrees C, during precipitation, in presence of excessive moisture (e.g., fog, dew, snow), nor in presence of high winds. Special installation procedures for weather conditions and temperature outside of the manufacturer recommended range shall be submitted to the Engineer and shall demonstrate that the procedure will meet the QC test requirements defined in Section 4 of this specification for approval.

3.3 Field Seaming

3.3.1 Production field welding shall be performed by a double-wedge fusion (thermal) welding process or an equivalent method approved by the Engineer.

3.3.2 Small areas, such as butt joints and repairs, as well as tie-in to the existing PVC liner shall be completed by a chemical fusion welding (seaming) process or an equivalent method approved by the Engineer.

3.3.3 The general requirements for welding (fusion and chemical) are as follows:

3.3.3.1 Welds shall commence as soon as practical after the sheet is deployed.

3.3.3.2 Weld area shall be free of all dirt, dust, moisture or other foreign material. The contact surface of the sheets shall be wiped with clean rags to remove any contamination.

3.3.3.3 Field joints shall be fabricated using hot wedge welding equipment and installation methods as described in this specification and to the manufacturer's recommendations.

3.3.3.4 All geomembrane liner sheets shall lay flat when being welded.

3.3.3.5 Horizontal field welds on slopes will not be permitted.

3.3.3.6 No personnel working on the liner shall wear shoes or other materials/implements that can damage the liner or engage in actions that could result in damage to the liner.

3.3.3.7 Joints shall be made so as to form a longitudinal sealed air channel to allow visual checking and air pressure testing prior to acceptance.

3.3.4 A chemical fusion agent is used for chemical welding existing PVC geomembrane to new PVC geomembrane and for repairs. The type of chemical fusion agent and application method used should be approved by the Engineer.

3.3.5 All 'T' joints shall be reinforced with chemical fusion welds or an equivalent method. The chemical welds shall extend a minimum of 150 mm (6 inches) beyond the intersection of the joint and shall be Air Lance testing. Other methods shall be approved by the Engineer.

3.3.6 To protect the deployed liner from the weather, no opens seams, holes or Leister (temporary) patches shall be allowed in the deployed liner at the end of the day.

3.4 Double Wedge Welding

3.4.1 The equipment used for double wedge welding of seams shall be self-propelled (but aligned manually) and have suitable controls for adjustment of the operating temperature and speed of travel along the seam. This equipment shall also be of the type that raises the liner of the floor in the area of the seam and applies pressure to the seam by upper and lower rollers.

3.4.2 To ensure the correct weld is achieved within seams, each item of equipment used for double wedge welding shall be calibrated and set prior to use for operating temperature, speed of travel along the seam and pressure applied to the seam by the rollers to make it satisfactory and compatible for the successful welding of the geomembrane. Calibration shall include producing a trial weld as describe in Section 4.1.

3.5 Fishmouths

3.5.1 'Fishmouths' are wrinkles in the liner, which occur in seams.

3.5.2 Extreme care shall be taken through the work to avoid fishmouths in the field seams. Fishmouths can usually be eliminated by gently tugging on the seam just completed in the direction of the completed seam.

3.5.3 Where fishmouths do occur, they shall be slit far enough from the seam to dissipate them, lapped, seamed together in the lapped area, and patching accordance with Section 3.6 of this specification.

3.6 Inspection and Repair

3.6.1 All punctures, cuts, tears, severe abrasion and similar damage or abuse suffered by the geomembrane liner during installation shall be repaired by patching. The location, time and extent of the patching shall be noted in the As-built Report.

3.6.2 Areas requiring repair or patching shall be prominently identified by suitable marking applied to sheet material outside the area to be repaired so as not to introduce marking substance into the seam area.

3.6.3 Patches shall be cut from flat, unwrinkled scraps of geomembrane liner and shall be free of defects, field seams and factory seams. Patches shall be sufficient size to extend a minimum of 150 mm (6 inches) in all directions beyond the limits of any puncture, cut, tear, abrasion, etc.

3.6.4 Patches shall be applied as per the requirements for chemically welded joints. The parent material shall be gently pulled and held flat in the area to be patched so as to provide an acceptable surface to receive the patch. The applied chemical weld shall be continuous around the patch.

3.6.5 Where patches over fishmouths are required, they shall extend a minimum of 150 mm (6 inches) each side of the edge of the overlap, and a minimum of 150 mm (6 inches) beyond the ends of the cut in the fishmouth.

3.6.6 All patches shall be inspected and tested using the Air Lance method as detailed in Section 4 of this specification.

4. Quality Control

4.1 Trial Welds

4.1.1 Trial Welds shall be on off-cut or fragment pieces of geomembrane liner in order to verify that adequate seams can be produced by the chosen equipment and settings in the prevailing conditions. It is important that the conditions under which these seams are made reflect the actual conditions influencing the seam welding.

4.1.2 Trial welds shall be carried out by the Lining Installation Contractor in the presence of the Owner’s Testing Agency during each shift:

4.1.2.1 Prior to commencement of each shift (start of the day);

4.1.2.2 Middle of each shift (approximately after 5 hrs); and

4.1.2.3 End of each shift.

4.1.2.4 Following every 150 m of completed weld (thermal and chemical) in the field.

4.1.3 Additional trial welds should be carried out following each alteration/repair to extrude or thermal controls.

4.1.4 Trial welds shall be a minimum of 1.5 m (5 feet) in length for all welds (thermal and chemical).

4.1.5 Roll No., time, date and prevailing environmental conditions that will influence performance of the weld shall be marked. In the event that a test is carried out in the course of executing a field weld, the type of weld and its location within the site works shall be clearly identified on the test strip.

4.2 Field Seam Testing

4.2.1 Each seam shall be carefully inspected by the Lining Installation Contractor and the Engineer after the welding operations have been completed. Suspected discrepant areas shall be identified with a contrasting marker. A CQA sampling and testing guide is presented in Table 4-1.

Table 4-1: CQA Sampling and Testing Guide

Material	Tests	Frequency
60-mil PVC geomembrane liner	Destructive shear and peel tests (ASTM D7408)	Every 150 m (500 feet) of thermal and chemical seams (randomly located).
	Air Channel Testing (ASTM D7177)	Entire length of thermal welded field seams.
	Air Lance Testing (ASTM D4437)	Entire length of chemical welded field seams and repair areas.

4.3 Destructive Testing

4.3.1 The Contractor's Testing Agency shall select one test specimen for every 150 metres (500 feet) of field weld performed. The actual locations of seam tests shall be randomly determined in the field by the inspector from Owner's Testing Agency. Each specimen shall be 1 metres long (3 foot) (measured in the direction of the weld) by 0.3 metres (1 foot) wide. The specimen will be cut into three specimens of equal dimensions (cut across the weld direction) and the test work shall be carried out in accordance with criteria set in Table 4-2.

Table 4-2: Seam Strength Criteria for 60 mil PVC geomembrane liner

Destructive Seam Samples	ASTM D7408
Weld – Shear	20 kN/m (116 lbs/in) (80% of parent strength at yield)
Weld – Peel	2.6 kN/m (15 lbs/in)

4.3.2 Both weld interfaces on double-wedge welds shall be tested.

4.3.3 A film shearing bond (FTB) failure is defined as a failure of one of the sheets by tearing, instead of separating from the other sheet at the weld interface area. A separation greater than 10% of the width of the weld cross section shall constitute a non-FTB failure.

4.3.4 The minimum tensile strength of the parent material is defined to be equal to the value specified in the Liner Manufacturer's specification. Copies of the results of these tests shall be submitted to the Lining Installation Contractor, the Engineer, and the Construction Manager. Approval of test results must be obtained prior to coverage of the liner.

4.3.5 All field test welds and production welds shall be tested using ASTM D7408 with bonded seam (shear) strength equal to minimum of 20 kN/m (116 lbs/in), 80% of tensile strength of the geomembrane parent material and shall have a film tearing bond failure.

4.3.6 Peel tests for welds shall be performed in accordance to ASTM D7408 and have minimum strength of 2.6 kN/m (15 lbs/in) and shall exhibit film tearing bond failure.

4.3.7 The Contractor's Testing Agency shall mark, log and identify each type and location of repair to be made at all discrepant areas. No open seams, holes or Leister (temporary) patches shall be allowed at the end of the day.

4.3.8 The Engineer and the Construction Manager shall have the right to reject any field made seam for cause at no additional cost. Cause shall be defined to include poor workmanship, defective welds, and insufficient overlap of panels. Any field made seam rejected for cause shall be repaired or replaced to the satisfaction of the Engineer at no additional cost to the Owner.

4.3.9 Procedure for Destructive Testing

4.3.9.1 Specimen 1

- An independent testing authority, as approved by the Owner, shall test Specimen 1. The Lining Installation Contractor shall be organizing and paying for the following test work:
  - Five Peel Tests (both sides for double wedge welds); and
  - Five Tensile Tests.
- A test certificate, prepared by the testing authority, shall be submitted to the Owner and shall then be included within the Lining Installation Contractor's QA Report as detailed in this Specification.

4.3.9.2 Specimen 2

- Specimen 2 shall be tested by the Lining Installation Contractor on site prior to any additional welding being carried out and as soon as after the weld is made as possible. The testing will be carried out in the presence of the Engineer. The test work on Specimen 2 shall comprise of the following:
  - Five Peel Tests (both sides for double wedge welds); and
  - Five Tensile Tests.
- A passing test consists of four of the five test samples (for both peel and tensile) meeting the minimum seam strength as listed in Table 4-2 and the fifth sample exceeding 80% of the minimum strength listed.
- A field test report, detailing the results of this test work, shall be submitted to the Owner and shall then be included within the Lining Installation Contractor's QA Report as detailed in this Specification.

4.3.9.3 Specimen 3

- The Owner shall hold this specimen as a reference of the extracted weld specimen. The Location of the specimen shall be identified on the "As Built" Drawings.

4.3.10 Procedure in the Case of Destructive Test Failure

4.3.10.1 In the case that a destructive seam fails in either shear or peel, the entire length of seam represented by this test is in question. At a minimum, the procedure for destructive test failures shall be as follows:

1. The Lining Installation Contractor shall provide the Engineer with two additional destructive test samples spaced a minimum of 30 metres (100 feet) on either side of the failure test.
2. The Engineer and the Construction Manager reserve the right to take additional samples as warranted to adequately assess the quality of the work.
3. From each destructive test sample, ten test strips will be cut. Five of these samples will be tested for seam shear strength and five will be tested for peel strength. Both weld interfaces on double wedge welds shall be testing. A passing test for destructive samples is defined in Section 4.
4. If passing tests are achieved from the tracking samples obtained in Item 1, the 60 metre (200 feet) of seam represented by the passing test is in question. Additional samples at closer intervals can be taken or the 60 metres of seam shall be capped.
5. If a failing test occurs at the new destructive test location, an additional test will be taken at a minimum of 15 metres (50 feet) from the failed test. This procedure is repeated until the failed section is fully defined or the edge of the seam that was originally represented by the original test is reached.

6. If passing tests are achieved at the minimum 30 metres (100 feet) distance from the failed destructive test, additional destructive tests may be taken at a closer spacing from the failed test at the discretion of the Lining Installation Contractor. If the tests at the closer interval fail, additional destructive tests at a wider interval shall be taken until the length of the failed seam is fully defined.
7. Once the length of defective seam is identified, the Lining Installation Contractor shall either cut out the defective seam and wedge weld a new piece of liner in the seam area; or install a cap-patch strip over the affected seam area. Cap-patches shall be a minimum of 1 m in width and shall be centered over the defective seam. Chemical welding the exposed flap of liner on the wedge welded seams or additional chemical welding of chemical-welded seams shall not be allowed.
8. An additional destructive test sample shall be taken within the repaired area and tested in accordance with Item 3. Non-destructive testing by appropriate methods shall also be performed within the repaired area.
9. In the case that the retest of the repaired area fails, the procedure described above shall be repeated until passing tests are achieved.

4.4 Non-Destructive Testing

4.4.1 Air Channel Testing

4.4.1.1 The entire length of each field-welded thermal (wedge-welded) seam shall, under the observation of the Owner's Testing Agency, be tested by the air channel test in accordance with ASTM D7177. The test is completed to evaluate the strength and continuity of parallel PVC geomembrane seams separated by an unwelded air channel.

4.4.1.2 The unwelded air channel between the two distinct seamed regions is sealed and inflated with air to a predetermined pressure based on temperature according to ASTM D7177. If there is no pressure drop after two minutes, then the seam is deemed acceptable. If a pressure drop is noticed, the seam shall be repaired and retested.

4.4.2 Air Lance Testing

4.4.2.1 Each field welded chemical seams shall be testing using the Air Lance Test Method (ASTM D4437). The Lining Installation Contractor shall provide an air compressor, air hose and air lance wand with a pressure gauge capable of measuring the air flow at the tip.

4.4.2.2 The test involves placing the air lance wand ¼" to ½", but not more than 2", from the edge of the completed seam and closely monitoring the backside of the sheet for any air penetration through the seam. If air penetrates the seam area, the technician will either see this visibly or hear it audibly and the seam shall be repaired and retested.

5. Submittals

5.1 The Lining Installation Contractor shall submit reports of installations records and tests to the Engineer.

5.2 A copy of test results will be maintained at the construction site, and shall include the following:

- Date issued
- Project title and number
- Date of testing and/or sampling
- Designation or use of material tested
- Type of test and specification
- Location of test

5.3 Observations regarding compliance or non-compliance with plans and specifications

5.4 Upon completion of construction, the Lining Installation Contractor shall submit a final As-Built Report including all records from the installation, field and laboratory test results, and plan drawings detailing panels, field seams and locations of destructive testing. The As-Built plan shall be submitted in AutoCAD or compatible format.

5.5 Table 5-1 summarizes the documentations required to be submitted by the Lining Installation Contractor at various stages of the project.

Table 5-1: Submittal Checklist

Item	Description	Section
	Bid Document	
1	Material properties of the geomembrane	1.4.1.1
2	Manufacturing quality control program	1.4.1.1
3	List of Completed Projects	1.4.2.1
	After Award, Prior to Installation	
4	Quality Program Description	1.3.2
5	Resume of Seam Master	1.4.2.2
6	Quality Certificates by Resin Supplier	1.4.1.2
7	Quality Certificates of Geomembrane	1.4.1.2
8	Sample of Proposed Geomembrane	1.4.2.2
9	Proposed Panel Layout	1.4.2.2
	During Construction	
10	Destructive Test Results	5.2
11	Field Seam Test Results	5.2
	Post Construction	
12	As Built Report, including CAD liner panel	5.4