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Orano Canada Inc.**

**Mémoire d'
Orano Canada Inc.**

In the matter of

À l'égard d'

Orano Canada Inc.

Orano Canada Inc.

Application to renew the McClean Lake
Operating Licence for 2-year term

Demande pour le renouvellement du
permis d'exploitation de McClean Lake
pour une période de deux ans

**Hearing in writing based on written
submissions**

**Audience par écrit fondée sur des
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McClellan Lake Operation

Tailings Management

Technical Information Document

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Orano Canada Inc.



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Editor:		
Kebbi Hughes	Manager Environment and Geosciences	
Name	Title	Signature

Contributions from:

- Tyler Lohman, Geo-Environmental Technician
- Adam Liek, Geotechnical Engineer (SRK Consulting)
- Joseph Essilfie-Dughan, GeoChemist
- Svetlana Kurakina, Regulatory Coordinator
- Elizaveta Petelina, Environmental Lead
- Alda Behie, Hydrogeologist (Ret.)
- John Rowson, Sr. Scientific Advisor (Ret.)

Approver:		
Colin Braithwaite	Vice President, Safety, Health, Environment and Regulatory	
Name	Title	Signature

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Section B: JEB TMF Structural Mapping

Section C: Rock Stab Analysis – JEB Open Pit

Section D: Construction Reports TMF Optimization Stage 1

Section E: Tailings Deposition Method Application

Appendix C: Historical Geochemical Tailings Data

Section A: Historical Analysis of Uranium Tailings Chemistry

Section B: Initial Tailings Scoping Tests

Section C Initial Testing of Tailings Geochemistry 1994 – 1998

Appendix D: TOVP Studies and Supporting Data

Section A: Geotechnical Reports

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Section C: Definition of the Source Term

Section D: Historical TOVP Chemistry

Section E: TMF Water Balance

Section F: Embankment Failure Analysis

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Appendix E: Published Papers

Appendix F: TOVP Reports

Acronyms and Abbreviations

Term	Definition
AECB	Atomic Energy Control Board
am	Amorphous
AREVA	AREVA Resources Canada Inc.
As	Arsenic
c	Crystalline
Ca	Calcium
CCD	Counter Current Decantation Circuit
CCME	Canadian Council of Ministers of the Environment
CMT	Construction Management Team
CNSC	Canadian Nuclear Safety Commission
COCs	constituents of concern
CPT	Cone Penetrometer Testing
CSP	Corrugated Steel Pipes
CWQGs	Canadian Water Quality Guidelines
CX	Ammonium Sulphate Crystallization Plant
EA	Environmental Assessment
ECOP	Environmental Code of Practice
EEM	Environmental Effects Monitoring program
EHS	Environment Health and Safety
EMP	Environmental Monitoring Program
EMS	Environmental Management System
EPM	equivalent porous media
Fe	Iron
FML	Flexible Membrane Liner
FRP	Fiber Reinforced Plastic
Golder	Golder Associates Ltd.
HC	Hydrocarbon
HDPE	High Density Polyethylene
Hfo	Hydrous Ferric Oxide
ICP-OES	Inductively Coupled Plasma – Optical Emission Spectrometry
JEB site	The area containing the JEB TMF, JEB waste stockpile, ore pad, mill and office complex and the associated outbuildings.
JEB WTP	JEB Water Treatment Plan
LCF	Linear Combination Fitting
LSA	local study area
mASL	Meters Above Sea Level
MHI	Saskatchewan Ministry of Highways and Infrastructure
MMER	Metal Mining Effluent Regulations

Term	Definition
Mo	Molybdenum
MOE	Saskatchewan Ministry of Environment
NOx	oxides of nitrogen
NRCan	Natural Resources Canada
NSCA	Nuclear Safety and Control Act
PBTMF	Purpose Built Tailings Management Facility
PDP	Preliminary Decommissioning Plan
PM	Particulate Matter
PMP	Probable Maximum Precipitation
QEMSCAN	Quantitative Evaluation of Materials by Scanning Electron Microscopy
S/V TEMS	Sink/Vulture Treated Effluent Management System
SABRE	Surface Access Borehole Recovery Extraction
SEQG	Saskatchewan Environmental Quality Guidelines
SMOE	Saskatchewan Ministry of Environment
SO2	sulphur dioxide
SOE	Status of Environment
SPI	Standard Precipitation Index
SRC	Saskatchewan Research Council
SRK	SRK Ltd. Mining Consultants
SSWQO	Saskatchewan Surface Water Quality Objective
SX	Solvent Extraction
TDS	Total Dissolved Solids
TID	Technical Information Document
TMF	Tailings Management Facility (used to describe the McClean Lake Operation configuration)
TOVP	Tailings Optimization and Validation Program
TPC	Tailings Preparation Circuit
TPP	Tailings Preparation Process
TSP	Total Suspended Particulates
U	Uranium
WTP	Water Treatment Plant
WSP	WSP Engineering and Design
XANES	X-Ray Absorption Near Edge Structure
S-XRD	Syncrotron based X-Ray Diffraction

Executive Summary

The Tailings Management Technical Information Document (TID) provides discussion of the design, operation, and future decommissioning of the tailings management facility at the McClean Lake Operation. It describes operational performance and provides predictions of long-term, post-closure environmental effects. The tailings TID provides evidence that tailings placed in the TMF continue to exhibit the necessary geochemical and geotechnical characteristics for long-term protection of the environment.

The Tailings Optimization and Validation Program advances the science surrounding long-term tailings geochemistry. The current scientific understanding of tailings geochemical and geotechnical properties is captured in this report. Solute concentrations of constituents of concern in the tailings are predicted to remain well controlled over the very long term. Long-term control of soluble arsenic in the tailings has been the primary environmental concern. The McClean Lake Operation has continued to process ores with highly variable arsenic concentrations and successfully produce tailings that meet design criteria for arsenic concentrations in tailings pore water. The understanding of elements exhibiting aging behavior in the tailings, such as molybdenum and uranium, is also advanced. The hydraulic conductivity of the tailings adjacent to the surrounding host rock is sufficiently low to control contaminant transport from the TMF.

Background

Orano Canada (Orano) is the majority owner and operator of the McClean Lake Operation, a uranium mine and mill located in northern Saskatchewan, Canada. The McClean Lake Operation has had a long exploration, environmental assessment, and licensing history. Exploration activities commenced in the late 1970's, followed by environmental assessment in the 1990s and the initiation of mining and milling operations in 1995 and 1999, respectively. The initial environmental assessment for the McClean Lake Operation was completed in 1991. Since that time, there have been changes in environmental legislation, continued evolution in environmental assessment methodology, and advances in tailings management practices.

The 2025 Tailings Management TID provides a comprehensive, current understanding of tailings management at the McClean Lake Operation and operational performance to date. The first edition of the Tailings Management TID was issued in February 2004. Subsequently, a number of mining projects have been completed at the McClean Lake Operation. In 2015, the TID was restructured to integrate the validation of long-term tailings performance under the Tailings Optimization and Validation Program (TOVP). Section 2 of this TID provides a description of the regulatory history, key performance and compliance indicators, facility background, and future plans for the facility. Sections 3 and 4 discuss current operations to date and operational effects. Section 5 summarizes the most current research into the long-term geochemistry of the tailings as well as the geochemical and geotechnical results of the TOVP. Sections 6 and 7 address decommissioning of the tailings management facility and provide predictive modelling of post-decommissioning effects. Section 8 presents conclusions, a validation of compliance objectives during this reporting period, and suggested future monitoring and compliance changes.

For the McClean Lake Operation, the TIDs are used to facilitate notifications, current and future licensing actions, environmental assessments, and the interpretation of environmental effects. It is anticipated that this Tailings Management TID will be updated periodically with new operational performance data, or in conjunction with changes in McClean Lake Operation and anticipated activities that warrant a re-evaluation of potential environmental effects. In addition, a revision will be made every five years to the TID to reflect the latest understanding of tailings geochemistry and geotechnical conditions available from the TOVP and fulfill compliance requirements for in-situ tailings pore water quality.

Subsequent to the publishing of the 2025 version of this TID, the following activities have been conducted, warranting the current update:

- Progress in the TMF Expansion Program:
 - Construction of an embankment to an elevation of 457.5 mASL in 2021
 - Placement of soil bentonite liner from 448.0 mASL to 452.5 mASL in 2023
- Alterations to the tailings deposition system in 2021 2023, and 2024;
- The completion of the Tailings Optimization and Validation Program sampling campaign in 2023/2024; and
- Scientific investigations under the TOVP that have continued to produce advancements in the understanding of long-term tailings geochemistry, particularly for arsenic and uranium.

Tailings Management

The JEB Tailings Management Facility (TMF) serves as a repository for tailings resulting from uranium processing at the McClean Lake Operation. The initial design of the facility considered many options through application of evaluation criteria relating to overall performance and environmental acceptability. The primary criteria considered in evaluating the alternatives included the following: technical feasibility, operational feasibility, environmental considerations, public acceptability, and cost and management considerations. These criteria were applied to key design aspects including: tailings preparation alternatives, a natural pit surround versus a pervious pit surround, various pit liner alternatives, dewatering options, and final options for the decommissioned pit. The design of the tailings preparation process and the TMF were the subject of lengthy periods of government and public review dating back to 1991. As a consequence of responding to the many detailed technical questions and comments, a preferred, optimized TMF design evolved.

The preferred option for tailings preparation included the production of thickened tailings that are neutralized and treated to control radium-226, arsenic, and nickel concentrations in the pore water. Tailings are disposed within the TMF constructed in the mined-out JEB pit using a barge system. A raise water drift and base filter drain were constructed at the base of the JEB pit. Pumping from the base of the deposited tailings ensures hydraulic containment, by continually maintaining a hydraulic gradient in the groundwater towards the JEB TMF and enhances tailings consolidation throughout operations. The TMF uses a natural surround system, which will maintain hydraulic containment after decommissioning by creating sufficient hydraulic conductivity contrast between the tailings and the surrounding host rock, is established as a passive method to minimize the release of contaminants from the decommissioned facility in the long term. For decommissioning, an

engineered cover will be placed over the tailings mass. A mass of waste rock will provide a surcharge on the tailings to promote consolidation prior to cover placement.

Validation of Tailings Preparation Process Performance

The tailings preparation process has been optimized verified throughout the history of TOVP reporting as described in Sections 3 and 5 of this TID respectively. During the current reporting period ongoing monitoring of verification is conducted through the tracking of key performance indicators (KPIs) (described in section 2 of this TID) in the tailings preparation process, and in the as discharged tailings. To date these KPIs are met and provide confidence that the TPP is operating to design and producing tailings that will be perform as expected and be protective of the downstream environment.

Validation of Tailings Performance

The Tailings Optimization and Validation Program (TOVP), Version 2 (COGEMA 1999) was developed in March 1999 to optimize the tailings preparation process in the McClean Lake Mill and to validate predictions of the properties of tailings disposed within the JEB TMF. The need for the program arose from concerns expressed by stakeholders that significant concentrations of adsorbed arsenic and nickel might be released with time from the tailings solids to the pore water within the TMF and ultimately to the surrounding groundwater flow system.

The current role of the TOVP is to verify regulatory compliance of tailings performance, provide information to improve technical understanding of tailings performance, and validate predictions of long-term environmental effects on the receiving environment. This is facilitated by detailed *in-situ* assessments of tailings geochemical and geotechnical properties completed at five-year intervals. The validation of long-term environmental effects is completed following the five year in-situ assessments. As of 2015, this validation occurs in the Tailings TID. The most recent in-situ sampling campaign occurred in 2023/2024 and provided the first opportunity to examine placed Cigar Lake tailings.

For the first time, during the 2023/2024 sampling campaign, some of the deepest samples targeted could not be obtained due to the increasingly consolidated nature of the lower tailings in the JEB TMF, however many more samples of the newer Cigar Lake tailings were taken. Changes to the tailings sampling methodology are being contemplated to be implemented for the next TOVP in-situ sampling campaign in 2028. Despite these challenges Orano is confident that a sufficient number of representative samples of the tailings in the JEB TMF were taken to provide a clear picture of the future tailings source term.

Geochemical Models

A geochemical arsenic model has been developed through extensive scientific investigations, as the arsenic source term was identified as potentially problematic in early test work. The evolution of arsenic in the tailings solids has been found to result in the precipitation of a stable mineral phase (scorodite) which controls As pore water values over the long term. The precipitation of scorodite proceeds as a series of reactions which occur at different rates. As these reactions progress, pore water concentrations of an intermediate, transitory

arsenic phase (As^{3+}) are observed to first rise and then fall. Geochemical data collected in the 2023 sampling campaign again confirmed this rise and fall in arsenic pore water values and found that areas of increased arsenic in the pore water were associated only with As^{3+} . X-ray absorption spectroscopy (XANES) collected on tailings solids samples correlates the arsenic speciation and mineralogy of the solids with arsenic concentrations in the pore water. Correlation of pore water As concentrations with XANES data of the corresponding tailings solids supports the model observation that As^{3+} in the pore water is associated with mineral phases which are unstable under TMF conditions and will eventually evolve to scorodite. Pore water arsenic values associated with scorodite (As^{5+}) were observed to be controlled to approximately 1.5 mg/L, consistent with past sampling results, while XANES results show that the majority of total arsenic in the solids is present as oxidized As^{5+} . As arsenic in the solids evolves to scorodite, the associated pore water source term of the tailings will be controlled to approximately 1.5 mg/L.

Research into the model for the control of long-term molybdenum pore water values concluded in 2015 with two successful studies. The studies used XANES techniques to identify powellite as the long-term stable mineral form of molybdenum. Additional modelling based on the pore water geochemistry of the TMF solids found powellite to be stable. Pore water sampled in 2023 from areas identified as being close to equilibrium with powellite have molybdenum values consistently below 8 mg/L.

Work has continued on the geochemical model used to understand the controls on uranium in the tailings pore water. The precipitation of carbonate minerals in the tailings solids has been modelled as a long-term control on uranium pore water values. Geochemical modelling work performed in 2018 using TMF data shows that calcite precipitation will control the long-term tailings source term for uranium at approximately 8.5 mg/L. Weighted average TMF pore water uranium values from the 2023 sampling campaign generally show stable or decreasing values supporting the target source term value of 8.5 mg/L.

Geochemical Tailings Evaluation

Geochemical sampling of the TMF was conducted in 2023/24 and incorporated samples from eight boreholes. The geochemistry of the tailings is now divided for consideration between the earlier JEB/Sue tailings and the new Cigar Lake tailings. Geochemical analysis found that the pore water concentrations, irrespective of tailings ore source, of most ions continued to behave as predicted. Arsenic, uranium, and molybdenum were observed to develop within the expectations of their respective geochemical models. The pore water concentrations of arsenic comply with current regulatory administration and action levels and remain protective of the downstream environment.

Geotechnical Tailings Evaluation

Fine-grained tailings are found to have consolidated hydraulic conductivities that are consistent with design hydraulic conductivity. These values are sufficiently low to maintain the hydraulic conductivity contrast between the fine-grained placed tailings and the adjacent permeable sandstone, which largely limits the potential for significant solute release. Shallow dredge samples collected over this reporting period demonstrate that the range of coarse-grained tailings generally extends approximately 50 m from the deposition point in all directions before grading to fine-grained material at greater distances. Dredge sampling

has indicated that the samples at the edges of the pit are generally fine-grained, and that current operational controls are effective.

Prediction of Long-Term Environmental Effects

The ultimate purpose of the Tailings Optimization and Validation Program is to validate that the design of the JEB TMF is protective of the environment in the long term through detailed geochemical and geotechnical investigations. The pore water concentrations and placed tailings hydraulic conductivity from the TOVP serve as inputs to a groundwater and contaminant transport model, which demonstrates that surface water quality objectives will be achieved over the very long term. The overall performance of tailings management at the McClean Lake Operation is validated by this assessment.

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2 Regulatory and Facility Background

2.1 Regulatory Background

Tailings provide the greatest potential for long term contaminant transport at the McClean Lake Operation. As the key decommissioning liability, tailings management is a focused area of Orano design, management, maintenance, and numerical modelling. Similarly, tailings management remains of primary interest to regulatory authorities and rightsholders. The following section outlines the regulatory background and regulatory compliance for tailings management.

The JEB TMF was first licensed for operation through the McClean Lake Operating Licence AECB-MFOL-170-0.5 issued by the AECB on June 21, 1999, establishing the framework for operations, performance indicators, action levels associated with the operation of the JEB TMF, and the requirements for the TOVP.

Orano subsequently submitted annual TOVP Status reports to the regulatory agencies which describe the JEB TMF in-situ monitoring and sampling programs and laboratory investigations conducted in 2000, 2001, 2002, 2003, 2004 (COGEMA 2001, COGEMA 2002, COGEMA 2003, COGEMA 2004a, AREVA 2005a). In 2005, Orano submitted a report validating the long-term performance of the JEB TMF (AREVA, 2005b) which was formally accepted by the CNSC in 2006. A revised TOVP program document was submitted in 2007 (AREVA, 2007) which moved the TOVP to a 5-year reporting cycle and the program document was updated again in 2010 (AREVA, 2010a). Subsequently, TOVP Status reports were produced based on sampling in 2008 (AREVA, 2011a), 2013 (AREVA, 2015a), and 2018 (ORANO 2020b). The most current TOVP status report, based on sampling performed in 2023/ 2024, is contained in Section 5 of this report.

2.1.1 Compliance and Licensing Documentation

The components of the licensing basis for the McClean Lake Operation addressing the JEB TMF and tailings management have evolved over time. Historically, the documentation relating to the JEB TMF has three main components:

- 1) The **Tailings Management Technical Information Document (Tailings Management TID)** provides a comprehensive, current understanding of tailings management at the McClean Lake Operation and is recognized as a licensing basis document by the CNSC.
- 2) The **TOVP Reports** present and interpret in situ sampling campaign results (initially on an annual, and now 5-year basis), and associated research. As the TOVP is a key aspect of tailings management, Orano incorporated the TOVP Report into the Tailings Management TID starting in 2015. The current in-situ tailings pore water quality is determined using the methodology outlined in Section 5.1 of this report and is then compared to the existing administrative and action levels for in-situ tailings pore water. The most recent comparison for 2023 is discussed in Section 2.2.4.

- 3) **TOVP Definition Document** was the authoritative document regarding the compliance and licensing requirements for in-situ tailings pore water quality, i.e. administrative and action levels for tailings in-situ pore water quality. The TOVP Program Document was the sole, separate component of the licensing basis outside the otherwise comprehensive Environmental Protection Code of Practice (ECOP). The ECOP, which addresses real time and short-term compliance, outlines other compliance aspects for tailings including tailings thickener underflow pore water quality requirements as the tailings leave the mill, and TMF hydraulic containment requirements. In-situ tailings pore water concentrations are based on geochemical modelling and long-term equilibriums, so this compliance aspect was best addressed in the TOVP, outside the ECOP, which addresses real time or short-term compliance. In 2017 the TOVP definition document was removed from the licensing basis with the commitment to incorporate it into the Tailings Management TID. The 2020 update to the Tailings Management TID is the first time that the TOVP Program Document was merged into the Tailings Management TID as a single comprehensive document, complying with the removal the TOVP Program Document from the list of licensing basis documents included in the CNSC Licence Conditions Handbook.

2.1.1.1 GISTM Compliance

As a subsidiary of Orano Group, which is member company of the International Council on Mining and Metals (ICMM), Orano Canada Inc. applied the requirements of the ICMM's Global Industry Standard on Tailings Management (GISTM) to the JEB TMF. The consequence of an unlikely failure of the JEB TMF was analyzed and classified in the "very high" category and therefore compliance to the GISTM was required by August 5, 2023.

As part of GISTM conformance, Orano developed an Operations, Maintenance, and Surveillance (OMS) manual, and an Emergency Preparedness and Response Plan (EPRP) for the JEB TMF (Appendix A). These documents are reviewed on an annual basis and updated as required.

The OMS manual is intended to provide guidance and procedures for the operation, maintenance, and surveillance of the JEB TMF and its appurtenant structures. It covers roles and responsibilities, a facility description, general operational requirements, outlines the requirements for regular inspections and monitoring, and describes the processes for both routine and corrective maintenance.

The EPRP describes the emergency preparedness and emergency response protocols for the unlikely event of a failure of the JEB TMF. Included in the EPRP are the Trigger Action Response Plans (TARPs) utilized to mitigate specific identified credible failure modes. Responses are planned around potential failure scenarios and potential impacts to personnel, infrastructure, and the environment.

A full list of GISTM requirements and the steps Orano has taken to meet them is included in the Annual Disclosure in Appendix A.

2.2 Key Performance and Compliance Indicators

Licence condition 3.1 of the McClean Lake Operation Licence Conditions Handbook (LCH) states that licenced activities must comply with operating limits identified within the Tailings Management TID, specifically as informed by the TOVP (CNSC 2024). Key indicators of the performance of the tailings management system as a whole include:

- properties of production tailings from the Tailings Preparation Process (TPP) (which is contained in the Tailings Preparation Circuit (TPC)),
- the ability to maintain hydrodynamic containment within the JEB TMF, and
- the properties of in-situ tailings placed in the JEB TMF.

Although only selected tailings discharge parameters and in-situ tailings properties are explicitly defined in terms of administrative and action levels within this document, the following sections provide a summary of each key indicator, current monitoring, and relevant administrative and action limits as defined in the ECOP (Version 4, Orano 2023). In addition, the current regulatory approved consolidated tailings placement elevation is presented. This section covers the period of time from the start of operations to the end of the last reporting period (2020). Compliance over the current reporting period (2020-2025) is discussed in Section 8, along with any adjustments to monitoring and defined compliance values for application over the coming 5-year period.

Definitions: Consistent with the ECOP (Version 4, Orano 2023), Administrative and Action Levels are defined as controls to ensure continued environmental protection. **Administrative Levels** are set to define deviation from normal practice. The term “Action Level” indicates conditions requiring regulatory notification, within the context of the approach to action levels specified in the Uranium Mines and Mill Regulations, in which **Action Levels** are intended to indicate a potential loss of control. Administrative and Action Levels are subject to review, based on operating experience, as required through the life of the project. Accompanying the Administrative and Action Levels are prescribed actions to be taken in response to deviation from normal operations (i.e. Administrative Level) to potential loss of operational control (i.e. Action Level).

2.2.1 Properties of As-Discharged Tailings

The McClean Lake Mill commenced operations at the end of June 1999 and, except for brief scheduled shutdowns, operated continuously for over eleven years until the temporary shutdown from July 2010 to September 2014. From the intermittent restart in September 2014 (continuous production began in April 2015) to date, the McClean Lake Mill has been milling ore primarily from the Cigar Lake Mine. Over the entire operational period, the arsenic content in the ore feeding the mill has ranged over two orders of magnitude from approximately 200 µg/g to over 40,000 µg/g. To ensure that COPCs released from the mill in the tailings do not cause significant impacts to the environment, the tailings are monitored routinely in the TPC and at the point of discharge to ensure that they meet design criteria.

2.2.1.1 Monitoring

Operational Monitoring: Occurs on a daily basis in the TPC as outlined in Table 2.2-1. Operational monitoring, the purpose of which is to identify process upsets or changes in tailings preparations over time, is more comprehensive than administrative monitoring. Detailed information is collected and monitored by the McClean Lake Operation Metallurgical Group, and it can be modified at any time to collect additional or ad hoc samples to support special mill programs.

Table 2.2-1: Operational Monitoring of the Tailings Preparation Process

Location	Frequency	Material	Testing *(parameter controlled at this step)
Geochemical Parameters			
Tailings Feed	Real time	Liquids	pH*, Temperature, ORP
	Daily composite	Solids	pH, As, Ni, Ra-226 U, Fe and trace metals
Tailings Reaction Tanks 1 2 and 3	Real time	Slurry	pH*
Tailings Thickener Underflow	Daily Composite	Liquids	pH, As, Ni, Ra-226 U, and trace metals
	Monthly and Quarterly	Solids	Complete suite of metals and radionuclides
Tailings Thickener Overflow	Daily Composite	Liquids	pH, As, Ni, Ra-226 U, and trace metals
Geotechnical Parameters			
Tailings Thickener Underflow	Real time	Solids, Slurry, Liquids	Density & Volume
Tailings Thickener Overflow	Real time	Liquids	Volume

Administration Levels: To monitor tailings quality as it leaves the mill, Administration Levels have been derived for arsenic, nickel, radium-226, pH of tailings pore water, and tailings density (Table 2.2-2) which represent design values for the TPP. Administrative Levels are applied to daily composite samples of tailings pore water collected from the tailings thickener underflow.

Action Levels: An Action Level has been derived for arsenic, which is based on the upper bound for arsenic concentrations in the tailings pore water deemed to be acceptable over the long term (Table 2.2-2). The Action Level for arsenic was derived as two tiers of samples:

- Quarterly Action Levels represent a point at which correction is required to regain control.
- Annual Action Levels represent an absolute upper bound for the operation of the JEB TMF.

Quarterly and annual Action Levels are applied to their respective weighted average concentrations in the tailings pore water. Average concentrations are calculated from daily composite tailings pore water samples and are corrected for density and volume.

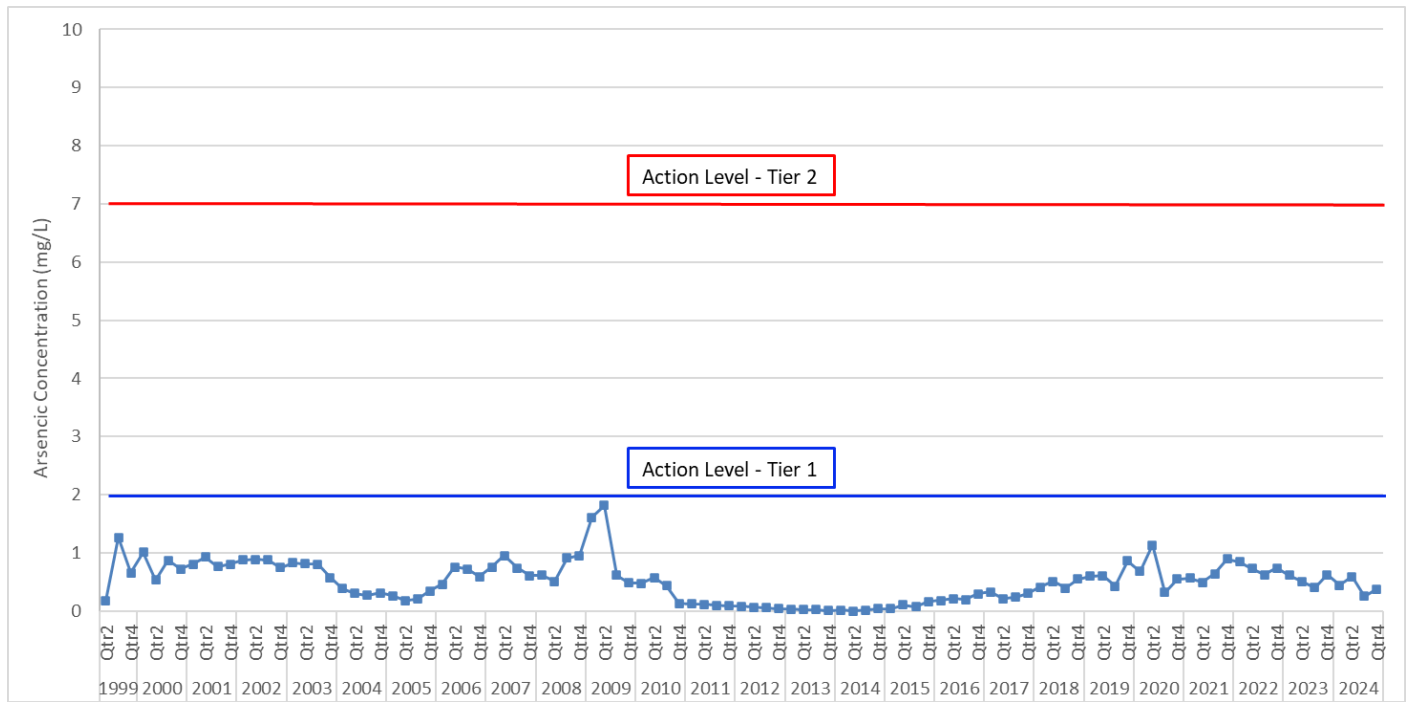
Table 2.2-2: As-Discharged Tailings Monitoring: Administrative and Action Levels

Parameter	Units	Administrative Levels	Action Levels			
		Daily Composite	Tier 1		Tier 2	
			Quarterly Average	Annual Average	Quarterly Average	Annual Average
Arsenic	mg/L	1.0	2.0	2.0	7.0	5.0
Nickel	mg/L	1.0				
pH		7.5 < pH < 8.5				
Radium-226	Bq/L	200				
Density	% solids	25 < % solids				

2.2.1.2 Regulatory Compliance

Figure 2.2-1 presents the quarterly weighted average arsenic concentrations achieved in as-discharged tailings pore water relative to Action and Administrative Levels. As illustrated, despite the large range of arsenic content in the feed ore, the arsenic concentrations in the tailings pore water have consistently been maintained within Action Levels identified in the McClean Lake Operation's Environmental Protection Code of Practice (Orano 2023).

Figure 2.2-1: Quarterly Average Arsenic Concentrations in Tailings Production



2.2.2 TMF Hydrodynamic Containment

The JEB TMF is designed and operated to maintain hydrodynamic containment such that the groundwater gradient is towards the TMF. Currently water removal at prescribed rates from the raise well system ensures hydraulic containment of tailings pore water during the operating period.

Original as-built condition 1999-2014: To complement the base drain pumping and minimize the volume of water requiring treatment, a ring of dewatering wells was originally installed around the perimeter of the pit, as illustrated in Figure 2.2-2. The submersible pumps in these wells were located at an elevation fixed slightly above the desired pond level to intercept and divert clean groundwater entering the TMF.

TMF Optimization/ Expansion Condition 2014-present: Orano is in the process of vertically expanding the TMF over time, as described in Section 2.4.2. Beginning with the JEB TMF Optimization Project in 2013 and 2018, a low permeability soil-bentonite liner has been placed in the upper portion of the pit above the overburden/sandstone contact. The TMF vertical expansion continued with the embankment raise and placement of the liner as a part of the JEB TMF Expansion Project, which began in 2021. The purpose of the liner is to provide containment for the TMF pond as the water level is increased and limit infiltration of TMF pond water into the overburden during the operating period.

As the tailings level of the TMF has risen over time, the TMF pond level has been correspondingly increased. After the completion of the TMF Optimization program (Section 2.4.1) the TMF pond level was allowed to move into the newly placed liner, above the overburden/sandstone contact in 2014 rendering the use of dewatering wells ineffective. Pumping from the dewatering wells was discontinued in 2014, and the dewatering wells have been decommissioned, with the exception of three (refer to Section 2.3.4.4). The three remaining dewatering wells are no longer operational and are scheduled to be decommissioned in future TMF expansion activity. Completed and contemplated expansion activities are described in Section 2.4.2. Figure 2.2-3 shows the present configuration of the JEB TMF monitoring wells. Hydraulic containment for the TMF is now provided exclusively by water removal from the raise well system.

2.2.2.1 Monitoring

Original As-Built Condition: In the original (pre-expansion) TMF design, hydraulic containment administrative and action levels were monitored relative to groundwater levels in well TW08 (Table 2.2-3). TW08 was one of a series of four external observation wells including TW01, TW03 and TW05, and four internal vibrating wire piezometers which were located within the previous dewatering ring as shown in Figure 2.2-2.

TMF Optimization/ Expansion Condition 2018-present: Wells TW01, TW02 and TW05 were decommissioned as a part of the TMF Expansion project and hydraulic containment monitoring Administration and Action Levels were updated (Lanice to Akhter and Lung, August 2018) (Table 2.2-3). As the TMF water levels continued to rise groundwater modelling was conducted in 2021 to further assess the target to maintain

hydraulic containment of the TMF through water removal from the raise well system. Administration and Action levels were again updated to reflect this modelling in 2023 (ECOP V4, Orano 2023):

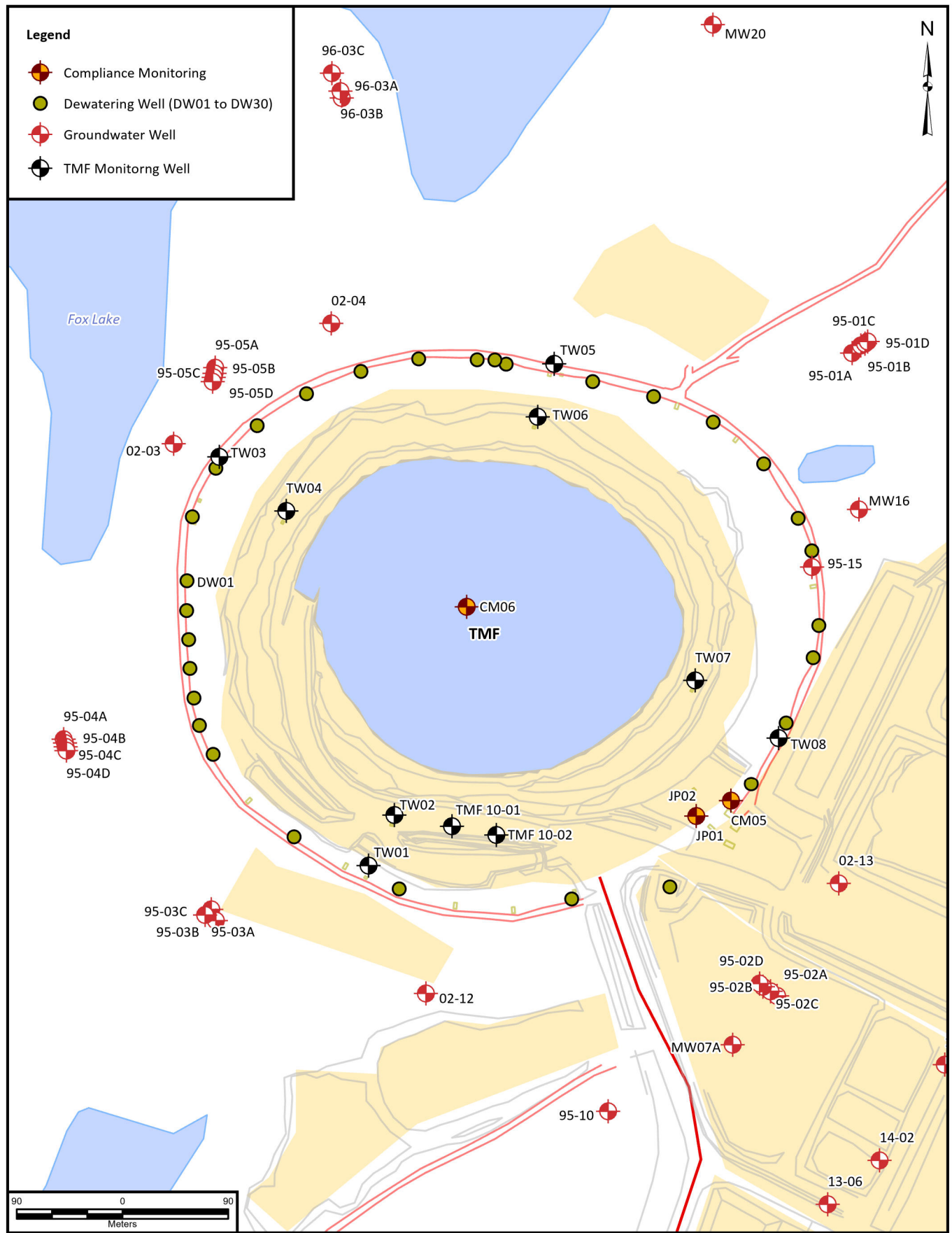
- Where the TMF pond elevation (CM05) was less than 445.7 mASL (reference of Fox Lake elevation) the water level difference between the TMF pond and raise system (CM06) must be maintained greater than 1.0 m.
- Where the TMF pond elevation (CM05) was between 445.7 and 455.0 mASL, the water level difference between Fox Lake elevation and the raise well system must be maintained greater than 1.0 m.
- Where the TMF pond elevation (CM05) was above 455.0 mASL, the water level difference between Fox Lake elevation and the raise well system must be maintained greater than 7.0 m.

Monitoring data demonstrates that hydraulic containment has been maintained throughout operations. A full discussion on the operational validation of TMF water management is presented in Section 3.4. Since 2021, as the TMF pond water moved above the groundwater level, Action Levels are now applied to the head differential between the raise well (CM05) and Fox Lake as presented in Table 2.2-3.

Table 2.2-3: JEB TMF Action Levels for Hydrodynamic Containment (Historical and Current)

Time Period	Parameter	Daily Administrative Level (m H ₂ O)	Action Level
1999-2018	Minium head differential between trend monitoring well TW08 (m H ₂ O) and JEB TMF pond (CM06) ($h_{TW08} - h_{POND}$)	0.5	0.0 (Daily)
2018-2023	Head differential between JEB TMF Pond (CM06) and Drift (CM05) monitoring well ($h_{POND} - h_{DRIFT}$)	0.2	0.0 (Over 3 days)
2023 - Present			
TMF Pond Elevation (mASL)	Parameter	Daily Administrative Level (m H ₂ O)	Action Level
<445.7	Head differential between pond and drift monitoring well ($h_{POND} - h_{DRIFT}$)	1.0	≤0.0 (Over 3 days)
>445.7 and <455.0	Head differential between Fox Lake and drift monitoring well ($h_{FOX LAKE} - h_{DRIFT}$)	1.0	≤0.0 (Over 3 days)

NOTES: 1. Definition of unit (mASL) – meter above sea-level;
2. Definition of unit:(m H₂O) – hydraulic head expressed as metres of water
3. Values presented represent minimum values



Projection: NAD 1983 UTM Zone 13N
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 Data Sources: Natural Resources Canada, Geobase®, Nation
 Topographic Database, ORANO Canada Inc.

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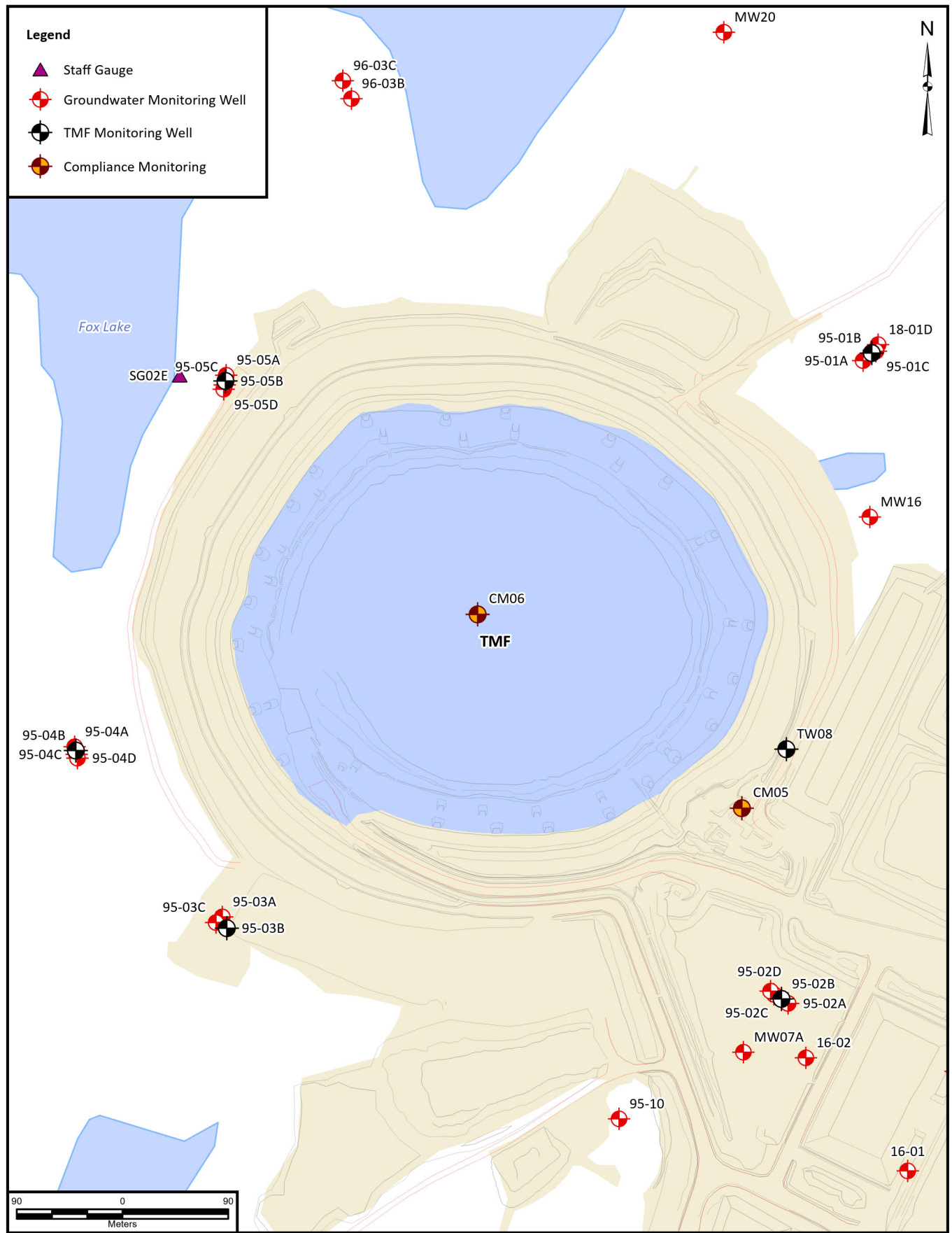
FIGURE 2.2-2

ORIGINAL CONFIGURATION OF MONITORING WELLS AROUND THE JEB TMF

TAILINGS MANAGEMENT TID



orano



Projection: NAD 1983 UTM Zone 13N
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 Data Sources: Natural Resources Canada, Geobase®, Nation
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FIGURE 2.2-3
 CURRENT LOCATIONS OF MONITORING WELLS
 FOR HYDRAULIC CONTAINMENT

TAILINGS MANAGEMENT TID



2.2.2.2 Regulatory Compliance

The compliance objectives for hydrodynamic containment have evolved over time as the pond level has risen however, hydrodynamic containment has been consistently maintained in the TMF over the life of operations (Section 4.4.1). During the current reporting period, relative to Table 2.2-3, the Action Level was not exceeded.

As the TMF water level continued to rise, the compliance objectives for hydrodynamic containment were the subject of a hydraulic containment assessment conducted in 2021. The assessment identified new compliance objectives which have been included in an updated to the ECOP (Version 4, Orano 2023). The JEB TMF pond elevation is now higher than the groundwater level. As the purpose of TW08 was to confirm that the TMF pond level was below the surrounding groundwater, this measurement is no longer valid. Currently, hydraulic containment is preserved by maintaining the base drain as a zone of low hydraulic potential in relation to the JEB TMF pond and the surrounding groundwater. Compliance targets were set as part of the 2021 modelling work and have been incorporated into the ECOP/OMS described in section 2.1.1.1. Indicators will continue to be reviewed under the ECOP/OMS as TMF Expansion plans progress, and appropriate indicators will be updated as needed to reflect the operational context.

2.2.3 In-Situ Tailings Properties: Geotechnical

Tailings as produced during mill operations, contain a significant amount of fine-grained materials. Consolidation of these materials produces a tailings mass with a hydraulic conductivity lower than that of the surrounding sandstone. Under these conditions, the consolidated tailings represent a low permeability plug and groundwater will preferentially flow around the tailings mass through the surrounding host rock. Advective flow of groundwater through the tailings will be negligible, and infiltration of meteoric water will be controlled with the placement of a cover on the TMF. These small contributions of advective flow are predicted and understood through appropriate groundwater flow models and established material properties. To ensure that the tailings develop into a low permeability mass, the geotechnical properties of the tailings are assessed. The hydraulic conductivity of the tailings is assessed and compared with the surrounding sandstone.

2.2.3.1 Monitoring

Detailed in-situ tailings assessments are conducted on a five-year frequency to collect geotechnical samples. Samples are classified according to soil type, logged, and tested for characterization in terms of their geotechnical properties including particle size gradation, density, hydraulic conductivity, and consolidation behavior. Cone penetrometer testing may also be employed to characterize tailings material using in-situ measurements. A discussion of this sampling and analysis is contained in Section 5.6.

Dredge sampling is also conducted annually. The samples inform assessments of tailings segregation, which are discussed, further in Section 3.5 (in relation to the tailings deposition system) and Section 5.6.3.4 (geotechnical testwork). Tailings segregation is an important aspect of the controls on tailings conductivity, as finer grained tailings have been found to travel farther from the deposition points towards the outside

perimeter of the TMF. The segregation of finer grained tailings towards the outside of the TMF ensures that the area of the lowest hydraulic conductivity will be adjacent to the host rock, where it is the most useful in enabling groundwater flow around the tailings mass.

2.2.3.2 Regulatory Compliance

The tailings hydraulic conductivities predicted by the TOVP sampling are incorporated into groundwater flow and contaminant transport modelling performed in compliance with TOVP reporting requirements. No Administrative or Action Levels are imposed on the geotechnical sampling, as the samples provide a prediction of future final consolidated state rather than an absolute value. Modelling allows an understanding of the effect of the hydraulic conductivity contrast on contaminant transport and identifies a minimum hydraulic conductivity that must be obtained to limit advective flow. The results of the modelling conducted using the latest TOVP geotechnical data is provided in Section 7.

2.2.4 In-Situ Tailings Properties: Geochemical

A principal design parameter used to control the migration of COPCs from the tailings to the downstream environment is the tailings solids chemistry. Tailings solids chemistry is designed to maintain the concentrations of COPCs in the tailings pore water at such low levels that releases by the diffusion process over the long term are environmentally acceptable. At the time of initial licensing, the primary COPC was arsenic. Arsenic pore water concentrations are the indicator parameter for long term tailings management with Administrative and Action Levels defined in the Tailings Management TID (Table 2.2-4). A summary of evolving arsenic controls is provided in the sections below. A suite of 18 COPCs is also evaluated under the TOVP to be used as input parameters to groundwater and contaminant transport modelling (Section 7.0).

2.2.4.1 Monitoring

Detailed in-situ assessments of the tailings are conducted on a five-year frequency to assess the geochemical interactions between the tailings solids and pore water.

Pore Water Source Terms

Weighted average pore water concentrations are determined for 18 COPCs of potential environmental significance (Section 5.2.4, Appendix D, Section C). The 18 COPCs are divided according to their predicted environmental impacts and observed aging behaviour in the tailings (Section 5.0). For three key COPCs (arsenic, molybdenum, and uranium) the weighted average pore water concentrations associated with placed tailings are compared to those predicted by geochemical modelling and supplementary investigations (e.g. research with university partners) (Section 5.5). These geochemical parameters are used to derive final source term concentrations considered representative of equilibrium state conditions within the tailings mass. The final source term concentrations, which are either the weighted average pore water values for most COPCs or specially derived source terms for key COPCs, are applied to the contaminant transport model to predict long term effects on the receiving environment.

Administrative and Action Levels for Arsenic

As a key COPC, the source term of arsenic is carefully considered with a long-term research program (Section 5.5.1), using the results of each 5 year in-situ tailings sampling campaign. A pore water source term for arsenic is selected based on investigations of the equilibrium geochemistry of the tailings and the validation of optimizations to the Tailings Preparation Process. Administrative and Action Levels are applied to the overall weighted average arsenic source term and not individual sampling results.

Historical Timeline of Arsenic Monitoring

In conjunction with the iterative evaluation of the evolution of arsenic pore water concentrations in the placed tailings, and the evolution of the groundwater flow and contaminant transport framework, the in-situ tailings arsenic pore water action levels have also evolved. Key developments in the evolution of these action levels are summarized below:

- **1999:** The initial McClean Lake Operation licence is issued and outlines an *in-situ* tailings arsenic pore water Action Level of 2 mg/L, and a Limit arsenic pore water concentration of 5 mg/L. The Action Level, if exceeded, requires regulatory agency notification along with a remedial action plan. The Limit was set to ensure that the surface water quality, with respect to arsenic in Fox Lake north basin, would not exceed Saskatchewan Surface Water Quality Objectives (SSWQO) in the long term. The surface water quality objective at the time was 50 µg/L; however, a 5 µg/L CCME surface water quality guideline for arsenic was being contemplated and was conservatively used as the criteria for protection of Fox Lake (Joint Panel 1997). If exceeded, the Limit requires suspension of mill production activities until such time that the remedial action plan receives regulatory agency approval and all steps required are completed. The sampling frequency for intrusive campaigns was set at annual for the next five years.
- **2000-2003:** Aging tests are completed which provide important information on the behaviour of arsenic in the TMF. Arsenic pore water concentrations are identified to rise and then fall to terminal values.
- **2004:** The underlying mechanisms of the arsenic aging process are better understood based on investigations into the higher than predicted arsenic source term identified in the Sue C tailings, and an arsenic geochemical model is developed (Section 5.5.1). Based on the arsenic geochemical model, and lessons learned from the processing of Sue C ore, adaptive management procedures are implemented in March of 2004 to minimize the effects of the aging process on arsenic pore water concentration. An interim source term is adopted, considering three years of tailings aging based on preliminary aging tests, which indicate that arsenic pore water values will decrease over time.
- **2005:** The first TOVP Validation Report (AREVA, 2005b) is developed, with a proposal for ongoing TOVP monitoring. The revised program is accepted by regulatory agencies and leads to the subsequent TOVP Program Document (AREVA, 2007). The Action Level for arsenic is set at 2 mg/L and the Limit at 5 mg/L.

- **2007:** The SEQG for arsenic is reduced to 5 µg/L and given that initial Action Levels considered the possibility of a 5 µg/L arsenic surface water concentration, the 2005 arsenic pore water Action Level and Limit are maintained. Orano had significantly advanced technical work that reduced uncertainties in the local hydrogeology and long-term environmental effects prediction. Recognizing that the original 2005 predictions are very conservative, the existing Action Levels are considered to remain appropriate for the new guideline, with a level of conservatism that is commensurate with remaining uncertainty. The in-situ sampling campaigns are revised to a 5-year frequency. The consideration of tailings aging is fully incorporated, and only tailings produced after March 2004 are considered in the tailings source term calculation as tailings produced before that point will continue to age over time.
- **2010:** The TOVP Program Document is revised to reflect advancements in Orano's understanding of source terms and geochemical evolution (AREVA, 2010a). An Administrative Level for arsenic is added and set at 2 mg/L to be consistent with post-aging terminal pore water concentrations. The Tier 1 and Tier 2 Action Levels are added to replace the previous Action Level and Limit, at 5 mg/L and 20 mg/L for arsenic, respectively. The Tier 2 Action Level continues, as the previous Limit was to be tied to the achievement of guideline in Fox Lake north basin (AREVA, 2010a). The calculation completed to meet guidelines in Fox Lake north basin incorporates numerous conservatisms (e.g. dilution only, no attenuation, non-depleting source term) for a case where the tailings elevation is 434 mASL (based on mine plans at the time). The increased value of 20 mg/L is based on updated contaminant transport modelling and an improved understanding of tailings pore water source term and local hydrogeology. The actions required of Orano for exceeding the Tier 1 and Tier 2 Action Levels remain unchanged.
- **2015:** The 2015 Tailings Management TID is submitted, containing results from the 2013 sampling campaign (AREVA 2015a). This submission merges the Tailings Management TID and TOVP reporting for the first time. The TOVP Program Document is removed from the list of licensing basis documents, and long term tailings pore water quality requirements are defined and evaluated in the Tailings Management TID going forward. In situ sampling results indicate that the milling of ores after Sue C have resulted in low and controlled pore water values, validating the lessons learned and modified process control parameters. The methodology used to calculate the weighted average concentration of arsenic in the tailings pore water is updated, to more accurately calculate the tailings weighted volumes using ArcGIS (Section 5.1).
- **2020:** Source terms were determined separately for JEB/Sue and Cigar Lake tailings, to account for the notably different mineralogy of the Cigar Lake ore and upgrades to the McClean Lake Mill. This is part of a continual improvement initiative to improve accuracy in the source term for contaminant transport modelling.

The previously calculated Tier 2 Action Level for arsenic (20 mg/L) was updated to reflect the currently approved case in the licensing basis with top of consolidated tailings at an elevation of 448 mASL. The Tier 2 Action Level was recalculated using the groundwater and contaminant transport model described in Section 7 and the same methodology as previously used in 1999 and 2010 (Section 2.2.4.1). The resulting value is 7 mg/L and is tied to the achievement of guideline values in Fox Lake north basin. The recalculated value reflects the overall average of all tailings placed in the

TMF, including JEB/Sue and Cigar Lake, considering the approved top of consolidated tailings at an elevation of 448 mASL.

The calculation is made using the following conservative assumptions:

- The resulting concentration of arsenic in the lake is calculated assuming a fully mixed lake, and
- The tailings source term is assumed to be steady-state (i.e. non-depleting source), meaning that the peak concentration is sustained rather than declining to background (as will occur when mass is depleted over time).

The Tier 1 Action Level of 5 mg/L for arsenic was not changed. This value approximates the calculated “All Tailings” arsenic pore water value for JEB/Sue based on the 2018 of 4.55 mg/L in this submission (Table 8.2-2). The “All Tailings” value does not reflect modified tailings inputs and adaptive management process controls that were implemented in response to the observed arsenic pore water evolution in placed Sue C tailings (Section 2.2.4.1; Section 5.5.1.3). The TOVP arsenic program, described in Section 5.5.1, outlines the success of mill optimizations implemented in 2004 in response to the monitoring results of Sue C placed tails. The “All Tailings” value therefore represents an upper bound of performance that has not been observed above the Sue C tailings horizon. The value of 4.55 mg/L is the upper bound case modelled in contaminant transport modelling as the overall average of JEB/Sue tailings.

Preliminary results for the Cigar Lake tailings show a low and controlled source term that is below current and revised Action Levels at both the average (0.28 mg/L), and the upper bound (0.5 mg/L) pore water concentrations (calculated in Appendix D, Section C). Both cases result in downstream water quality that is well below SEQGs (Section 7). The calculated JEB/Sue value of 1.69 mg/L (Appendix D, Section C), applying the process controls established in 2004, is well below the current and revised Action Levels.

2.2.4.2 Regulatory Compliance

Table 2.2-4 presents a summary of the evolution of the Administrative and Action Levels for arsenic, as described in the section above. The summary covers until the end of the last reporting period, which was concluded with the submission of the 2020 Tailings Management TID (AREVA 2015a) in May 2020.

Compliance for the most recent reporting period (2020-2025) are discussed in Section 8.

Table 2.2-4: Summary of TMF Pore Water Compliance and Licence Requirements – Previous Reporting Periods¹

Authoritative Program Document	TOVP Validation Report	Average Weighted Pore Water Concentration As (mg/L)		Administrative Level ² As (mg/L)	Tier 1 Action Level ³ As (mg/L)	Tier 2 Action Level ⁴ As (mg/L)	
		All Tailings ⁸	Modified tailings inputs, adaptive management process controls ⁹				
TOVP Program Document/Validation Reports (1999-2015)							
TOVP Rev. 2, March 1999 ⁵	September 2005	4.3	1.5	n/a	2	5	
TOVP Rev. 3, July 2007	April 2011	3.8	1.9	n/a	2	5	
TOVP Rev 4, October 2010 ⁶	n/a	n/a	n/a	2	5	20	
Tailings Management TID (2015-Present)							
May 2015		4.38		2.37	2	5	20
		J/S ¹⁰	CL ¹¹	J/S ¹⁰			
May 2020 ⁷		4.55	0.28	1.69	2	5 ¹²	7 ¹³
November 2025		2.98	0.76	1.27			

- Administration Level, Tier 1 Action Level, and Tier 2 Action Level are currently applied following each 5-year TMF in-situ sampling campaign in the Tailings Management TID. Prior to 2017, the levels were applied in the TOVP Validation Report/Program Document.
- Administration Level, if exceeded, requires an internal investigation and remedial action plan. An Administrative Level was established in 2010.
- Tier 1 Action Levels (referred to as "Action Level" prior to 2010), if exceeded, require regulatory agency notification together with submission of a remedial action plan.
- Tier 2 Action Level (referred to as "Limit" prior to 2010), if exceeded, requires suspension of mill production activities until such time as the remedial action plan has received regulatory agency approval and all steps required by Orano have been completed.
- TOVP Rev. 1 document was revised prior to mill start-up.
- The submission of the 2010 Program Document did not coincide with a TOVP Validation Report; therefore, an average pore water concentration was not presented at that time.
- Authoritative document currently in force in the licensing basis, to be replaced by this submission.
- All tailings results included in average with outliers (as determined by statistical analysis removed).
- When higher arsenic source terms were first identified, an interim source term was adopted considering 3 years of tailings aging based on preliminary aging tests which indicated that arsenic pore water values would decrease over time.
- JEB/Sue tailings – the modified tailings inputs/adaptive management process controls value of 1.27 mg/L is the value compared to compliance requirements.
- Cigar Lake tailings – modified tailings inputs/adaptive management process controls apply only to JEB/Sue; therefore, the "All Tailings" value of 0.76 mg/L is the value compared to compliance requirements.
- Reflects the "All Tailings" value for JEB/Sue of 2.98 mg/L, prior to the implementation of process controls –upper bound in the contaminant transport model.
- Reflects the overall average of all tailings placed in the TMF in the 457.5 mASL expansion case, to meet SEQGs in Fox Lake north basin with conservative assumptions.

2.2.5 Tailings Placement Elevation

The McClean Lake Operation's Licence Conditions Handbook Section G.1 (CNSC 2024) provides a list of authorized activities by the CNSC. In relation to the JEB TMF, Orano is authorized to vertically expand JEB TMF up to 468 meters above sea level (mASL) and to dispose of tailings up to a consolidated tailings elevation of 462 mASL.

2.2.5.1 Monitoring

Tailings surface surveys are conducted semi-annually to annually, generally coinciding with movement(s) of the tailings deposition points. The surveys are an important input to tailings deposition modelling and provide validation of tailings deposition predictions and placed densities.

2.2.5.2 Regulatory Compliance

See Section 2.4 below for overview of regulatory applications to increase capacity in the JEB for the disposal and storage of tailings and approved consolidated tailings elevation.

2.3 Facility Background and Operation

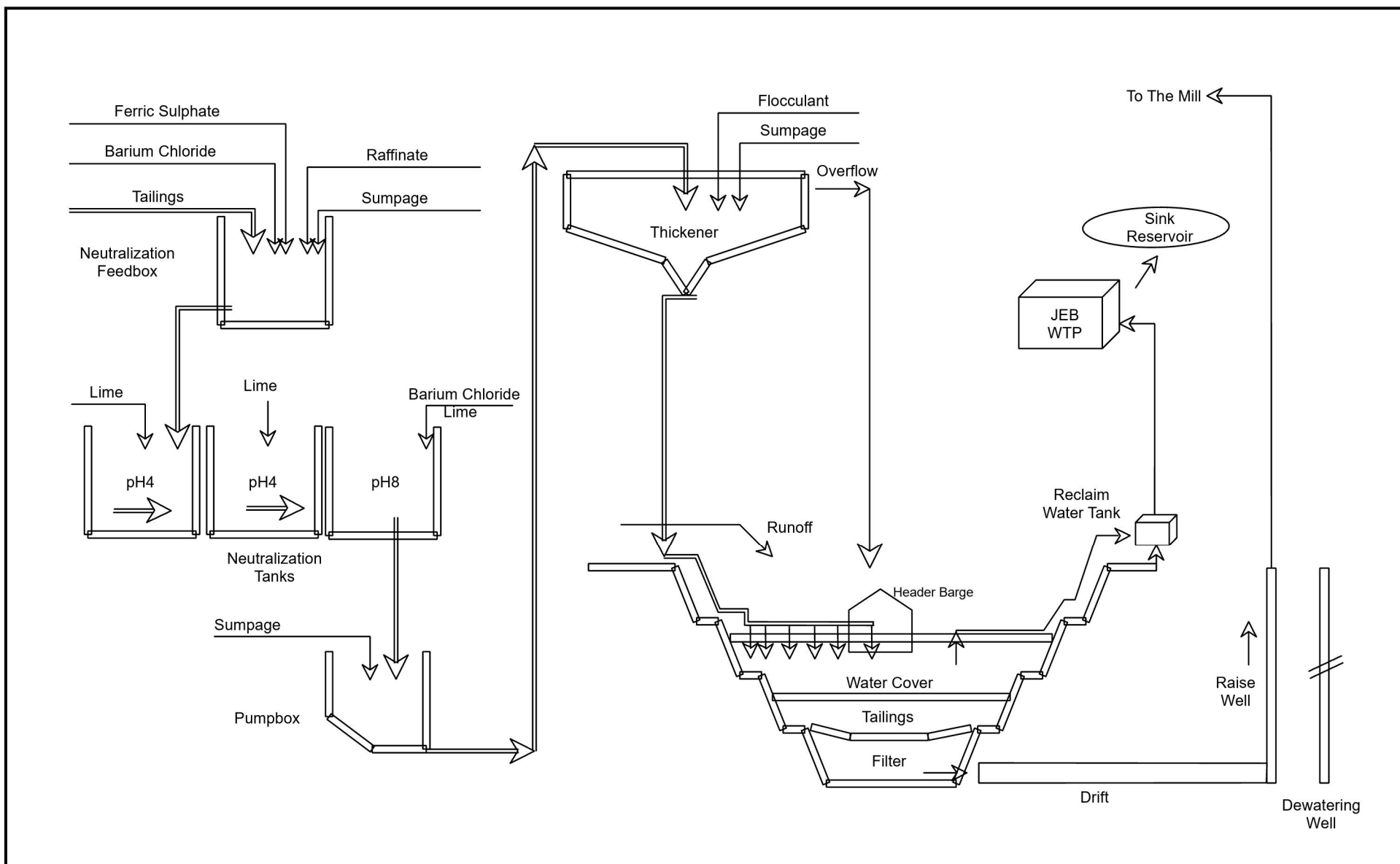
The overall tailings management system is comprised of the I) McClean Lake Mill tailings preparation process, II) the tailings delivery system, III) the JEB TMF, and IV) the tailings deposition system. A schematic diagram of the overall system is presented as Figure 2.3-1

2.3.1 Initial Tailings Management Alternatives Analysis

The primary criteria considered in evaluating the initial TMF alternatives included the following:

- technical feasibility: key factors included chemical and hydraulic containment, the use of proven technology, and reliability;
- operational feasibility: key factors included radiation protection, safety, operational efficiency, and ability to monitor and control;
- environmental considerations: key environmental considerations included source term control, hydraulic containment, impact to the receiving environment, and ability to monitor;
- cost and management considerations: key factors included construction, operation and maintenance costs, construction and operation schedules, staffing, and overall project management implications; and
- public acceptability: at the time public acceptability was included within the considerations of environmental impacts.

Table 2.3-1 summarizes the design alternatives considered. The decision sequence leading to the current JEB TMF design is summarized in Figure 2.3-2.



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FIGURE 2.3-1

McCLEAN LAKE TAILINGS MANAGEMENT SYSTEM SCHEMATIC DIAGRAM

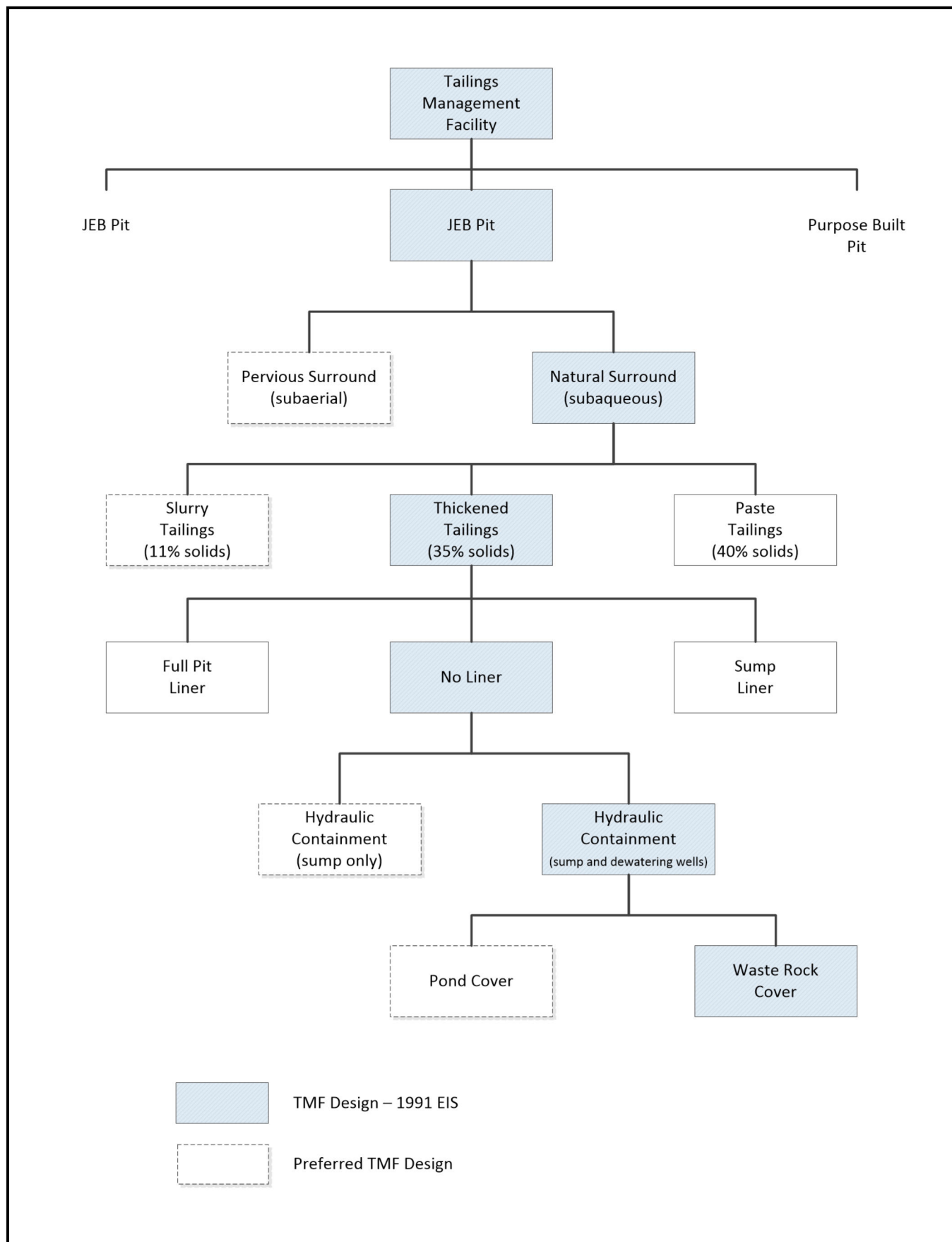
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Table 2.3-1: JEB Tailings Management Facility Design Alternatives and Final Design

Tailings Preparation			
Alternatives Considered	Initial Tailings Management Facility Design	Preferred Tailings Management Facility Design	Justification
Tailings neutralization to strong alkaline pH with CaO. Tailings neutralization with CaO and Fe ₂ (SO ₄) ₃ to pH 8.5	Tailings neutralization with CaO only to strong alkaline pH	Engineered tailings chemistry with BaCl ₂ and Fe ₂ (SO ₄) ₃ addition and final neutralization to pH 8 with CaO	Minimize Ra source through addition of BaCl ₂ ; minimize As and Ni source terms in tailings mass through ferric sulfate addition and pH control; lower diffusive flux from tailings on closure.
Unthickened tails, thickened tails, paste tails	Unthickened Tails (11% solids)	Thickened tails (25%-35% solids)	Thickened tailings minimize water to be treated.
JEB TMF Design			
Alternatives Considered	Initial Tailings Management Facility Design	Preferred Tailings Management Facility Design	Justification
Above ground versus in-pit disposal	In-pit	In-pit	In-pit disposal minimizes environmental impacts and provides best long term physical isolation and security.
Pit siting	JEB pit	JEB pit	JEB pit chosen over SUE C or purpose-built pit due to capacity requirements and no decrease in environmental impact if sited elsewhere; cost of purpose-built pit prohibitive.
Full pit liner vs. partial pit liner vs. no liner	No liner	No liner	Full pit liner may be impossible to construct in a flooding pit. Partial pit liner does not have a significant effect on reducing diffusive flux to environment.
Pervious surround vs. natural surround	Pervious surround (subaerial)	Natural surround (subaqueous)	Natural surround minimizes in-pit construction, protects worker safety; effective containment of tailings pore water; decreased contaminant flux to Fox Lake; minimizes in-pit construction.
Final cover - water or solid materials	Final cover - till cap and pond	Final cover - complete backfill with waste rock and till cap	Waste rock cover allows enhanced tailings consolidation and lower tailings hydraulic conductivity; better isolation from surface environment on closure; no flux from tailings to overlying surface pond.
Dewatering sump, dewatering wells, dewatering drift	Dewatering drift and raise and pit sump	Dewatering drift and raise complemented by dewatering wells	Enhanced hydraulic containment; minimizes amount of water requiring treatment and minimizes loading of contaminants to the environment during operations.
Tailings Deposition			
Alternatives Considered	Initial Tailings Management Facility Design	Preferred Tailings Management Facility Design	Justification
Subaerial vs. subaqueous placement	Subaerial	Subaqueous	Subaqueous placement reduces worker exposure to dust, gamma radiation and radon exposure (subaqueous deposition); provides for less tailings segregation and lower hydraulic conductivity in consolidated tailings; no frost lens formation in tailings mass.



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FIGURE 2.3-2

TAILINGS MANAGEMENT FACILITY OPTIONS

TAILINGS MANAGEMENT TID



2.3.1.1 Dewatering Options

A system of dewatering wells around the pit perimeter was evaluated and compared to the in-pit sump configuration. The dewatering well system offered a number of advantages, including:

- control of groundwater flow adjacent to the pit;
- additional hydraulic containment; and
- minimization of water treatment requirements through interception of uncontaminated water prior to entering the pit.

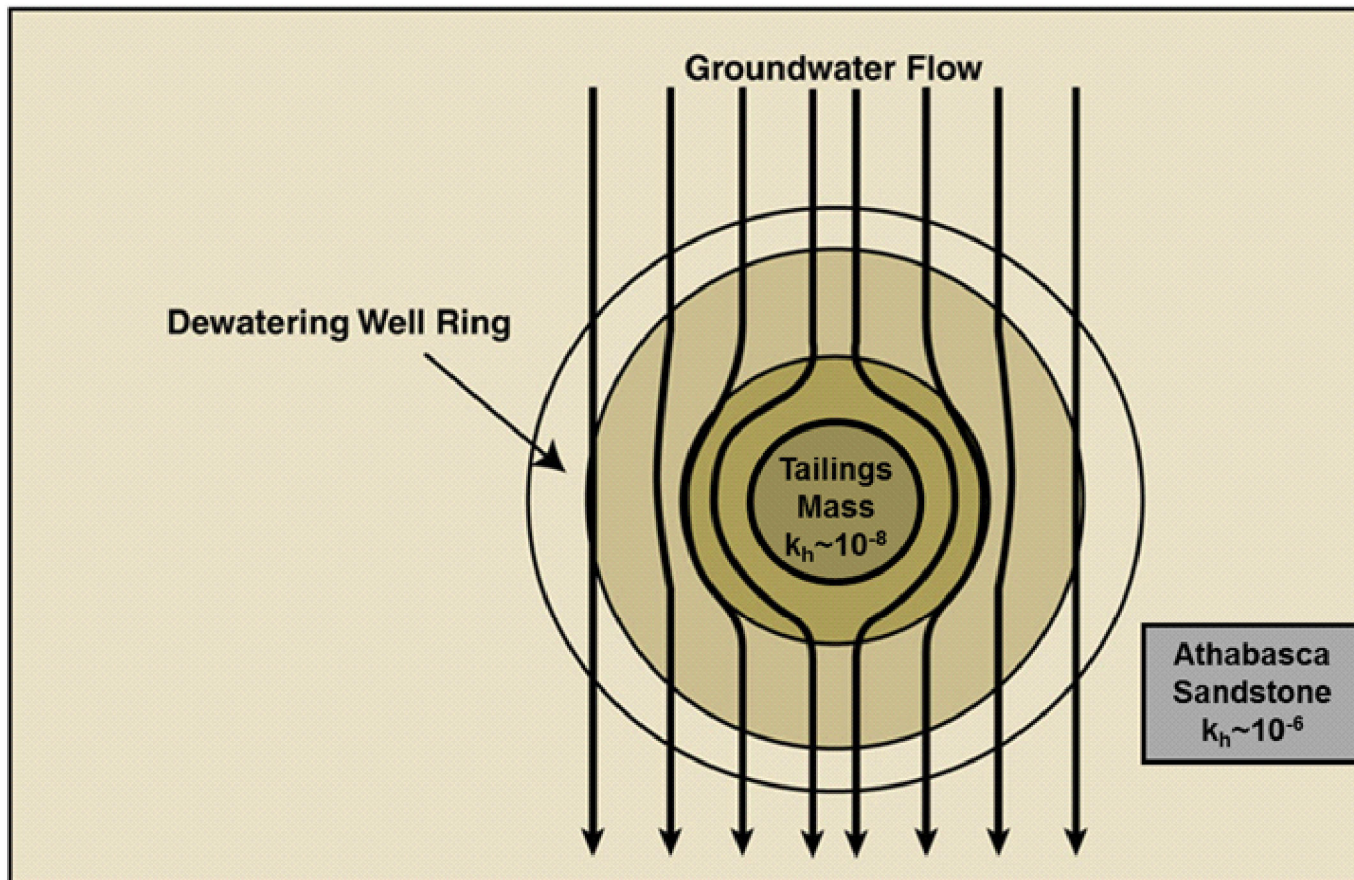
Given these advantages, a dewatering well system was incorporated into the final design. The dewatering wells functioned as the primary method of maintaining hydraulic containment until the JEB TMF pond level rose above the overburden/sandstone contact, rendering the use of dewatering wells ineffective, pumping from the dewatering wells was no longer required to intercept clean groundwater. In 2017, a program to progressively decommission dewatering well infrastructure was initiated. Hydraulic containment is currently maintained through a combination of raise well and reclaim pumping (Section 2.2.2).

2.3.1.2 Pervious Surround versus Natural Surround Alternative

A key design issue for the JEB TMF concerned the method of long-term isolation of the tailings within the JEB TMF from the natural groundwater flow system to control the migration of COPCs out of the tailings mass and into the groundwater. Isolation can be accomplished by producing a tailings mass of uniform low hydraulic conductivity, but the overall performance remains influenced by the surround and more specifically by the hydraulic conductivity difference between the consolidated tailings mass and the surround. Two fundamental design alternatives were considered for the surround and accompanying deposition method: natural surround with subaqueous tailings deposition, and pervious surround with subaerial tailings deposition.

Creating a pervious surround involves placing a pervious material around the perimeter of deposited tailings to promote groundwater flow around the tailings mass rather than through the tailings mass. Contaminant release from the tailings is then limited due to advection, making the release rate more reliant on the process of diffusion. With the pervious surround, tailings are exposed at the surface because they are deposited subaerially to allow for construction.

The natural surround concept was incorporated into the design of the JEB TMF. This design accommodates subaqueous tailings deposition, which promotes more uniform tailings placement, decreased tailings segregation, and eliminates zones of frozen tailings when compared to subaerial deposition required for the pervious surround system. Frozen layers in the tailings mass would likely impede consolidation of the tailings, resulting in lower tailings densities and higher hydraulic conductivity. The advantages of the natural surround system contribute to producing a tailings mass with a sufficiently low hydraulic conductivity. When the hydraulic conductivity contrast between the consolidated tailings and the surrounding rock is a sufficiently low, as is the case for the JEB TMF, contaminant release from the tailings is dominated by diffusion (Misfeldt et al. 1999) (Figure 2.3-3).



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McCLean Lake Operation

FIGURE 2.3-3
 PLAN VIEW DEPICTING THE PRINCIPLE PHYSICAL CONTAINMENT CONTROL

TAILINGS MANAGEMENT TID



A pervious surround layer between tailings and surrounding rock tends to increase the concentration gradient between tailings pore water and groundwater flow through the pervious surround. This in turn provides a slight increase in contaminant mass flux released relative to the natural surround system (Misfeldt et al. 1999).

The natural surround subaqueous system is also superior to the pervious surround subaerial system for disposal of tailings from high-grade ore. The underwater placement of tailings virtually eliminates dust, and very significantly lowers exposures to radon and gamma fields, thus protecting workers from radiation exposure.

2.3.1.3 Pit Liner Alternatives

The effect of constructing a pit liner to minimize the release of contaminants from the tailings mass was evaluated. The following pit liner alternatives were considered:

- a full pit liner;
- sump liner only; and,
- no liner.

Numerical modelling determined that a full liner, if constructed with a very low permeability, similar to tailings mass, would be slightly more effective than the natural surround design in minimizing diffusive contaminant flux to the surroundings (COGEMA 1997). However, analyses of the short- and long-term environmental behaviour of the natural surround design (no liner) indicated that the estimated contaminant flux was well within the bounds of environmental acceptability.

A sump liner was also determined to have an insignificant effect on reducing contaminant flux, as only a minor component (approximately 4%) of the total contaminant flux was determined to migrate through the area of the sump. Furthermore, since the sump drain extends upward along the pit walls to intersect flow from above the unconformity between the basement gneiss and overlying permeable sandstone, a liner would interfere with movement of this groundwater, thereby reducing the effectiveness of the hydraulic containment of the facility during operations. For these reasons, a liner was not considered in the final design of JEB TMF.

At a later stage, as a part of the JEB TMF Optimization Project design (Section 2.4.1), liner alternatives were evaluated to allow for the tailings pond elevation, and subsequently the elevation of placed tailings to move above the till/sandstone interface during operations. The evaluation of liner alternatives for this project are presented in Section 2.4.1.1.

2.3.1.4 Engineered Cover at Decommissioning

At the decommissioning stage of the TMF, a cover system and slope reduction will be utilized. The cover system will consist of waste rock, a low permeable soil bentonite layer and other layers to complete a final landform. Test plots will be implemented to monitor the performance and optimize the cover the design prior

to decommissioning and implementing the cover system. In addition to the cover system, the TMF slopes will be flattened and the entire facility blended into the JEB clean waste rock pile. This will create a single landform that is also blended into the natural landscape.

2.3.2 Current Facility Operations

2.3.2.1 Tailings Preparation Process

Several key processes are applied to the tailings in the TPP to ensure the long-term geochemical stability of the tailings in the JEB TMF. Long-term geochemical stability is achieved through control of the movement of COPCs into the receiving environment via groundwater. The principal reagents and associated functions of the TPP are summarized below.

Sulfuric Acid: Sulfuric acid is added as required to the mix tank to maintain a pH below 1.4. The low pH neutralizes any carbonate/bicarbonate by generating CO₂ and prevents the precipitation of any dissolved arsenic in the mix tank. The amount of acid required is generally small as free acidity of the raffinate is sufficient in most cases when the two solvent extraction circuits are operating.

Ferric Sulfate: Ferric sulfate is added during tailings preparation primarily to precipitate dissolved COPCs such as arsenic and molybdenum as secondary mineral phases. Additional ferric sulfate is added which precipitates as ferric hydroxide (ferrihydrite) to account for the oxidation of residual primary reduced minerals (e.g. sulphides and arsenides) and the precipitation of COPCs in the placed tailings. This enhances the formation of stable oxidised mineral phases in the JEB TMF as geochemical controls on the potential migration of contaminants to the down-stream environment.

Hydrogen Peroxide: hydrogen peroxide is added as an oxidant to the tailings principally to destroy any hydrocarbons reporting to the tailings from the mill process (principally from solvent extraction crud containing mainly kerosene). Unoxidized hydrocarbons in the placed tailings have been found to gradually oxidize overtime producing highly soluble ionic species that bond with uranium and pull it into solution. The addition of hydrogen peroxide eliminates this process and therefore controls the uranium source term in the placed tailings.

Barium Chloride: addition of barium chloride to the Tailings Neutralization Circuit removes radium-226 from solution through co-precipitation with barium into a low solubility barium sulfate mineral phase which prevents radium from reaching the environment.

Lime: lime addition controls the solution pH at two points in the TNC, first to bring the pH up from approximately 1.4 to 4-4.5 and then moving the pH up again within the range of 7.5 to 8.2 for final tailings discharge. The two-stage pH adjustment is done to maximize the efficiency of arsenic precipitation by ferric sulfate while at the same time controlling nickel and other trace metals (COGEMA 1997).

Tailings Thickener: Geotechnical controls are also imposed on the tailings before their disposal in the JEB TMF which occurs mainly in the tailings thickener. The neutralized slurry from the TPP is forwarded to a tailings thickener. The thickener consists of 18 m diameter tank and a rake mechanism to scrape the settled tailings to the center where the underflow extraction lines are located. Flocculent is added to the tailings before they are fed to the thickener. The tailings are settled to the bottom while tailings thickener supernatant stream (overflow) is pumped to the JEB TMF reclaim pond, for eventual treatment through the JEB WTP. Disposal of thickened tailings was incorporated to minimize the initial water content and segregation of the tailings during deposition. Thickened tailings accelerates the consolidation and minimizes the hydraulic conductivity of the tailings mass.

2.3.2.2 Expanded Tailings Preparation Process

In May 2008, Orano requested approval to proceed with performing improvement activities to the existing TPP (previously referred to as Tailings Neutralization Circuit) as part of the McClean Lake Mill Improvement Program (AREVA 2008a).

In June 2008, Orano received approval from the CNSC under licence UMOL-MINEMILL-McCLEAN.04.2009 condition 3.1 to conduct the Tailings Preparation Process improvements (AREVA 2008a). An Approval to Construct, Alter or Extend a Pollutant Control Facility was issued by the SMOE in June 2008 (AREVA 2008b). Before this work proceeded, mining at the McClean Lake Operation ceased and the improvements were postponed.

In 2011, Orano submitted an application to conduct the McClean Lake Mill Upgrade Project (AREVA 2011c). The physical alterations associated with this project provided the ability for the McClean Lake Mill to achieve an annual production capacity of 24 million pounds (AREVA, 2011c) and process 100% of the high-grade ore slurry from the Cigar Lake Mine. The improvements/expansion to the TPP that had been proposed and approved in 2008 were incorporated into the upgrade construction. The new TPP at the McClean Lake Mill was commissioned and started operating on April 5, 2017. The expanded TPP had three key upgrades:

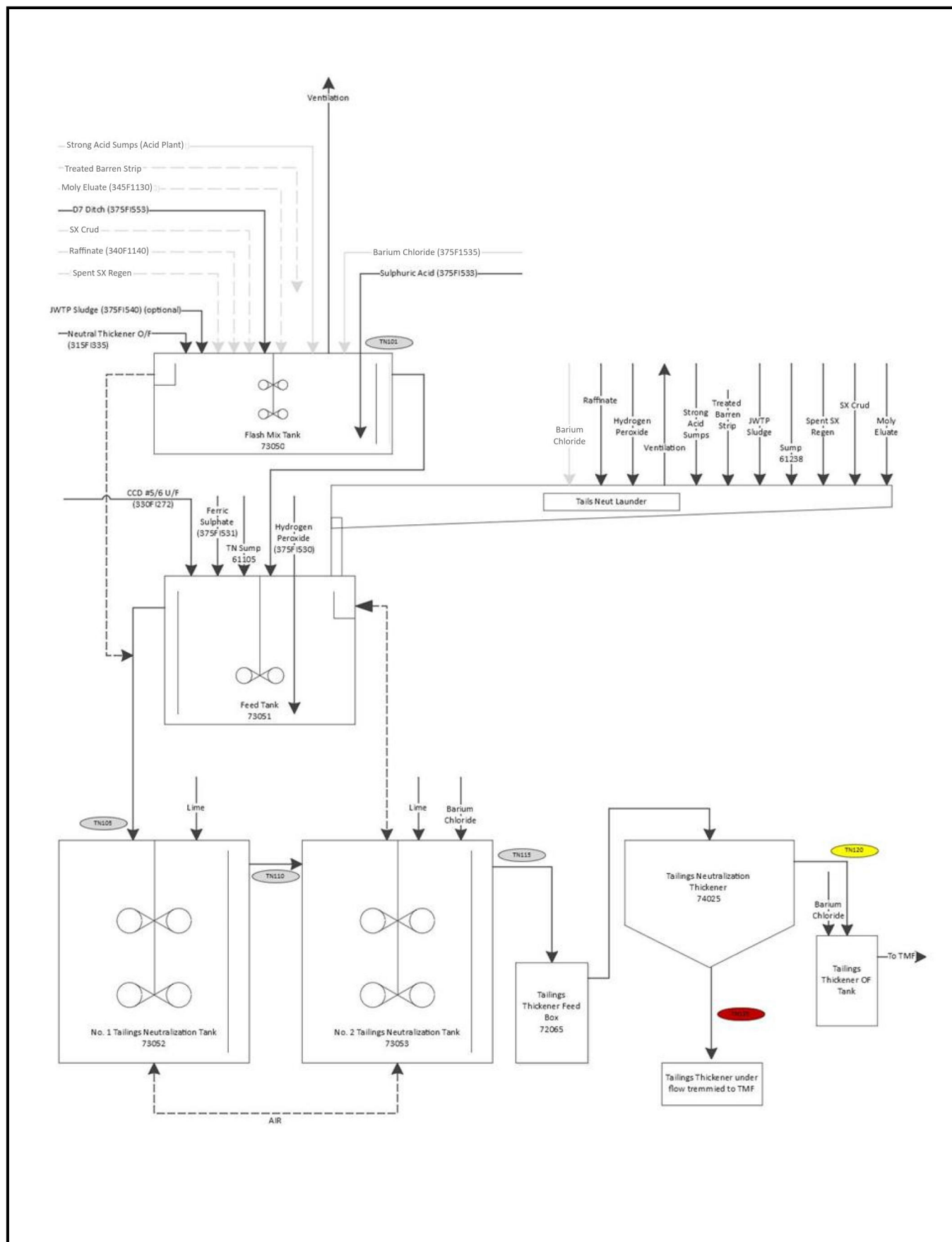
- process tanks (feed and reaction tanks) sizes were expanded to accommodate increased raffinate volumes from the expanded Solvent Extraction (SX) circuits while maintaining the same residence times which are key to successful tailings production.
- a third reaction tank was added (the previous TPP had two) to potentially increase reaction time and also give the flexibility to by-pass one reaction tank in order to conduct cleaning or maintenance without disruption to the tailings production process
- increased pump capacity in the tailings thickener overflow. With the upgrade of the overflow pumping capacity, the tailings thickener can maintain a hydraulic balance and therefore increase the underflow slurry density as required.

Design

The expanded TPP was constructed adjacent to the tailings thickener at the McClean Lake Mill in a new purpose built building (28.5 m in length, 15 m wide and 26.6 m tall). The expanded TPP consists of a mix and a feed tank (each 37 m³), followed by three 315 m³ tailings neutralization tanks, and a 50 m³ sludge tank for receiving and processing waste sludge from the JEB Water Treatment Plant. Provisions have been made to bypass one of the neutralization tanks, if required for maintenance purposes. A summary comparison between the old and new circuits is presented in Table 2.3-2 as well as Figures 2.3-4 and 2.3-5. As is evident from the comparison in Table 2.3-2, the improvement activities associated with the expanded TPP did not change the scope of previous authorized activities pertaining to tailings neutralization. A complete description of the original TPP can be found in the 2015 Tailings Management TID (Section 2.3.1, AREVA 2015a).

Table 2.3-2: Comparison between the Original and the Expanded Tailings Preparation Process.

	Original Tailings Preparation Process	Expanded Tailings Preparation Process
Mix Tank	One 5m ³ mix tank	One 37m ³ mix tank
Feed Tank	One 6m ³ feed tank	One 37m ³ feed tank
Neutralization Tank	Two 150m ³ neutralization tanks	Three 315m ³ tailings neutralization tanks
Sludge Tank	N/A	One 50m ³ sludge tank
Reagents in Neutralization Process	• Sulfuric acid if required for pH adjustment in the mix tank • hydrogen peroxide • ferric sulfate • lime • barium chloride	• Sulfuric acid if required for pH adjustment in the mix tank • hydrogen peroxide • ferric sulfate • lime • barium chloride
Waste Sludge Pumping	Pumped from the JEB Water Treatment Plant combined sludge tank through the tailings neutralization launder to the mix tank	Pumped from the JEB Water Treatment Plant combined sludge tank and the 50m ³ sludge tank located in the new circuit through the tailings neutralization launder to the mix tank



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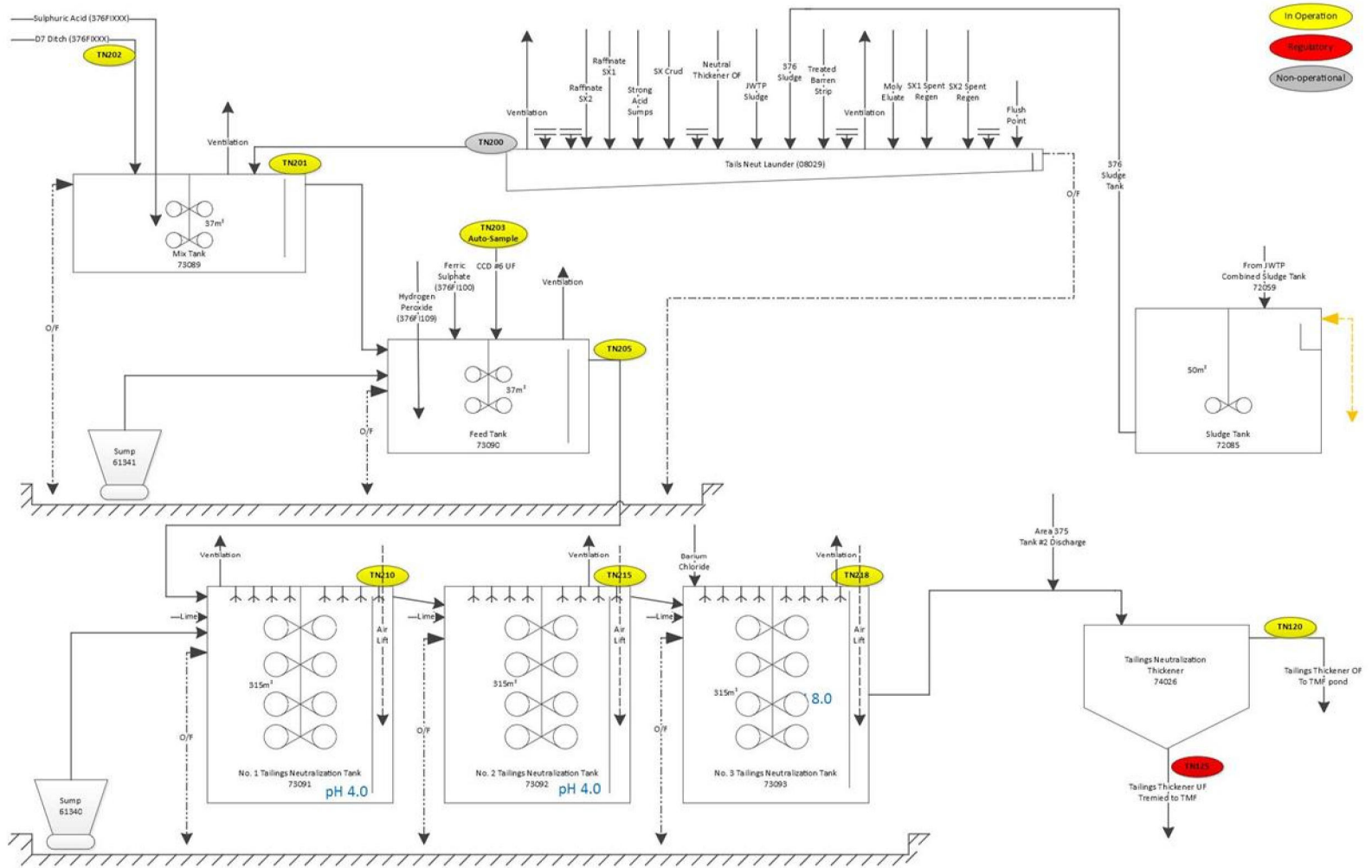
McCLEAN LAKE OPERATION

FIGURE 2.3-4

BLOCK DIAGRAM OF THE OLD TAILINGS PREPARATION PROCESS

TAILINGS MANAGEMENT TID





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FIGURE 2.3-5
BLOCK DIAGRAM OF THE EXPANDED TAILINGS PREPARATION PROCESS

TAILINGS MANAGEMENT TID

McCLEAN LAKE OPERATION



Operation

Similar to the original TPP, the expanded TPP treats the following process waste streams:

- underflow slurry from the last countercurrent decantation (CCD) thickener, CCD #6, carrying washed leach residue;
- raffinate from the raffinate surge tank in the solvent extraction circuits;
- sludge slurry from the JEB Water Treatment Plant;
- solvent extraction circuit cruds;
- spent regenerant solution from the solvent extraction circuits;
- molybdenum eluate from the molybdenum carbon columns;
- supernatant solution from the neutral thickener in the Slurry Receiving Circuit;
- collected run-off from the JEB ore pad;
- process condensate from the Ammonium Sulfate Crystallization process (optional);
- clean-up sumpage that cannot be returned to the process; and
- grey water from the mill dry and office building.

With the exception of the CCD #6 underflow slurry (which is pumped to the feed tank) and the run-off from the JEB ore pad (which is pumped to the mix tank), the rest of the mill process waste streams listed above are introduced into the mix tank of the expanded TPP through the tails neutralization launder (Figure 2.3-5). In the TPP, sulfuric acid, hydrogen peroxide, ferric sulfate, slaked lime and barium chloride are utilized to precipitate COPCs from solution. These reagents are contained in tanks in the reagent area of the plant and pumped to the TPP.

If one of the neutralization tanks in the expanded TPP is bypassed for maintenance, the pH of the first neutralization tank in service would be controlled at approximately 4 and the pH of the second neutralization tank in service at approximately 8.

The neutralized slurry is forwarded to a tailings thickener located adjacent to the expanded TPP. The thickener consists of 18 m diameter tank and a rake mechanism to scrape the settled tailings to the center where the underflow extraction lines are located. Flocculent is added to the tailings before they are fed to the thickener. The tailings are settled to the bottom while tailings thickener supernatant stream (overflow) is pumped to the JEB TMF reclaim pond, for eventual treatment through the JEB WTP.

Tailings are thickened to a target density of ~25% solids by weight before being drawn off the bottom of the thickener by an underflow pump and pumped to the JEB TMF. The process flowsheet is presented as Figure 2.3-6.

The installation of the thickener and associated tanks and pumps is nearly identical to the other thickeners in the Counter Current Decantation (CCD) area. A concrete gallery leads to the bottom of the thickener. The bottom of the thickener cone protruding through a concrete base is lined with a 24 mm thick layer of lead. A second gallery extends out over the top of the thickener to the rake mechanism drives in the center. The thickener is located within a containment structure consisting of a concrete apron with a concrete containment

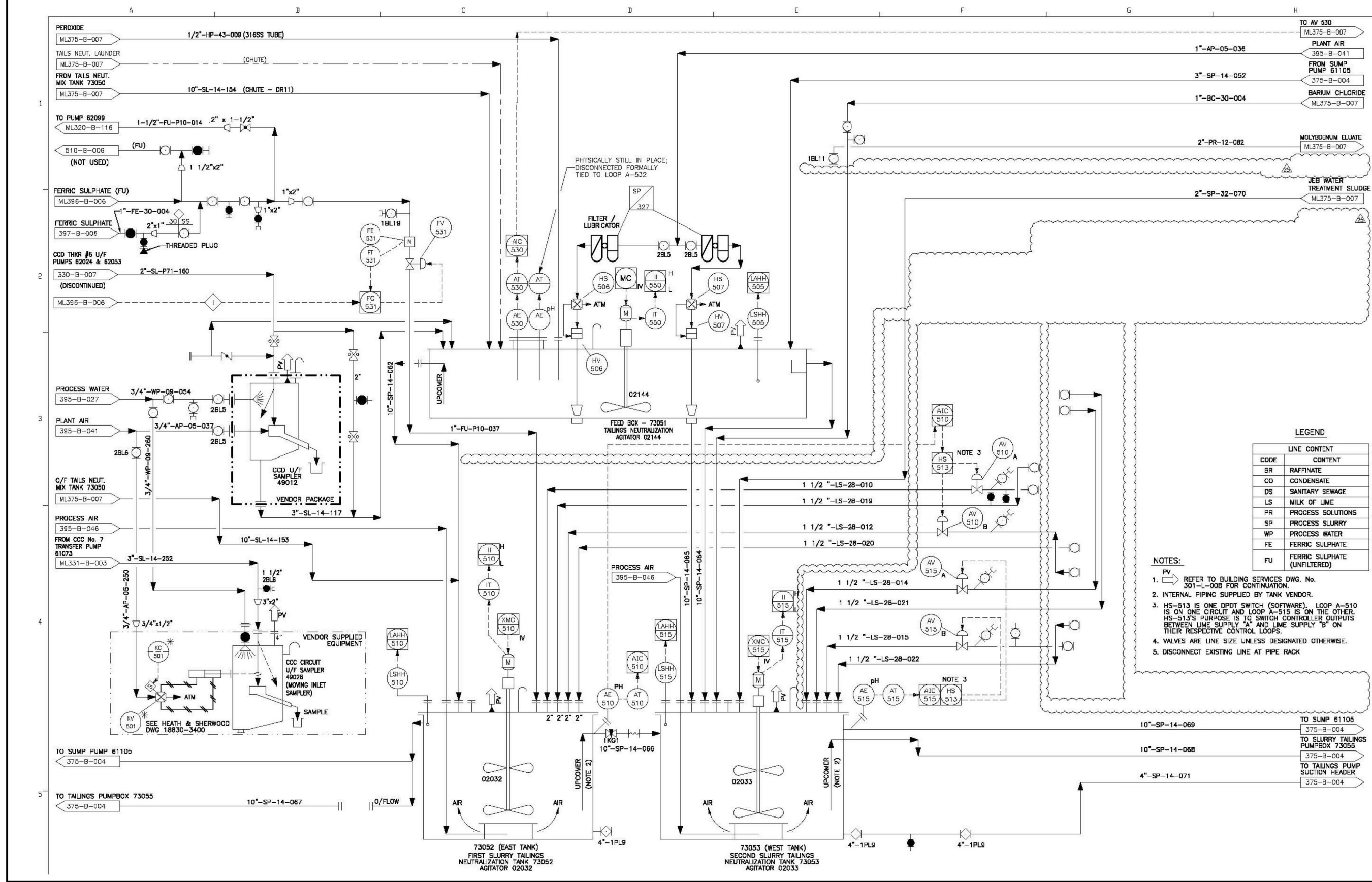
wall surrounding the apron. The structure contains a volume at least 10% greater than the total thickener volume. Details of the installation are provided in Figure 2.3-7

The design scope of the expanded TPP was not outside of previous authorized activities pertaining to tailings neutralization, and the internal Orano mill tailings preparation Administrative limits outlined in the McClean Lake Operation Environmental Protection Code of Practice (ECOP)(Version 4, Orano 2023).

Ferric Sulfate Production

Removal of arsenic (As) from mill waste solutions is achieved in the TPP through co-precipitation with ferric iron. The primary source of ferric iron for arsenic treatment in tailings preparation is dissolved iron from the ore in the raffinate. Additional ferric iron is provided by addition of ferric sulfate reagent. The TPP can use sourced commercial grade ferric sulfate or locally manufactured ferric sulfate produced at the McClean Lake Mill. In both cases, the ferric sulfate is transferred to the mill reagents area. Pumps distribute the solution to the ferric sulfate reagent loop, where an auto-valve controls the addition rate of ferric sulfate to the TPP.

Three ferric sulfate reactors and a product-holding tank have been constructed within the JEB WTP building (Figures 2.3-8A, 2.3-8B, and 2.3-8C). The reactors are fed magnetite ore slurry and sulfuric acid resulting in the formation of a mixture of ferric sulfate and ferrous sulfate. Gaseous oxygen is then sparged into the pressurized reactor vessels to oxidize the ferrous iron. This two-step reaction results in the preparation of a 45% ferric sulfate solution. The ferric sulfate solution is then transferred from the reactors to a holding tank located in the in the JEB WTP (Figure 2.3-9). Upon cooling, the product is routed to the ferric sulfate storage tank in the reagents area (Figure 2.3-10), where it is dispensed for use throughout the mill, as required.



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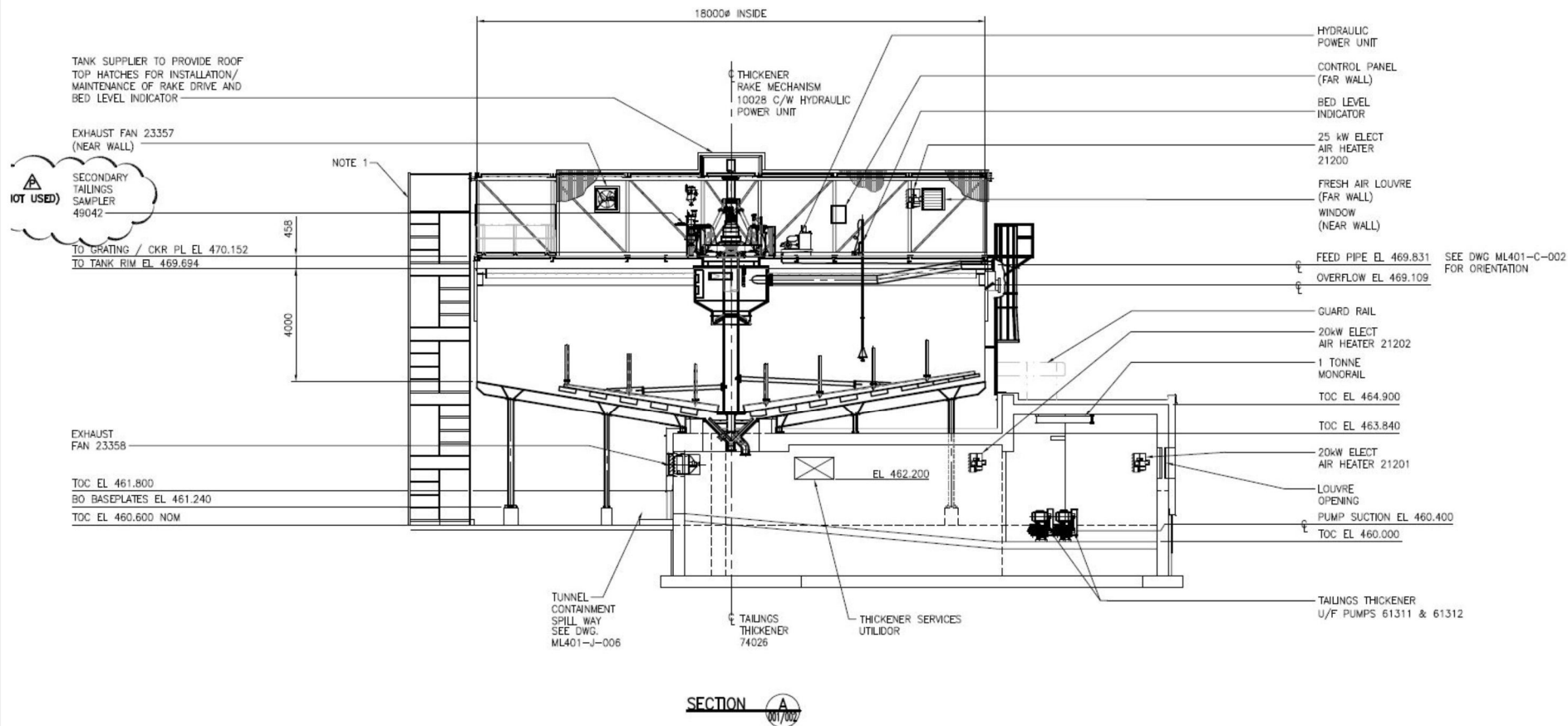
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FIGURE 2.3-6
McClellan Lake Mill Tailings Process Flowsheet

McClellan Lake Operation

Tailings Management TID





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FIGURE 2.3-7
McCLEAN LAKE MILL TAILINGS THICKENING

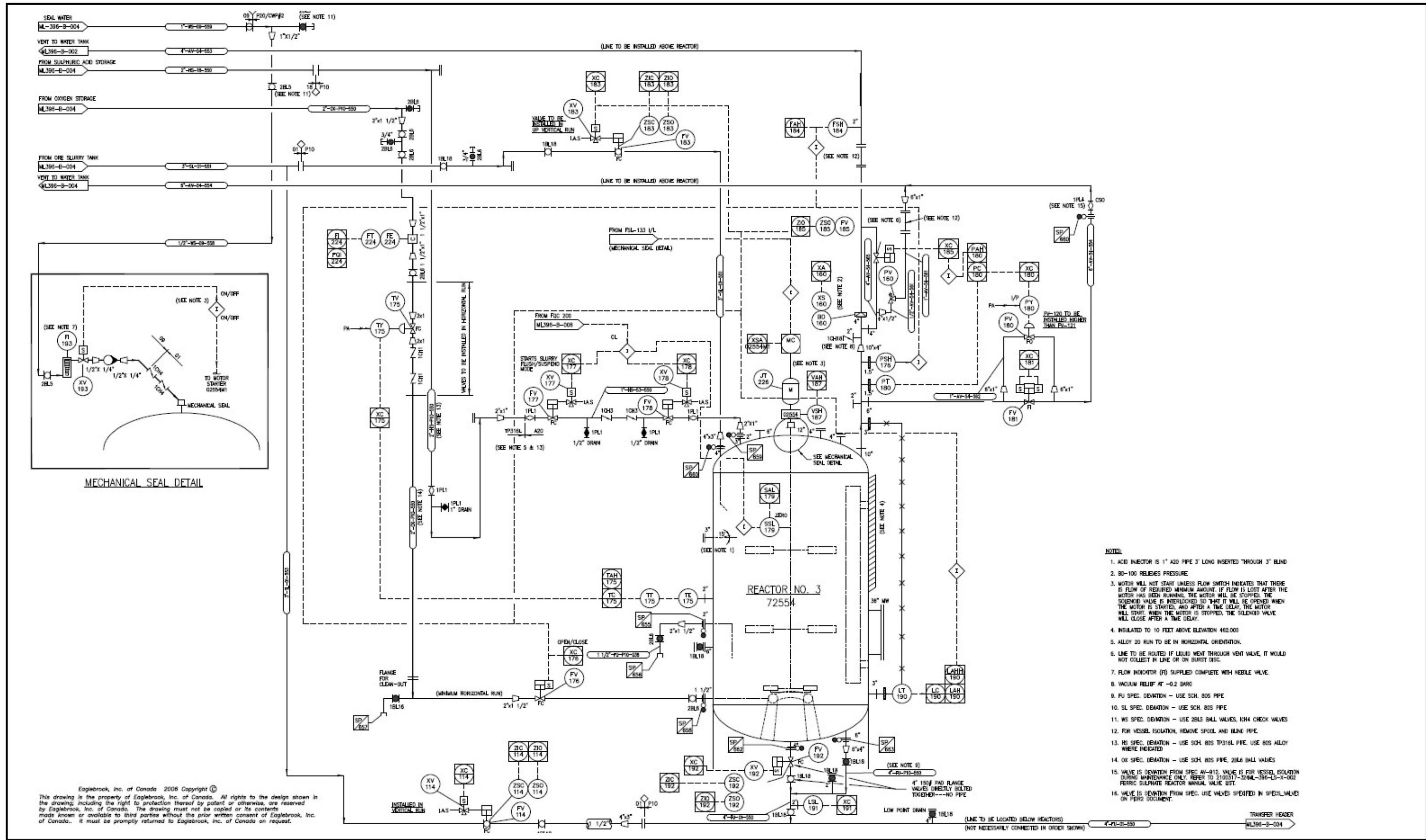
TAILINGS MANAGEMENT TID

McCLEAN LAKE OPERATION



Commercial ferric sulfate which is transported by tanker truck is received as 45% ferric sulfate solution, and stored in a ferric sulfate storage tank in the reagents area of the mill (see Figure 2.3-10). The flowsheet, piping, and instrument diagram for reagent unloading are shown in Figures 2.3-11 and 2.3-12. Figure 2.3-13 shows the piping and instrument diagram for addition of ferric sulfate to the TPP feed tank.

The flow rate of the 45% ferric sulfate solution to the tailings feed tank is monitored with a magnetic flow meter and is adjustable by changing the speed of the ferric sulfate-metering pump.



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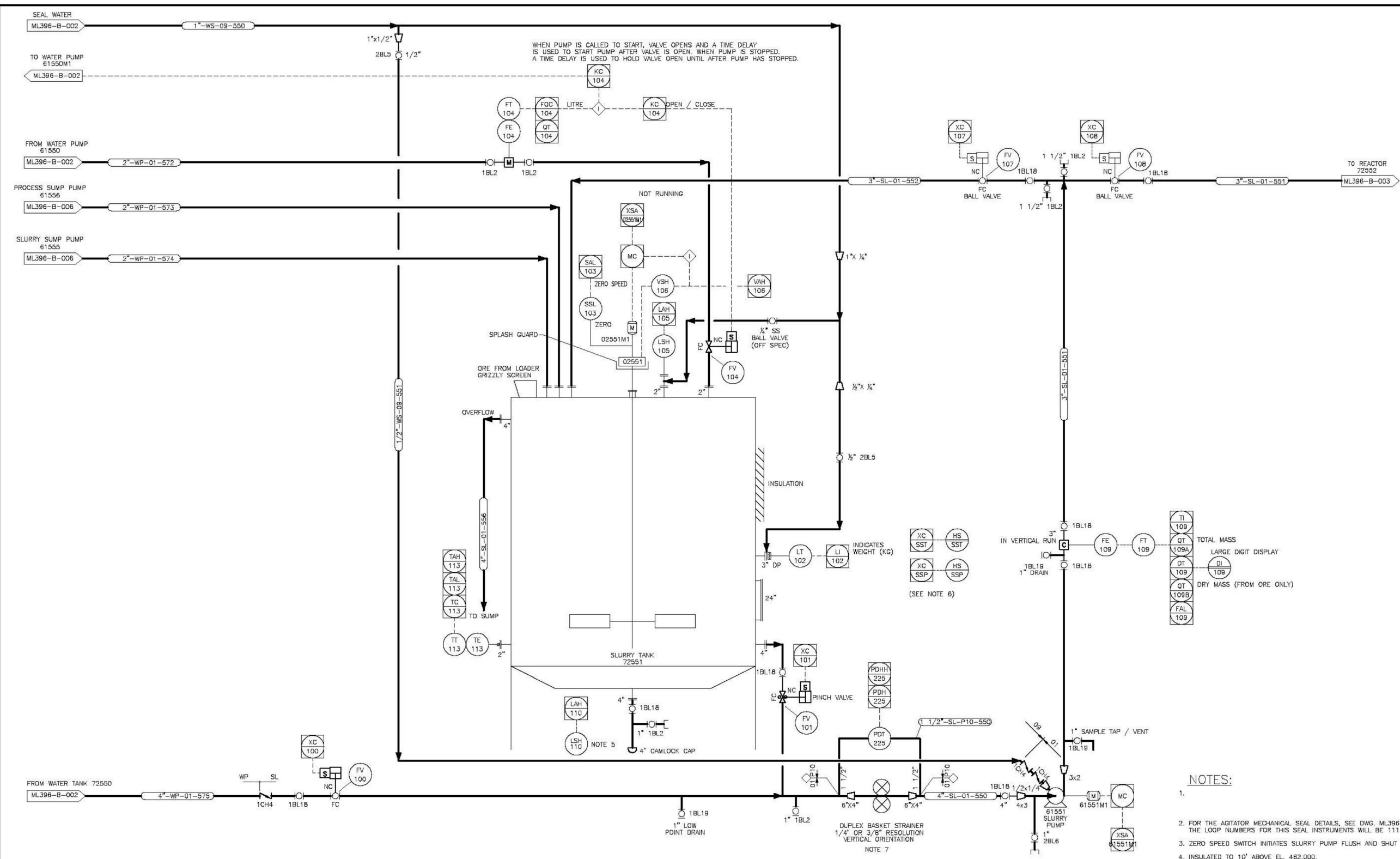
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McCLEAN LAKE OPERATION

FIGURE 2.3-8C
McCLEAN LAKE MILL FERRIC SULPHATE PLANT REACTOR No.3

TAILINGS MANAGEMENT TID





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ZERO SPEED SWITCH SHUTS OFF ORE ADDITION WHEN MADE AND OPENS FV100 TO FLUSH WATER INTO SLURRY TANK

NOTES:

- 1.
2. FOR THE AGITATOR MECHANICAL SEAL DETAILS, SEE DWG. ML396-B-003. THE LOOP NUMBERS FOR THIS SEAL INSTRUMENTS WILL BE 111.
3. ZERO SPEED SWITCH INITIATES SLURRY PUMP FLUSH AND SHUT DOWN.
4. INSULATED TO 10' ABOVE EL. 462.000.
5. CONTAINMENT ALARM LOCATED AT LOWEST POINT OF FERRIC PLANT.
6. FIELD PUSH BUTTONS TO START AND STOP SLURRY MAKEUP PROCESS
7. SEE "SURE FLOW EQUIPMENT INC. DRAWING # Q07019" FOR DUPLEX STRAINER DETAIL.
8. 398-F-110 INSTRUMENT INTERNAL COMPONENTS REMOVED.

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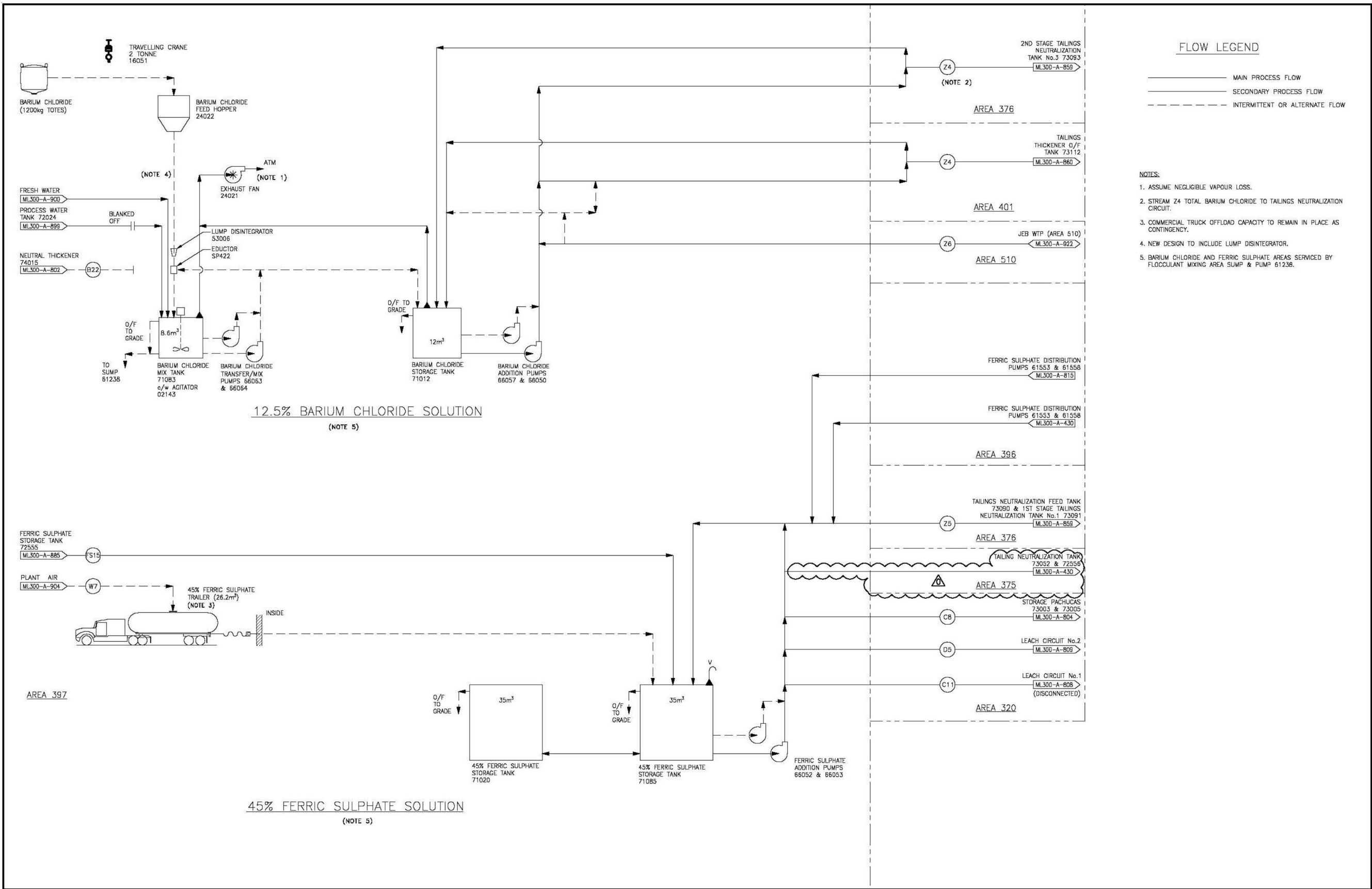
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McCLeAN LAKE OPERATION

FIGURE 2.3-10
 McCLeAN LAKE MILL FERRIC SULPHATE PLANT SLURRY TANK

TAILINGS MANAGEMENT TID





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FIGURE 2.3.11
McCLEAN LAKE MILL BARIUM CHLORIDE AND
FERRIC SULPHATE PROCESS FLOWSHEET

McCLeAN LAKE OPERATION

TAILINGS MANAGEMENT TID



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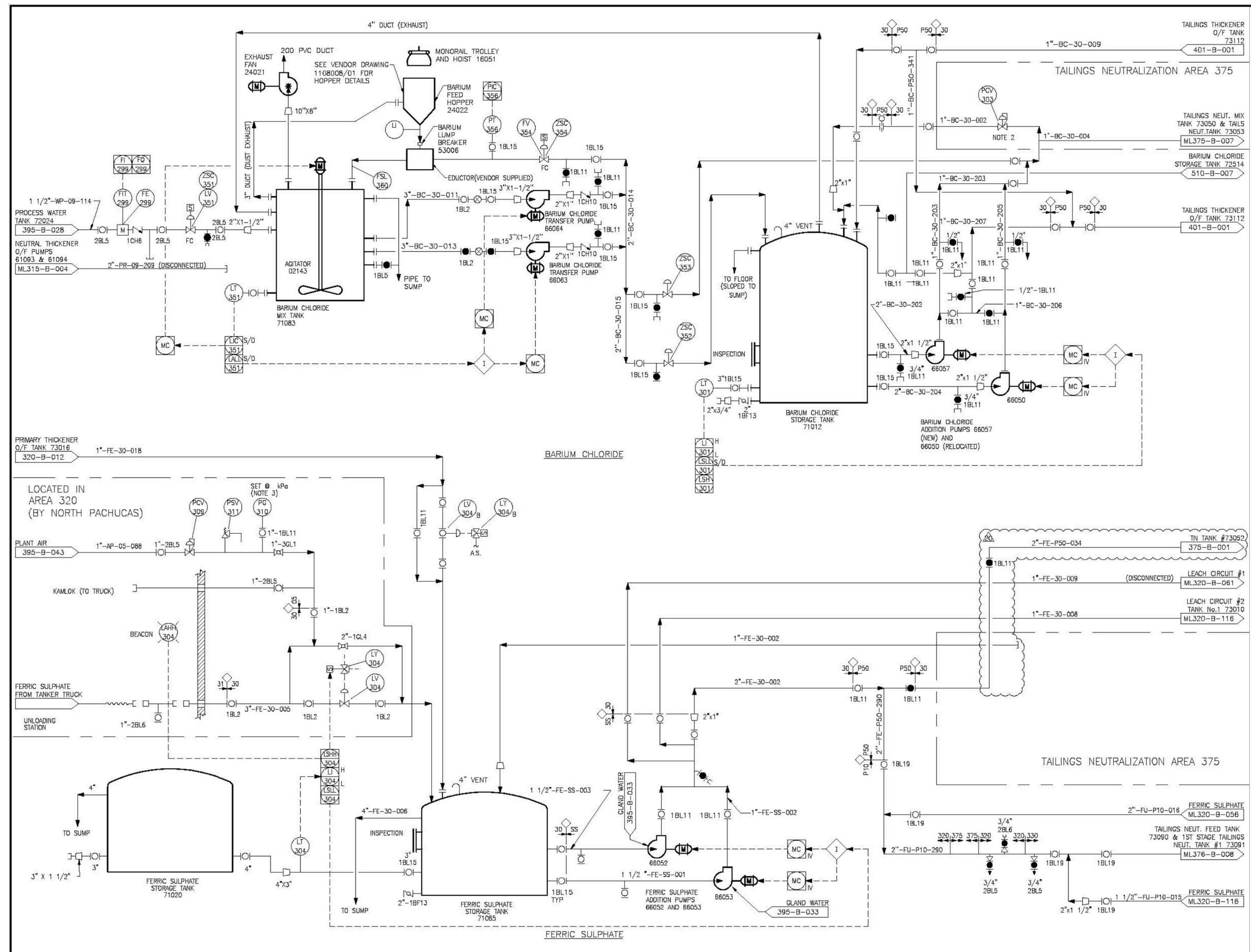


FIGURE 2.3-12
McCLEAN LAKE MILL PROCESS PLANT PIPING AND INSTRUMENTATION
DIAGRAM BARIUM CHLORIDE AND FERRIC SULPHATE

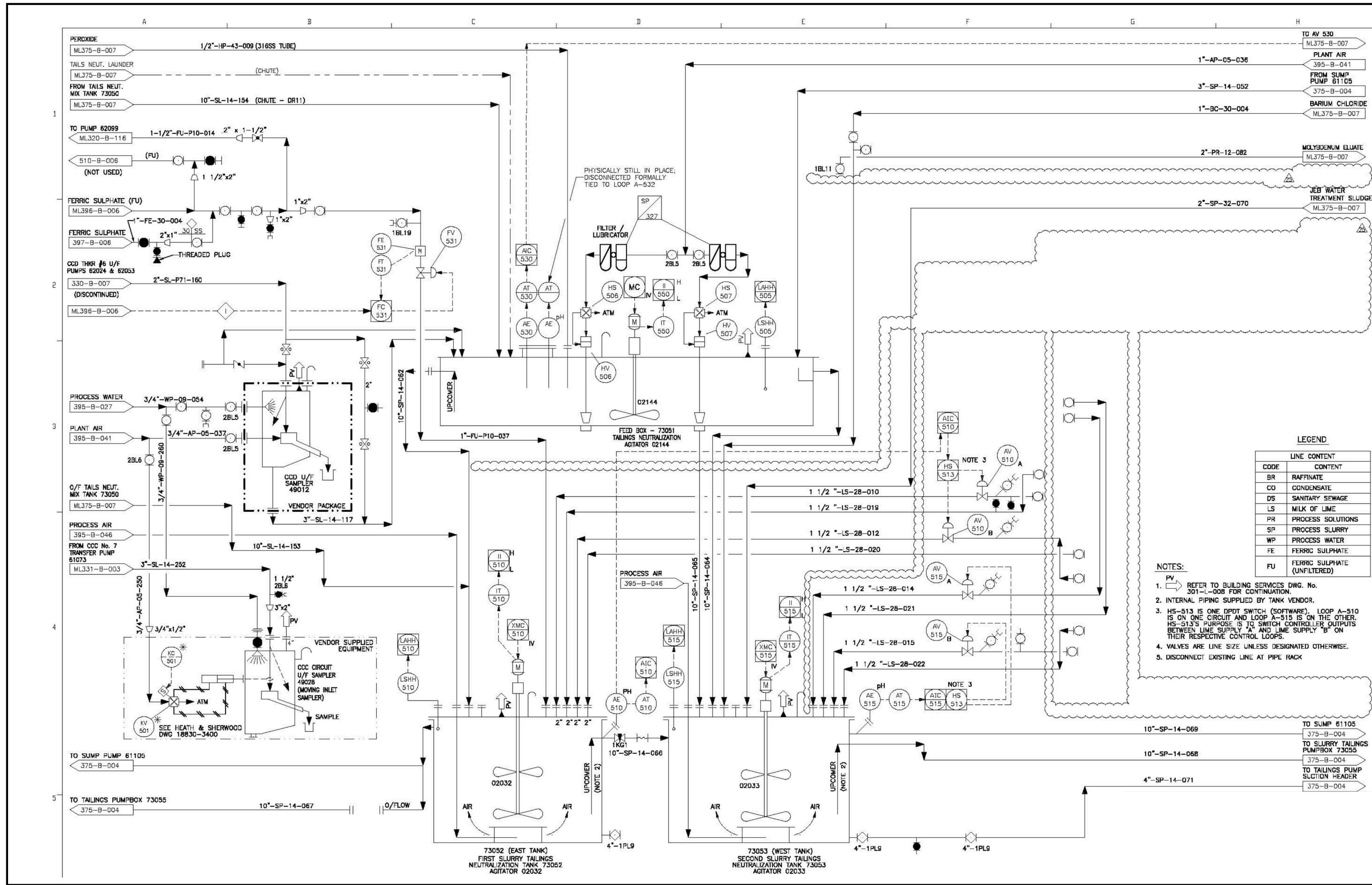
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McCLEAN LAKE OPERATION

TAILINGS MANAGEMENT TID





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FIGURE 2.3-13
McCLeAN Lake Mill Process Plant Reagents
PIPING AND INSTRUMENTATION DIAGRAM

McCLeAN LAKE OPERATION

TAILINGS MANAGEMENT TID



Barium Chloride Addition

Radium is removed from solution through a barium sulfate co-precipitation mechanism by adding barium chloride in the TPP. Barium chloride is received in 1200 kg totes. Individual totes are placed on a hopper on top of the automated mixing apparatus. A negative ventilation system is incorporated into the mixing system to ensure that the barium chloride dust is contained. The barium chloride solution is made up to an approximate concentration of about 12.5% by weight and transferred by pump to a storage tank. The prepared barium chloride solution is metered to the TPP. A sight flow indicator is installed at the discharge of the barium chloride-metering pump for local flow monitoring and control. All operating data for the radium treatment process is archived in the mill database.

The mix tank and storage tank are located in the same general reagents area as the ferric sulfate tank, as shown in Figure 2.3-10. The flowsheet, piping and instrument diagram for the barium chloride mixing and transfer system are shown in Figure 2.3-13. The piping and instrument diagram (Figure 2.3-13 shows the optional addition of barium chloride to the tailings neutralization feed box or the final neutralization tank. The preferred addition point, based on operational performance, is neutralization tank #2 and neutralization tank #3 if required.

Performance

For the purposes of this document the performance of the expanded TPP is considered from April of 2019 to March of 2024. Results are compared to current Administrative Levels for as-discharged tailings as presented in Section 2.2.1. Over the current period of operation of the expanded TPP:

- Arsenic nickel and radium concentrations in the pore water of the tailings thickener underflow slurry have consistently been below the internal Administrative Levels of 1 mg/L, 1 mg/L and 200 Bq/L respectively as outlined in the ECOP (Orano, 2023).
- The tailings thickener underflow pore water pH averaged is 8, which is within the internal administrative levels $7.5 < \text{pH} < 8.5$.
- The tailings thickener underflow slurry density (% solids) have also seen improved consistency since the start of operation of the expanded TPP; averaging at 24.7% solids (w/w) which is just below internal Administrative Level of 25% solids (Table 2.2-2). The improvement in the consistency of the slurry density is in comparison with challenges of achieving the target underflow slurry density encountered at the start of the milling of Cigar Lake ore (AREVA, 2015b).

The expanded TPP was fully commissioned, with full-time operation beginning in April 2017. Cumulative waste stream flow rates to the TPP have averaged $\sim 100 \text{ m}^3/\text{hr}$. Since the commissioning and start of operation, the expanded TPP has performed consistently to the criteria detailed in both the Tailings Optimization and Validation Program (AREVA, 2015a) and the ECOP (Orano, 2023). The temporal bypass of neutralization tank #1 or #2 for maintenance have not affected the TPP as it is a provision in the design of the expanded TPP to bypass one of the neutralization tanks if required for maintenance purposes.

2.3.2.3 Tailings Delivery System

The routing of the pipeline from the McClean Lake Mill to the edge of the JEB TMF is shown in Figure 2.3-14. The underflow (UF) from the tailings thickener is routed to one or both underflow pumps located in the tailings thickener UF “tunnel” and then through one of two independent (one standby), three-inch diameter high density polyethylene (HDPE) pipelines. The specifications for the HDPE pipelines are DR-11 (1,100 kPa [160 psi] rating) from the underflow pumps to the crest of the JEB TMF and DR-17 (1,379 kPa [200 psi]) from the crest to the bottom of the pit. The primary carrier pipelines are continuous, without flanges or fittings, along the entire route to the bottom of the JEB TMF. A dual containment system is used from the CCD building to the edge of the pit and a single carrier pipe from the edge to the bottom.

From the discharge of the pumps, the pipelines are routed upward about 5 m before exiting the building. This routing facilitates the drainage of the lines when the pumps are stopped. Vacuum release valves are installed at the peak of the upward loop to prevent a vacuum from developing in the pipelines when the pumps are stopped, which could prevent draining of the tailings lines.

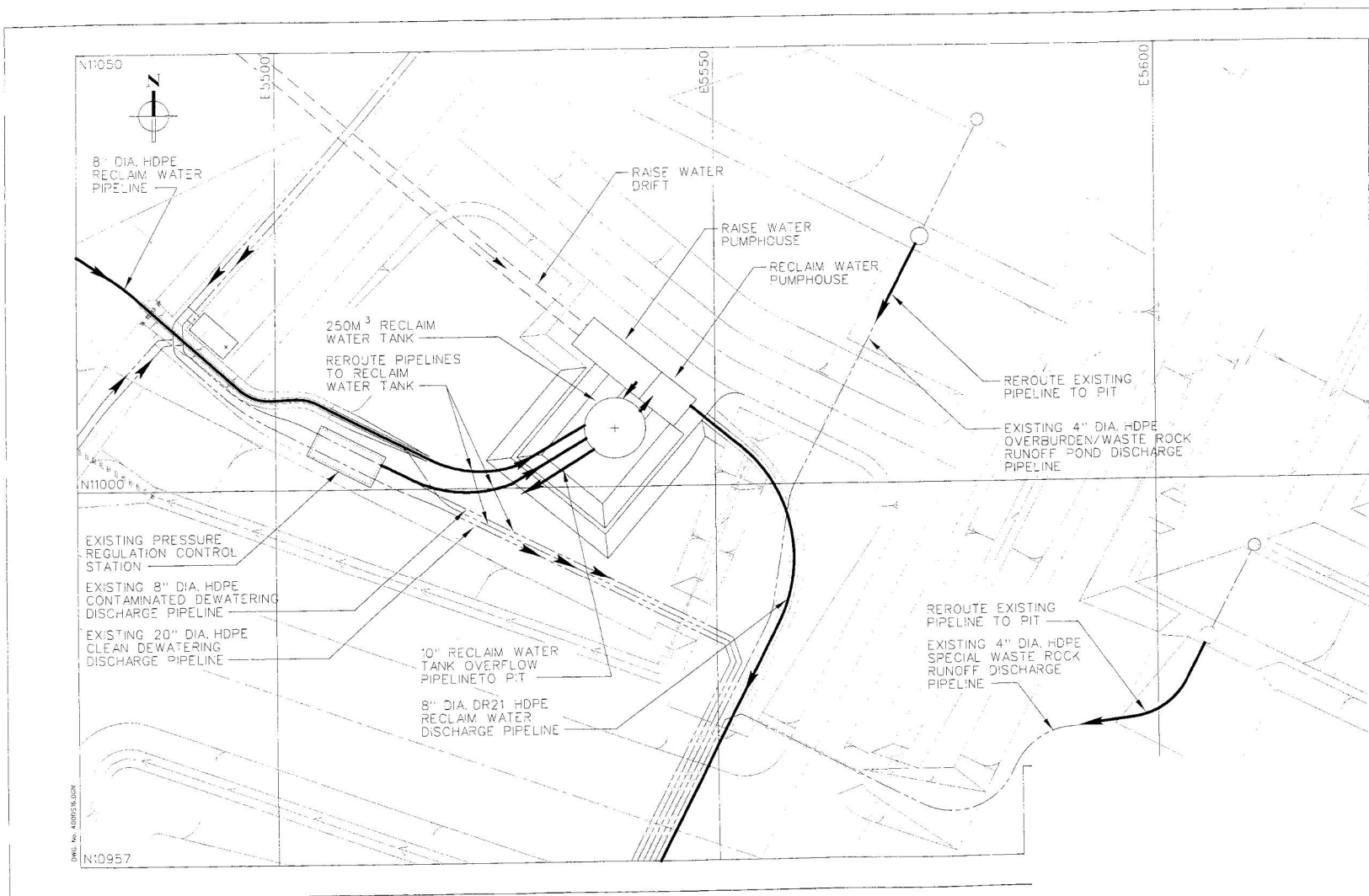
Once the pipelines exit the building, they descend to ground level where they are routed along a pipeline bench which extends the entire length (approximately 600 m) to the pit crest. There are two road crossings along the route where the tailings pipelines are enclosed in corrugated steel pipes (CSP) for protection. The berms are graded to provide a continuous downward slope along the entire route to promote draining of the pipeline to the JEB TMF.

Access to the bottom of the JEB TMF is provided with a ramp, which circles the pit to maintain a downward grade of approximately 10%. The pipeline bench is separated from the ramp by a safety berm to prevent them from being damaged by vehicle traffic.

Dual Containment

The entire length of pipeline from the end of the dual containment piping to the bottom of JEB TMF is insulated with urethane foam. The air space in the annulus of the dual containment system pipeline provides sufficient insulation to prevent the tailings from freezing during the winter.

In the event of a leak in a pipeline inside of the CCD building, the floors are sloped so that the leakage is directed to a sump. Any spillage is pumped back into the circuit.



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FIGURE 2.3-14
 THICKENED SLURRY TAILINGS ROUTING

TAILINGS MANAGEMENT TID

McCLEAN LAKE OPERATION



The secondary containment pipeline is a dual containment system specially designed by PLEXCO engineering. The piping sections are fabricated in 12 m lengths, which consist of the containment pipe, the carrier pipe, and all the internals. A centralizer has been fusion-welded to both pipes at each end of a piping section. The centralizer ensured that neither of the pipes would move during the fusion welding of two sections of pipeline plus it restricts any differential thermal expansion between the outer and the carrier pipe within each section. The centralizers consist of an HDPE disc with four holes in it with a diameter of 0.75 inch (~1.9 cm) each. The annulus between the containment pipe and the carrier pipe is maintained along the entire length of each piping section by the installation of "spiders" at intervals of about 1.2 m. The design of the secondary containment pipelines is shown in Figure 2.3-15.

The dual containment piping system is divided into three monitoring zones with approximately 200 m of pipeline in each (see Figure 2.3-14). At the downstream end of each zone, an end seal was welded to both pipes to block the annulus to provide a location to monitor for leakage from the carrier pipe into the annulus. This seal would also contain any leakage within one zone. Upstream of the end seal, a piping tee was installed in the outer 8-inch pipe and contains a flanged cap. An ultrasonic, gap type, level switch was installed at each tee to detect the presence of water in the annulus of each zone. The wires from the level switch were run to the control room to indicate an alarm to the operators in the event of a leak in the carrier pipe. The wires from the level switches were run through a separate conduit located outside the dual containment piping. The level switches are easily tested by simply removing the cap on the tee, removing the switch and immersing it in a liquid to initiate an alarm. Details of the monitoring system in the secondary containment pipeline system are shown in Figure 2.3-15.

The dual containment system piping is easily repaired and provides proper protection of the worker in the unlikely event of leakage of the carrier pipe or plugging of the tailings line. It is particularly well suited to contain any leakage outside of the carrier pipe within the annulus so that a spill of tailings material does not occur.

A leak in the carrier pipe into the annulus would be detected in the applicable zone and the underflow pumps would be stopped immediately. Operation is resumed by switching to the standby tailings line. A flush connection for the tailings line has been provided in the mill to allow the carrier line to be flushed with water to the JEB TMF. The section of pipeline with the leaking pipe contains a larger deposit of tailings solids than other sections of pipe in the zone. This section is readily detected by scanning the pipeline with a gamma radiation probe. Depending on the extent of the tailings release into the annulus, the annulus would either be flushed using a nozzle which is installed at the upstream end of each zone and the material and water collected at the tee, or, the section of piping with the leak would be simply cut out of the line. The design of the dual containment system allows one or more sections of 12 m of piping or the entire 200 m in a zone to be cut and removed from the pipeline. Normally, the pipeline would be cut at a fusion weld, which is located either between two centralizers or between a centralizer and an end seal. The section of pipe would be removed and a new section butt fusion welded into the location. If it were necessary to cut the pipe in an area where a centralizer is not located, a new centralizer would be fusion-welded into each section of pipe using a special fusion head. The two sections of pipe would then be butt fusion welded together as usual.

The pipeline is located on an elevated berm, which allows leakage resulting from cutting the pipeline to be collected. A plastic apron would be placed under the pipeline and the leakage directed into a collection tank placed beside the berm. The collection tank would typically be a section of pipe, 24 to 36 inches in diameter,

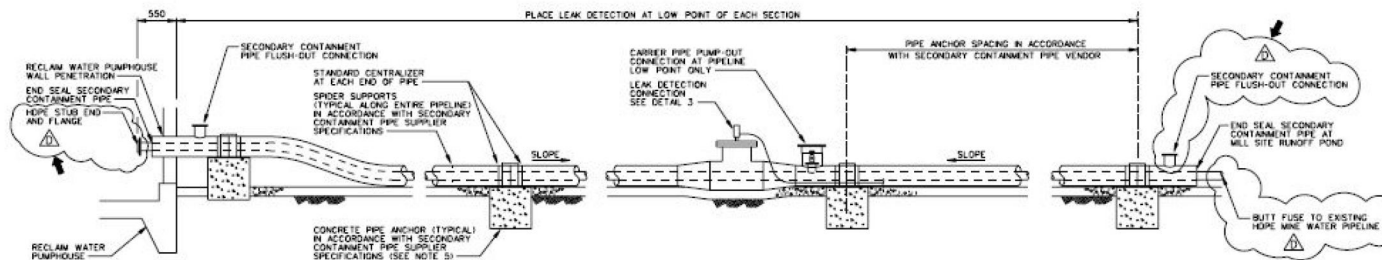
with end seals and nozzles fused onto it. Alternatively, either a vacuum truck would be used to collect the leakage or a specially designed hard plastic collection sleeve would be placed around the pipeline to direct the flow to a tank. The best alternative to prevent spillage would be determined by the location of the pipe to be cut.

For a plugged carrier pipe, the location of the plug would also be detected with a gamma probe. The plugged sections would be cut out of the pipeline and reinstalled using the same procedure as for the leaking carrier pipe. However, in this case, the pipeline upstream of the plug would be depressurized before it is cut. A robar connection would be attached to the pipeline immediately upstream of the plug location. A hole would be drilled into both the containment and carrier pipes through a valve to prevent the pressurized contents from spraying out. A hose would be connected to the robar and the pipe depressurized by draining the contents to a container or the tailings pond through a valve. The annulus would be cleaned as described previously. A plastic sheet would be placed under the pipeline wherever it would be cut to divert any leakage to a storage container. Normally, an extracted section of pipeline that could not be reused would be disposed of in the contaminated materials landfill.

At the pit crest, the three-inch tailings pipelines are routed along the pipe bench that runs along the outside edge of the ramp down to the bottom of JEB TMF. If a leak were to develop, the tailings would flow down into the pit. In this case, the line would be flushed prior to cutting the damaged section out of the line and a new section butt fusion-welded into the line. Any tailings within the bermed pipe bench from the leak would either be washed to the bottom of the pit or the material excavated with machinery and transported to the JEB TMF.

If the pipeline were to become plugged partway down into the pit, extra precautions would be required to depressurize the pipeline before it was opened. In this case, a robar coupling would be installed on the pipeline immediately upstream of the plug location. The pipeline would be depressurized by drilling a hole in the pipe through a valve and draining the contents either to a container located beside the berm or directly to the tailings pond. The section of pipeline containing the plug would be cut out and a new section fusion-welded into it. A plastic sheet would be placed under the pipeline wherever it was cut to divert any leakage to a storage container.

The dual containment system piping provides the best protection for the worker should a problem occur. Tailings would be contained in the event of failure of the carrier pipe. The carrier pipe would be flushed of tailings material prior to cutting it. The pipeline would be cut at a location, which would provide sufficient distance from the contained tailings material to minimize radiation exposure and tailings leakage could easily be collected to prevent a spill. In the event that the pipeline was plugged, precautions would be taken to depressurize the pipe prior to repairing it. McClean Lake Operation maintenance personnel receive training on the various repair procedures associated with the pipelines prior to performing any repairs.



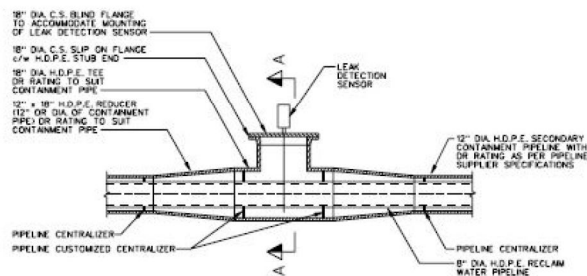
DETAIL 1
RECLAIM WATER / RAISE WATER PIPELINE
SECONDARY CONTAINMENT SYSTEM
CONCEPTUAL LAYOUT
N.T.S.

NOTES:

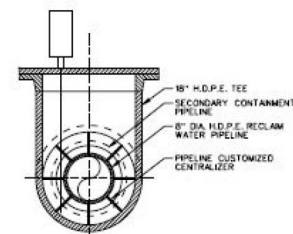
1. GRID SYSTEM IS CODEMA RESOURCE'S INC. MINING GRID BASED ON UNIVERSAL TRANSVERSE MERCATOR, NORTH AMERICAN DATUM (NAD27). CODEMA Q N IS UTM 5456000N CODEMA Q E IS UTM 563000E
2. ALL CO-ORDINATES ARE IN METRES.
3. ALL ELEVATIONS ARE GEODETIC DATUM IN METRES AND DECIMALS THEREOF.
4. ALL DIMENSIONS ARE IN MILLIMETRES, UNLESS NOTED OTHERWISE.
5. NEW DISCHARGE PIPELINE RESTRAINTS AND CONCRETE PIPE ANCHORS WILL BE PLACED INDEPENDANT OF EXISTING SUPPORTS WHERE REQUIRED. PIPE RESTRAINT AND CONCRETE PIPE ANCHOR DESIGN TO BE IN ACCORDANCE WITH PIPE SUPPLIER SPECIFICATION.

LEGEND

NEW FACILITY OUTLINE.....
EXISTING FACILITY OUTLINE.....



DETAIL 3
LEAK DETECTION SYSTEM
CONCEPTUAL PROFILE
N.T.S.



SECTION A-A
N.T.S.

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Date:
Data Sources: 400DSK5

Drawn:
Scale:

McCLEAN LAKE OPERATION

FIGURE 2.3-15
TAILINGS DISPOSAL AND TAILINGS DISCHARGE PIPELINES

TAILINGS MANAGEMENT TID



2.3.3 JEB TMF Design: Open Pit

Following the completion of JEB mining, the top perimeter of the mined-out pit was approximately circular with a diameter of about 420 meters. The facility was excavated through approximately 10 m of glacial till overburden, 75 m of sandstone, and into the granitic basement rock to a total depth of approximately 118 m below grade.

Pit Wall Stability: During excavation of the JEB pit benches were constructed at intervals as the pit was mined, providing a more stable pit wall. A ramp was constructed from the top to the bottom of the pit at an average grade of 10%. The stability of rock slopes, as well as the stability of the overburden slopes, in both the short- and long term, were considered during construction. The following Sections outline the design of both the overburden slopes and the rock slopes and provide an overview of the construction experience.

Overburden Slopes: The area of the JEB TMF has a groundwater table at surface, and so the estimated factor of safety of the overburden slopes was 1.5, which meets the largest long-term factor of safety of 1.25 with respect to slope stability. The safety of the slopes was reinforced by the wide (22 m) safety berm at the top of the bedrock that safely contained any sloughing or slumped material.

As part of the JEB TMF Optimization and Expansion projects, overburden till slopes were flattened to a final slope of 3H:1V to provide a stable slope suitable for liner construction. Details are discussed further in Section 2.2.3.

Rock Slopes: The overall backwall design slope in the rock section is 45°. Structural measurements of the major joints (more than 3,000 measurements) have been collected over the full depth of the JEB pit and are presented in Appendix B, Section B. Details of the data collection and analysis of the rock slopes is included in Appendix B, Section C. None of the analyses identified unacceptable risk of major slope failures within the JEB pit, but indicated that some ravelling and minor toppling of the slopes could be expected. Scaling and inspection was recommended to control ravelling, including routine inspection and maintenance of the safety berms.

Regular geologic mapping of the pit was conducted as mining progressed. The pit was constructed as designed but, locally, overbreak has caused some oversteepening on backwalls, and ravelling has encroached on the safety berms, reducing their width over short sections. There was a low potential for major slope failures within the pit. There was a higher potential for minor plane failures when shallow dipping structures daylight on the backwalls. With the continued filling of the JEB pit the possibility of failures has been eliminated.

2.3.4 JEB TMF Design: Tailings Management

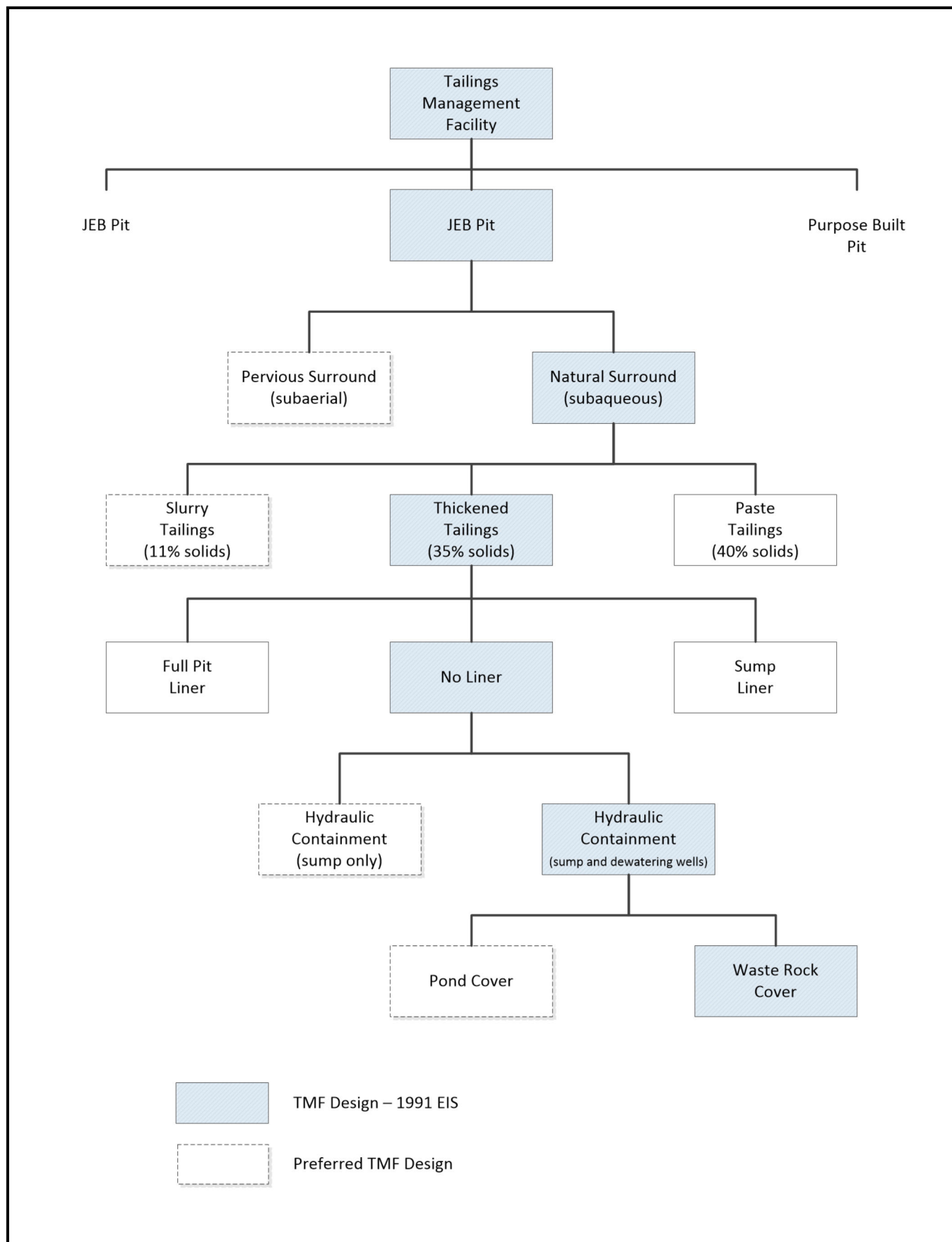
The JEB pit is 120 m deep from the lowest point at the bottom of the pit (342 mASL) to natural ground at the raise water wells (462 mASL). The cross-sections on Figure 2.3-17 show that the natural dimensions at the top of the pit are approximately 350 m in the north-south direction and 460 m in the east-west direction. The cross-sections also show that benches were constructed at intervals as the pit was mined, providing a more stable pit wall. A ramp was constructed from the top to the bottom of the pit at an average grade of 10%.

The following components were installed in the JEB open pit to create the JEB TMF:

- perimeter dewatering wells (now decommissioned) for a full description see (COGEMA, 2004);
- base filter/drain connected by a drift to the raise water reclaim system; and,
- pond water reclaim system.

The preferred option for tailings management at the McClean Lake Operation is provided in Figure 2.3-16. The preferred option consists of producing thickened tailings that are neutralized and treated to control radium-226, arsenic, and nickel concentrations. Tailings are disposed within a JEB TMF constructed in the mined out JEB pit. The JEB TMF utilizes a natural surround system. Tailings are currently deposited subaqueously using an extended line supported by a float and anchor system. The base drain and graded filter package, constructed at the bottom of the pit of sand and crushed rock, collects tailings pore water, contains the tailings solids above the filter, and enhances tailings consolidation by promoting dissipation of excess pore water pressure within the tailings mass. Water collected in the base drain is pumped to surface for recycle or treatment through a dewatering drift and raise system.

Figure 2.3-1 provides an overview of JEB TMF and associated components.



Projection: N/A
 Compiled: T.Lohman
 Date:
 Data Sources:

Drawn: T.Lohman
 Scale:

FIGURE 2.3-16
 JEB TMF PREFERRED DESIGN OPTIONS

McCLEAN LAKE OPERATION

TAILINGS MANAGEMENT TID



2.3.4.1 Filter and Base Drain

Design

The filter and drain design at the bottom of JEB pit has been designed to collect groundwater and allow movement of water downward around the perimeter of the pit. The drain design consists of three filter zones consisting of a coarse drain rock, a filter gravel, and a filter sand (Figure 2.3-17).

When mining of JEB pit was completed in July 1997, groundwater was observed flowing into the pit at several locations around the perimeter. All inflows were occurring at the base of the sandstone along the unconformity, which varies slightly in elevation around the pit. The lowest elevation of inflow was around 353 mASL and the highest at nearly 370 mASL (Figure 2.3-18 for seepage locations).

The purpose of the JEB TMF base drain/filter is to allow drainage of the tailings mass to promote tailings consolidation. Maintaining a lower head in the filter, in conjunction with pumping from the pond will also maintain hydrodynamic containment throughout operations.

The JEB base filter was designed as a zoned filter consisting of a filter sand layer, a filter gravel layer, and a drain rock layer with layers becoming progressively coarser towards the base. The filter sand layer collects drainage from the base of the tailings mass and prevents migration of tailings fines into the base filter. The filter gravel layer acts as an intermediate zone between the filter sand and drain rock to prevent migration of filter sand material into the drain rock layer while allowing flow from the filter sand to enter the drain rock layer. The drain rock layer collects flow from the filter gravel and from the base of the sandstone above the unconformity and conducts these flows to the dewatering drift.

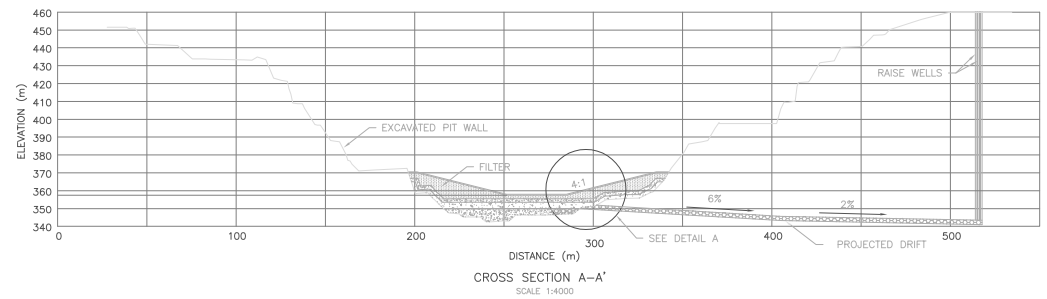
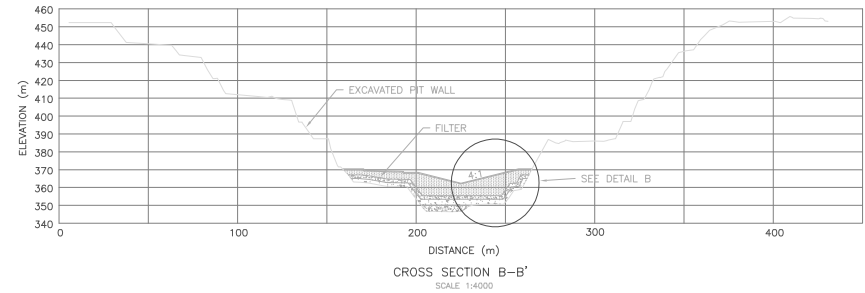
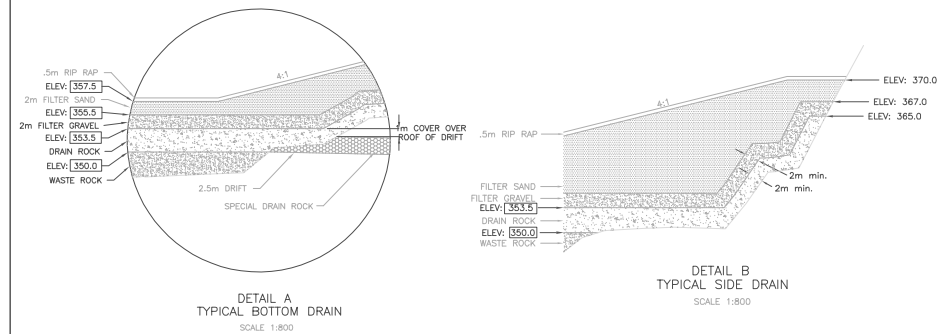
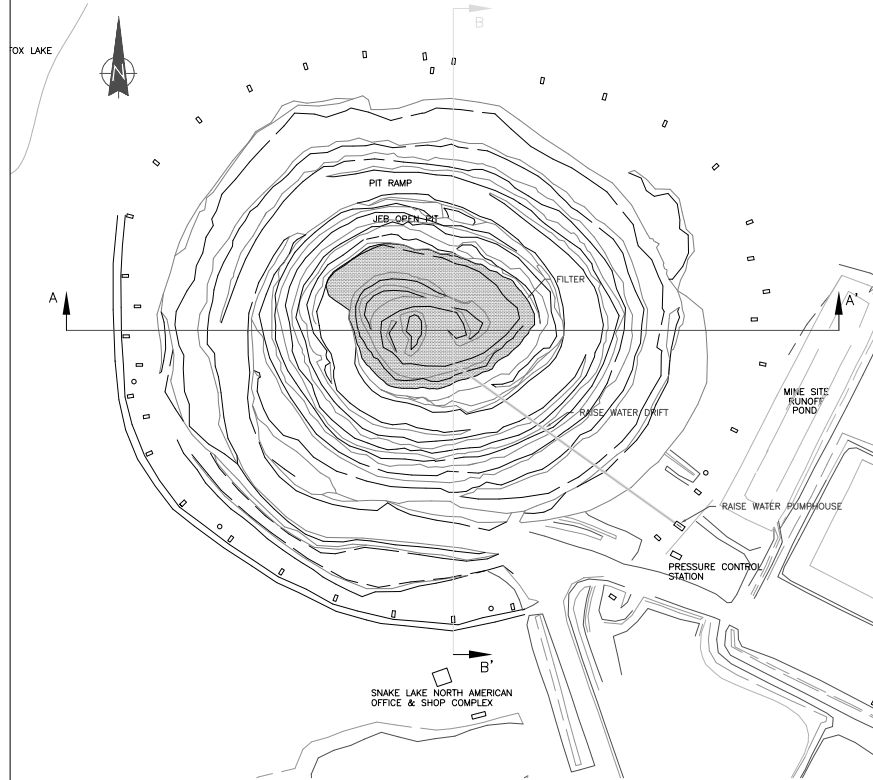
The drain rock layer was extended up the side of the pit to minimum of 5 m above the unconformity to intercept the flows observed along the unconformity and provide a means for drawing flow through the sandstone into the base filter.

Finally, the filter sand was covered with a layer of rip rap material. The function of the rip rap is to ensure that the sand filter does not slough after it was placed or wave action did not cause beaching before the water level was raised above the top of the sand layer. It also provides a readily identifiable base of exploration for future drilling programs, which may penetrate the sand layer.

Material Specifications

The design specifications required that the filter and drain materials meet the following criteria:

- adequate durability to resist breakdown during processing and placement;
- remain chemically inert to resist degradation from sulfate and calcite-rich leachate;
- adequate hydraulic conductivity to conduct seepage to the raise water system; and,
- suitable gradation to maintain a stable filter with respect to fines migration.



CONSTRUCTION NOTES:

1. SEE TECHNICAL SPECIFICATION 02520 AGGREGATE, LOAD, HAUL AND PLACE MATERIAL SPECIFICATIONS
2. PLACE MATERIALS IN ACCORDANCE WITH TECHNICAL SPECIFICATION 02520 AGGREGATE, LOAD, HAUL AND PLACE
3. INSTRUMENTATION TO BE INSTALLED BY OTHERS PROVIDED ON DRAWING No.2 FILE No. PIT MONITORING

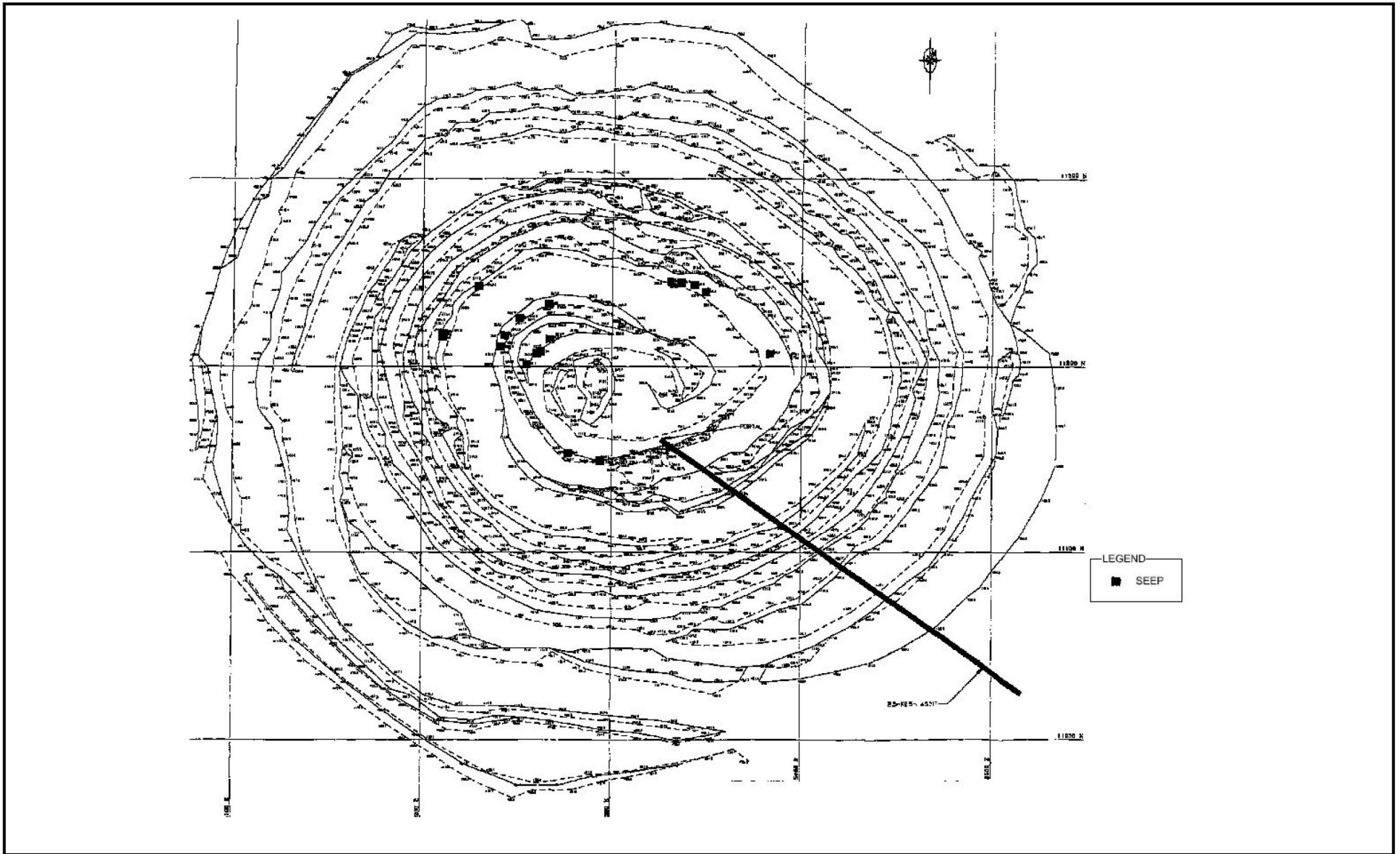
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 Data Sources: Golder Associates, Orano Canada Inc.

McCLean Lake OPERATION

FIGURE 2.3-17 JEB PIT AND BASE FILTER DRAIN

FIGURE:
 REPORT: TAILINGS MANAGEMENT TID





Projection:
 Compiled: Drawn:
 Date: Scale:
 Data Sources: ORANO Canada Inc.

McCLean Lake Operation

FIGURE 2.3-18
 JEB PIT AND ADIT LOCATION

TAILINGS MANAGEMENT TID



Filter

The sand layer prevents the tailings from passing through it and into the drainage system and the raise water system. The natural surround of the pit wall provides a suitable barrier to prevent the transport of the tailings material out of the side of the pit. Geologic mapping of the pit wall identified that, although fractures existed in the walls, they were filled with dry sand or sandy clay which formed an impervious barrier to the tailings particles.

Conventional rules for the design of filters centre around the 15%, 50% and 85% grain size fractions (D_{15} , D_{50} and D_{85} respectively). Table 2.3-3 presents a summary of the rules for the design of graded filters.

Table 2.3-3: Summary of Rules for Design of Graded Filter

To Minimize Head Loss in Filter	To Prevent Movement of Fines	Rules Chosen for Design
$R_{15} > 4$ and preferably > 9	$R_{15/85} < 5$ $R_{50} < 30$ $R_{15} < 30$	$R_{15} = 4$ to 30 $R_{50} = 4$ to 30 $R_{15/85} < 5$

1 Notes:

$$1) R_{15} = \frac{D_{15} \text{ filter}}{d_{15} \text{ base}}$$

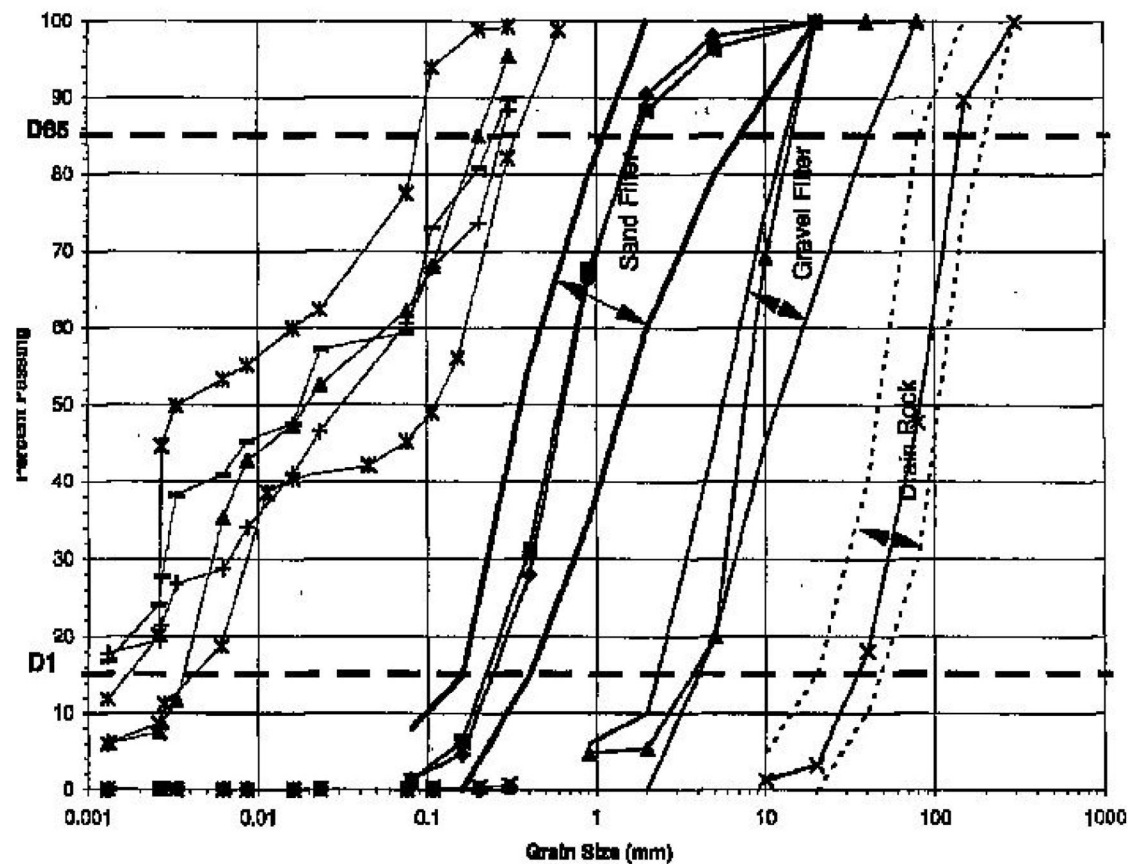
$$2) R_{50} = \frac{D_{50} \text{ filter}}{d_{50} \text{ base}}$$

$$3) R_{15/85} = \frac{D_{15} \text{ filter}}{d_{85} \text{ base}}$$

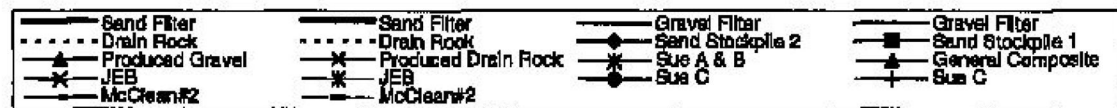
Where 'D' and 'd' represent the particle size for the filter and base material, respectively, and the number represents the percent passing fraction.

The gradation of the tailings and the designed gradation of the filters are presented in Figure 2.3-19. The tailings are fine grained, with approximately 50% silt and clay particle sizes. These fine-grained fractions, particularly where they are cohesionless, are difficult to retain and therefore it was not practical to produce a filter which obeyed the R_{15} and R_{50} rules. For this reason, it is usual to produce the finest practical filter. The finest filter that can usually be produced with reasonable quality control was equivalent to a washed concrete sand or, if suitable natural material was available without processing, a material with gradation equivalent to asphalt filler sand.

The finest gradation limit on the sand filter (Figure 2.3-19) was slightly finer than the normal fine limits on concrete fine aggregate. The coarse grain size limits correspond approximately to the coarse limits for fine concrete aggregate.



SOURCE: McCLEAN LAKE
PROJECT: JEB TAILINGS
FACILITY CONSTRUCTION,
LICENSE ADDITIONAL
INFORMATION APPENDIX
VOLUME 1 APRIL 1998
APPENDIX 1 FIGURE 4



Projection:
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Date: Scale:
Data Sources: Natural Resources Canada, Geobase®, Nation
Topographic Database, ORANO Canada Inc.

McCLean Lake Operation

FIGURE 2.3-19
FILTER DESIGN

TAILINGS MANAGEMENT TID



Two other filter zones were required to satisfy the filter criteria. The drain rock zone forms the basal drain to conduct water from the pit to the dewatering raise. The gravel filter forms an intermediate zone between the rock drain and the sand filter, which satisfied the filter design criteria for an intermediate filter zone between the sand and drain rock zones.

A summary of the filter design ratios is given in Table 2.3-4. It can be observed that, with the exception of the R_{15} and R_{50} ratios at the tailings-sand filter interface, all other zones satisfied the filter design criteria. As indicated above, this is not an unusual condition and experience at Key Lake and Rabbit Lake indicated that the sand filter, as designed, will retain the tailings without migration of fines that could cause blinding or plugging of the sand filter.

Table 2.3-4: Summary of Filter Design Ratios

Zone	R_{15} Actual	R_{50} Actual	$R_{15/85}$ Actual
Design	4 to 30	4 to 30	<5.0
Tailings/Sand Filter Interface	$\geq 30(1)$	$\geq 30(1)$	0.7 – 4.2
Sand Filter/Gravel Filter	4 to 30	4 to 30	0.3 – 4.1
Gravel Filter/Rock Drain	4 to 23	4 to 25	0.5 – 4

Desirable filter ratios are exceeded at the tailings/fine filter interface, even with the finest practical filter.

Empirical methods are commonly used to estimate the hydraulic conductivity of coarse-grained soils. The most commonly used is the Hazen formula (Holtz and Kovacs 1981), which is:

$$k = 100 D_{10}^2,$$

where:

k = hydraulic conductivity (cm/s); and,

D_{10} = diameter, in cm, of 10% passing fraction.

Geocon (1985) reported results of large diameter permeameter tests on the coarse-grained materials at Key Lake. From these tests an empirical relationship was developed which stated that:

$$k = 23.2 D_{15}^{0.85},$$

where:

k = hydraulic conductivity (cm/s); and,

D_{15} = diameter, in mm, of the 15% passing fraction.

A summary of hydraulic conductivity values calculated by the two methods is given in Table 2.3-5. Also included in this table are the values chosen for design, which were:

- sand filter, 5×10^{-2} cm/s;
- gravel filter, 10 cm/s; and,
- rock drain, 100 cm/s.

Table 2.3-5: Summary of Calculated Hydraulic Conductivity Values

	D ₁₀	(mm)	D ₁₅	(mm)	Hazen k	(cm/sec)	Geocon k	(cm/sec)	Design Value (cm/sec)
	Range	Average	Range	Average	Range	Average	Range	Average	
Tailings			<0.001-0.005	0.0035					
Sand Filter	0.12-0.35	0.22	0.15-0.42	0.27	$1 - 12 \times 10^{-2}$	5×10^{-2}	4 - 10	7	5×10^{-2}
Gravel Filter	2 - 3.2	2.6	2.5 - 4.0	3.3	4 - 10	7	50 - 75	64	10
Rock Drain	15 - 40	30	20 - 50	35	225 - 1600	900	320 - 710	520	100

Hazen k (cm/sec) = $100 D_{10}^2$ where D_{10} is in cm.

Geocon (1985) k (cm/sec) = $23.2 D_{15}^{0.85}$ where D_{15} is in mm.

These values provide a hydraulic conductivity contrast of approximately four orders of magnitude between the tailings and sand filter and at least one order of magnitude between each of the other drainage zones. This is more than adequate to conduct consolidation seepage from the tailings to the drain.

Durability

Durability is a concern mainly with the coarse aggregate since particle breakdown tends to produce fines, which can clog the voids of filters. Los Angeles abrasion losses of up to 50% are acceptable for uses such as concrete aggregate, railway ballast, roadway, or dam construction.

Representative samples of potential aggregate sources were subjected to laboratory testing to determine gradation, physical properties, and durability. Durability was assessed using the mill abrasion and Los Angeles abrasion tests. The mill abrasion test measures the resistance of an aggregate to degradation through abrasion by other aggregate particles.

Durability of the aggregate was further tested through repeated wet/dry cycles using a sodium sulfate solution. The purpose of this test was to determine whether the aggregate was prone to breakdown through growth of salt crystals in the pore spaces. After ten cycles of wetting and drying, the loss ranged from 1.65% to 1.99%, indicating the aggregate had an acceptable level of resistance to degradation freeze-thaw cycles.

Resistance to Chemical Alteration

The filter aggregates will undergo long-term exposure to the tailings solution, which may be saturated with gypsum and calcite. The most likely sources of fine aggregate include fine reject from aggregate processing, and surface gravel from an ice contact deposit some distance from the JEB TMF. The surface gravel material has been naturally sorted, and soluble or deleterious particles removed. Potential fine and coarse aggregate sources were subjected to petrographic examination to determine whether any minerals present were reactive with tailings pore water solutions.

Petrographic analyses indicated that both the fine and coarse aggregates resulting from processing the Athabasca Sandstone were composed primarily of quartz with a minor amount of clay (approximately 3% or less), resulting in a very low potential for chemical weathering. None of the mineral types identified were reactive with the tailings leachate solutions. The rock was hard, tough and durable.

2.3.4.2 As-built Filter

The following presents the results of QA/QC testing conducted during construction of the final base drain/filter of the JEB TMF and the as-built details of the completed facility.

Through all portions of the base drain construction, construction management team (CMT) representation consisted of a Geotechnical Superintendent on site with inspection provided by Materials Inspectors on a 24-hour basis.

Drain Rock

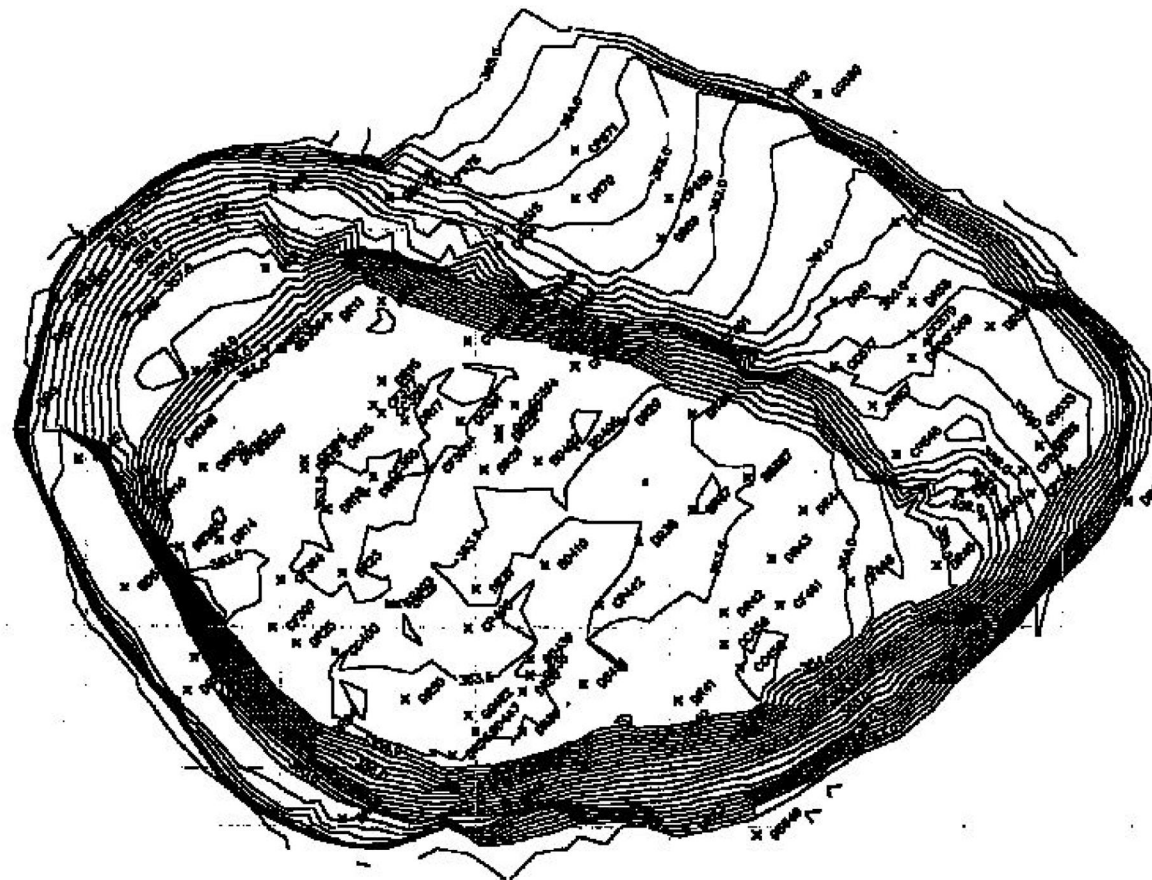
Testing conducted on drain rock samples through construction included:

- assessment of the suitability of Athabasca Sandstone for use as drain rock in the JEB TMF base drain;
- grain size analyses (CSA A23.2-2A Sieve Analysis of Fine and Coarse Aggregates);
- Los Angeles abrasion testing for Grading 1, and 3 (ASTM C535-96);
- petrographic analyses to identify % bleached sandstone; and
- survey of placed material.

An assessment of the suitability of Athabasca Sandstone for use as drain rock was performed as part of the Deficiency #6 Assessment Report (COGEMA 1999). The assessment concluded that Athabasca Sandstone in the JEB waste rock stockpile was suitable for use as drain rock in the JEB TMF base filter.

A total of 37,200 m³ of drain rock was placed in the JEB TMF filter. A total of 118 grain size tests were conducted, representing one test for every 315 m³ of in-place drain rock compared to a minimum required frequency of one test per 2,000 m³. Figure 2.3-20 presents the sampling locations for all drain rock samples taken through filter construction. Figure 2.3-21 presents the average of all the in-place samples of drain rock. Figure 2.3-22 presents the % passing the 10 mm sieve size for all samples of drain rock representing the in-place material.

A total of 40 Los Angeles abrasion tests were performed on in-place drain rock samples. Figure 2.3-23 provides a graphical summary of all tests.



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Data Sources: ORANO Canada Inc.

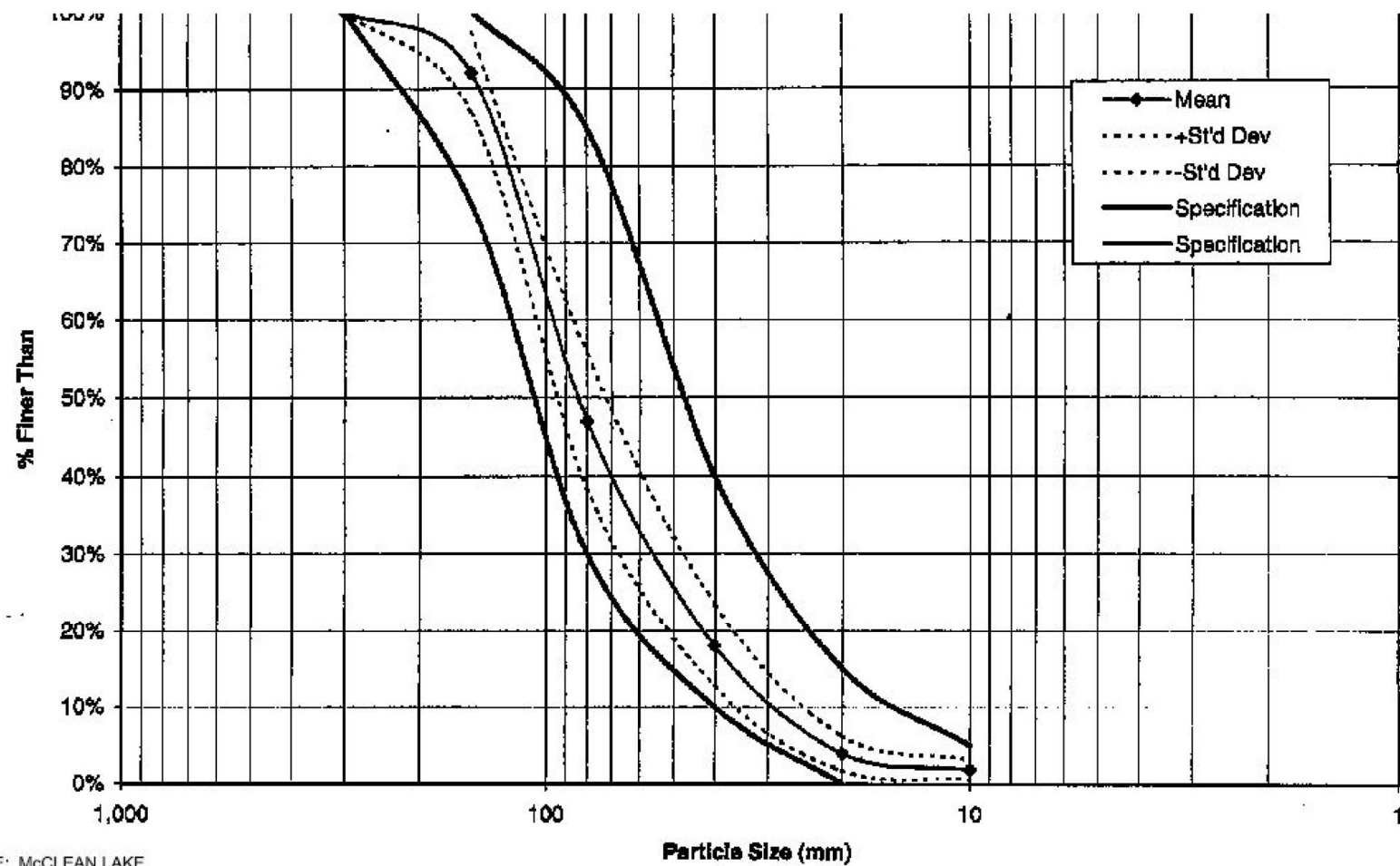
McCLEAN LAKE OPERATION

FIGURE 2.3-20
JEB PIT TAILINGS MANAGEMENT FACILITY
DRAIN ROCK GRADATION TEST LOCATIONS

TAILINGS MANAGEMENT TID



orano



SOURCE: McCLEAN LAKE
PROJECT: JEB TAILINGS
FACILITY CONSTRUCTION,
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INFORMATION APPENDIX
VOLUME 1 APRIL 1998
APPENDIX 1 FIGURE 4.2-2

FIGURE 2.3-21

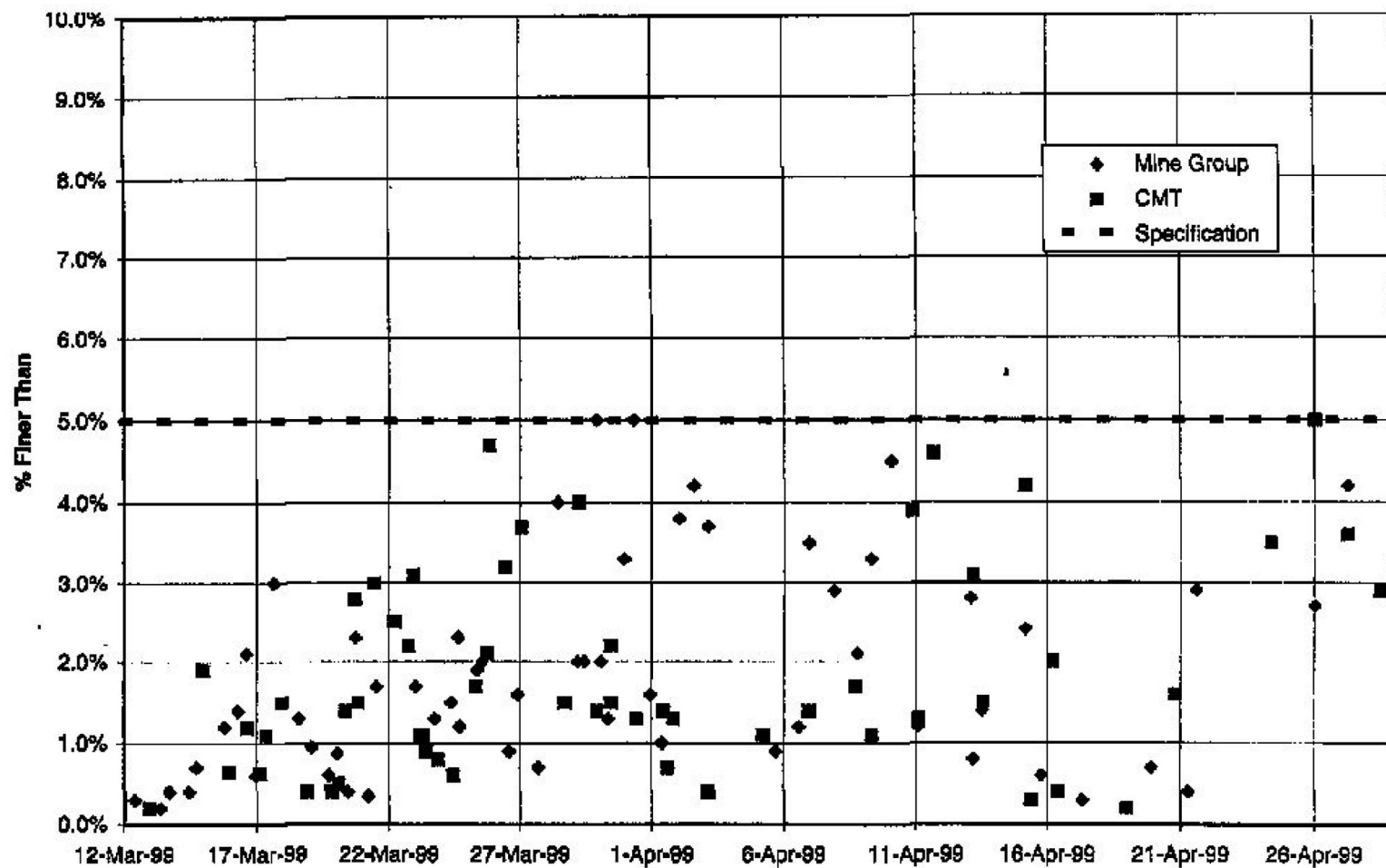
SUMMARY GRAIN SIZE TESTS PERFORMED
ON DRAIN ROCK PLACED IN TMF

TAILINGS MANAGEMENT TID

Projection:
Compiled: Drawn:
Date: Scale:
Data Sources: ORANO Canada Inc.

McCLEAN LAKE OPERATION





SOURCE:
McCLEAN LAKE PROJECT; JEB TAILINGS FACILITY CONSTRUCTION,
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APPENDIX 1 FIGURE 4.2-3

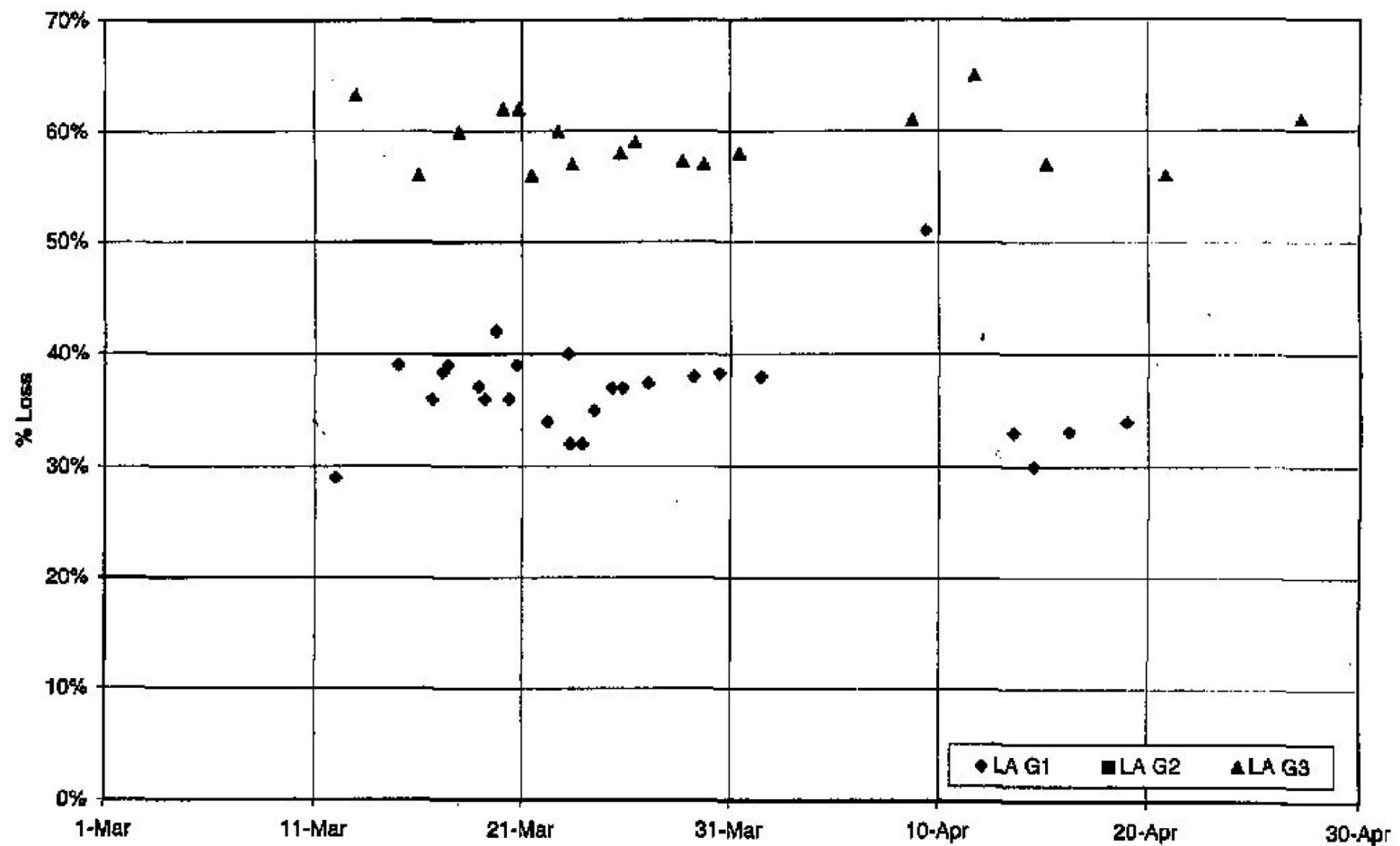
FIGURE 2.3-22
SUMMARY % PASSING 10MM SIEVE SIZE - DRAIN ROCK PLACED IN TMF FILTER

TAILINGS MANAGEMENT TID

Projection:
Compiled: Drawn:
Date: Scale:
Data Sources: ORANO Canada Inc.

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SOURCE:
McCLEAN LAKE PROJECT; JEB TAILINGS FACILITY CONSTRUCTION,
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APPENDIX 1 FIGURE 4.2-4

FIGURE 2.3-23
SUMMARY LOS ANGELES ABRASION TESTING - DRAIN ROCK PLACEMENT

TAILINGS MANAGEMENT TID

Projection:
Compiled:
Date:
Data Sources: ORANO Canada Inc.

McCLEAN LAKE OPERATION



A total of 28 petrographic evaluations to determine the proportion of bleached sandstone were performed on in-place samples, a graphical summary is provided in Figure 2.3-24. On average, the placed drain rock was comprised of 5% bleached sandstone.

Figures 2.3-25, 2.3-26, and 2.3-27 present the as-built geometry of the drain rock layer. In all cases the placed drain rock material meets the design requirement of 3.5 m thickness on the base and a minimum of 2 m thickness on the side drain.

Seven deficiencies through filter construction were associated with the placement of the drain rock. Three of the deficiencies resulted from grain sizes being too coarse, three from grain sizes being too fine, and one deficiency was associated with the geometry of the side drain. In all cases where the gradation of the placed material did not meet the gradation specification, the material was removed and replaced with material meeting specification. In the case of the geometry of the side drain, the area was repaired prior to any further material placement.

Hydraulic conductivity of the drain rock was estimated during a hydraulic test conducted as part of the commissioning of the JEB TMF. The drain rock hydraulic conductivity was estimated to be at least 100 cm/s (Clifton 1999), which is in close agreement with the theoretical value estimated from the design grain size and laboratory test work.

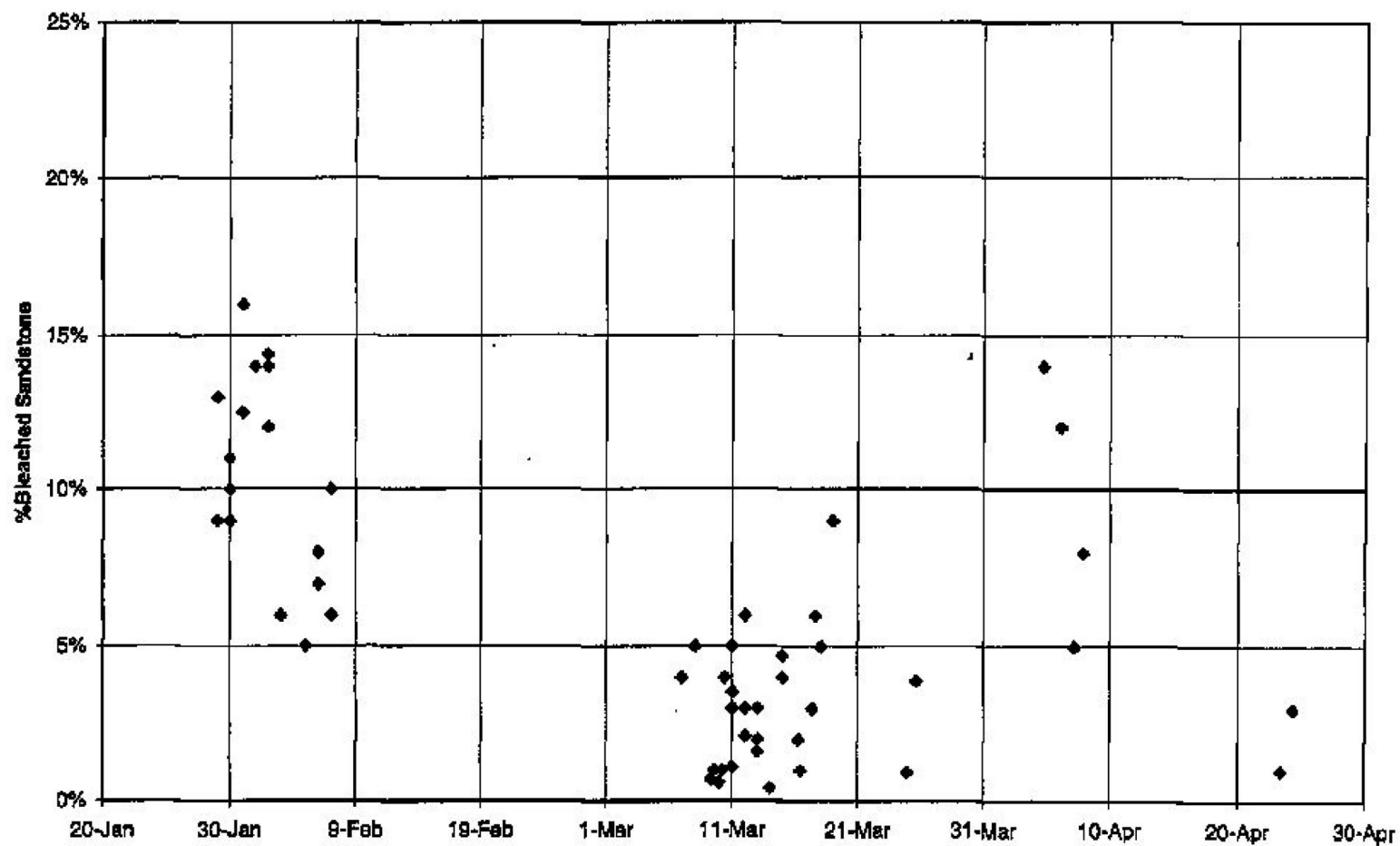
Filter Gravel

Testing conducted on filter gravel samples through construction included:

- grain size analyses (CSA A23.2-2A Sieve Analysis of Fine and Coarse Aggregates);
- Los Angeles abrasion testing for Grading 1, and 3 (ASTM C535-96);
- hydraulic conductivity testing (ASTM D2434); and
- survey of placed material.

A total of 29,300 m³ of filter gravel was placed in the JEB TMF filter. A total of 138 grain size tests were conducted, representing one test for every 210 m³ of placed filter gravel compared to a minimum required frequency of one test per 2,000 m³. Figure 2.3-28 presents the sampling locations for all filter gravel samples taken through filter construction. Figure 2.3-29 presents the average of all the in-place samples of Filter Gravel. Figure 2.3-30 presents the % passing the 1 mm and 0.08 mm sieve sizes for all samples representing the in-place material.

A total of 68 Los Angeles Abrasion Grading C tests were performed on in-place filter gravel samples. Figure 2.3-31 provides a graphical summary of all tests.



SOURCE:
 McCLEAN LAKE PROJECT; JEB TAILINGS FACILITY CONSTRUCTION,
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 APPENDIX 1 FIGURE 4.2-5

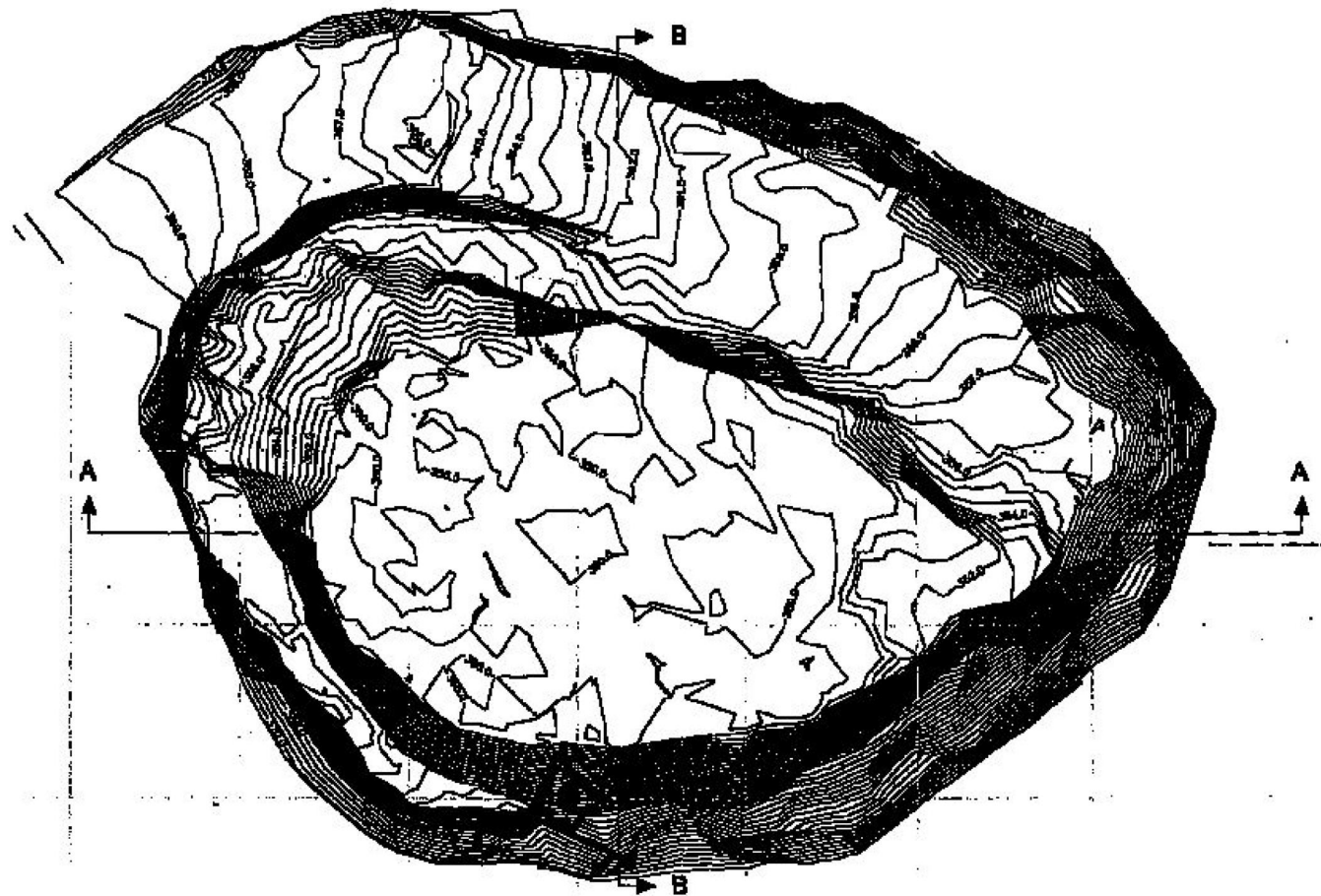
FIGURE 2.3-24
 SUMMARY % BLEACHED SANDSTONE - DRAIN ROCK PLACEMENT

TAILINGS MANAGEMENT TID

Projection:
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APPENDIX 1 DRAWING JEB99-C0001

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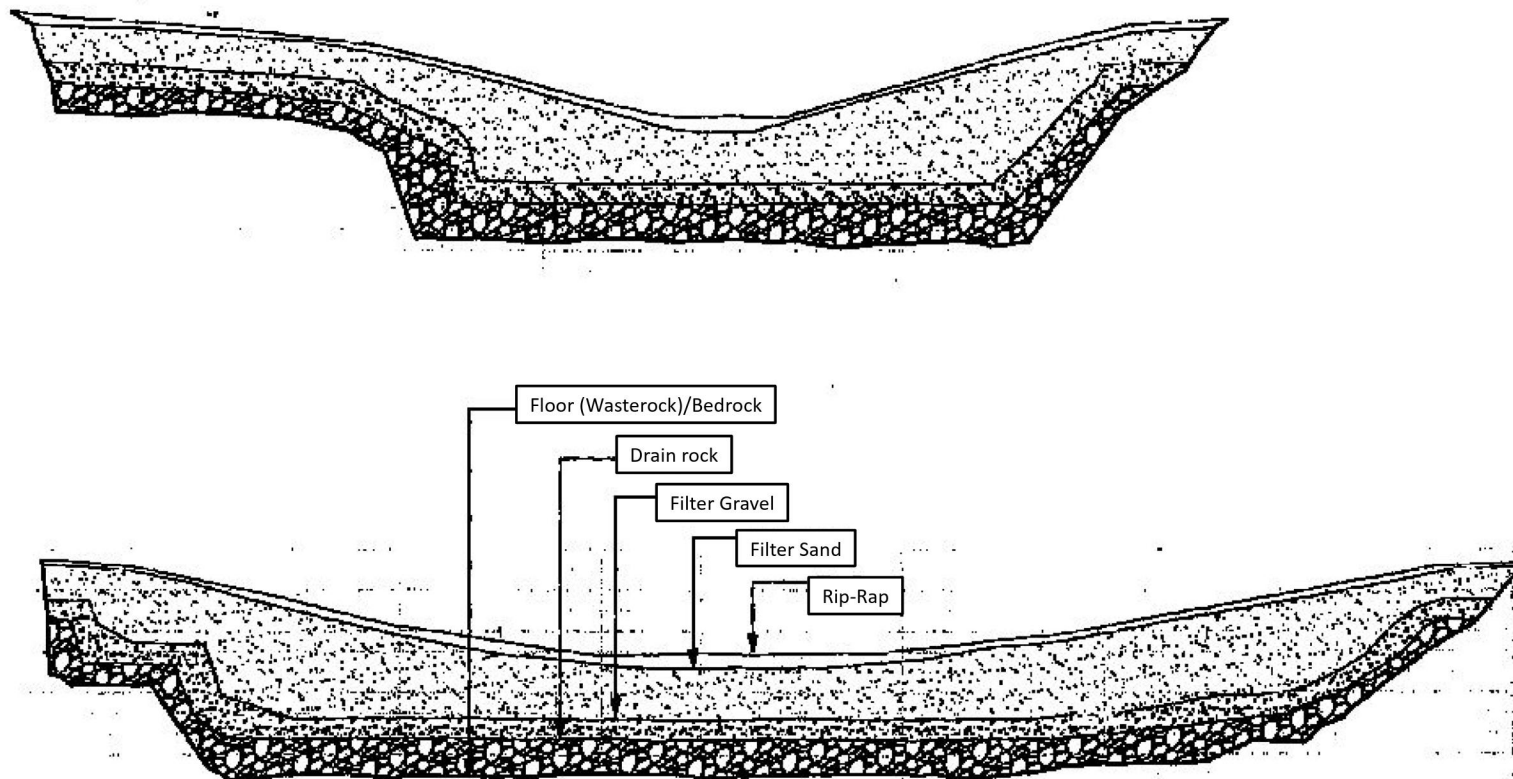
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FIGURE 2.3-25
JEB PIT TAILINGS MANAGEMENT FACILITY FLOOR
AND BEDROCK SURFACE AS-CONSTRUCTED CONTOURS

TAILINGS MANAGEMENT TID

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APPENDIX 1 DRAWING JEB99-C0002

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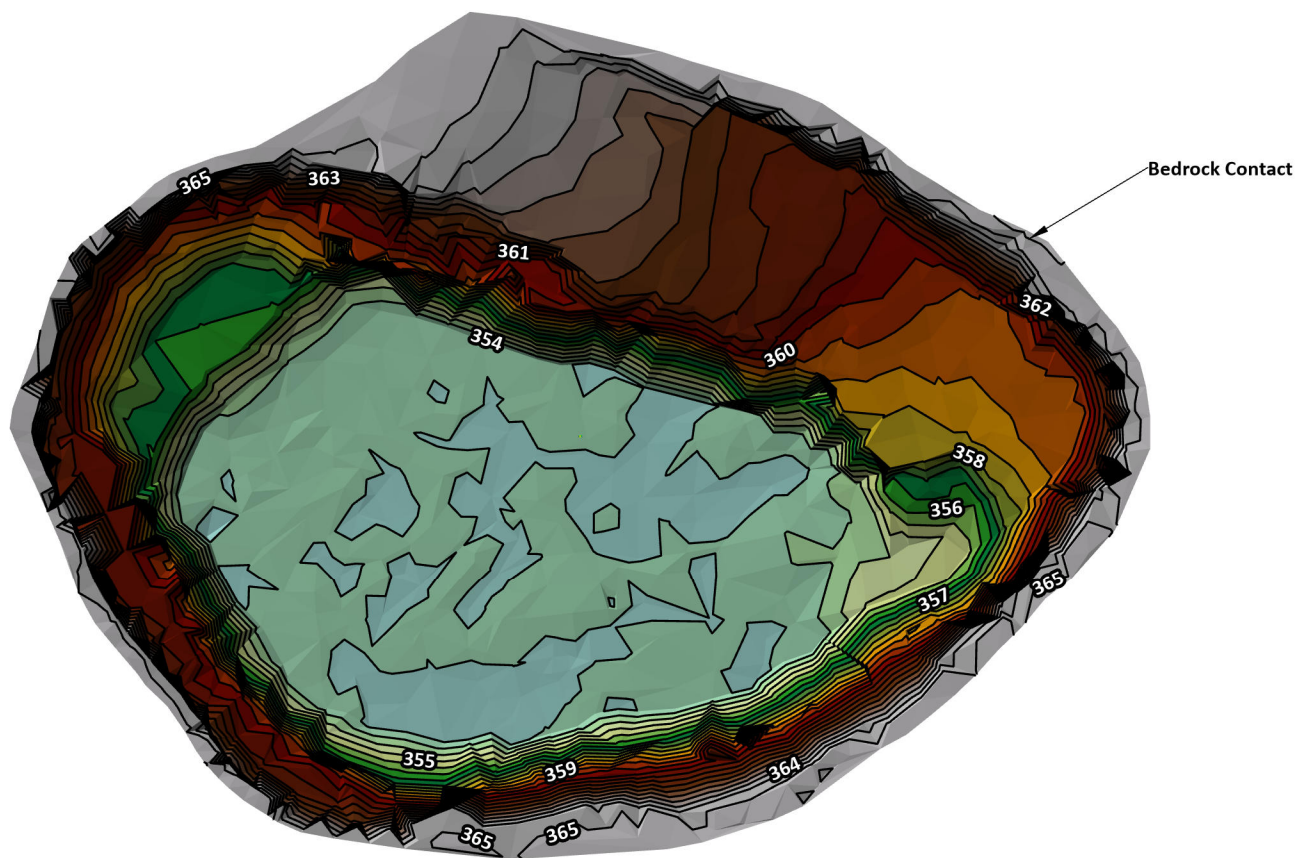
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FIGURE 2.3-26
JEB PIT TAILINGS MANAGEMENT FACILITY
CROSS SECTIONS AS-CONSTRUCTED

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TAILINGS MANAGEMENT TID





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FIGURE 2.3-27
 JEB PIT TAILINGS MANAGEMENT FACILITY DRAIN
 ROCK SURFACE AS-CONSTRUCTED CONTOURS

McCLEAN LAKE OPERATION

TAILINGS MANAGEMENT TID



Five hydraulic conductivity tests were conducted on in-place samples of filter gravel. The measured conductivity results are consistent with the estimated conductivity of 10 cm/s used in the basis of design.

Figures 2.3-26 and 2.3-32 presents the as-built geometry of the filter gravel layer. In all cases the placed material meets the design requirement of 2 m thickness on the base and a minimum of 2 m thickness on the side drain.

Three construction deficiencies through the filter construction were associated with the placement of the filter gravel. One deficiency resulted from grain sizes being too coarse, one from grain sizes being too fine and one deficiency was associated with runoff down the access ramp contaminating some of the filter gravel. In all cases where the gradation of the placed material did not meet the gradation specification, the material was removed and replaced with material meeting specification. In the case of contamination with runoff, the contaminated filter gravel was removed and replaced with new material meeting specification.

Filter Sand

Testing conducted on Filter Sand samples through construction included:

- grain size analyses (CSA A23.2-2A Sieve Analysis of Fine and Coarse Aggregates);
- hydraulic conductivity testing (ASTM D2434); and
- survey of placed material.

A total of 74,000 m³ of Filter Sand was placed in the JEB TMF filter with a total of 135 grain size tests conducted, representing one test for every 550 m³ of placed Filter Sand compared to a minimum required frequency of one test per 2,000 m³. Figure 2.3-33 presents the sampling locations for all Filter Sand samples taken through filter construction. Figure 2.3-34 presents the average of all the in-place samples of Filter Sand. Figure 2.3-35 presents the % passing the 0.08 mm sieve size for all samples representing the in-place material.

Seven Hydraulic Conductivity tests were conducted on in-place samples of Filter Sand. The measured conductivity results are consistent with the estimated conductivity of 0.05 cm/s used in the basis of design.

Figures 2.3-26 and 2.3-36 present the as-built geometry of the filter sand layer. In all cases the placed material meets the design requirement of 2 m thickness on the base, a minimum of 2 m thickness on the side drain, and a minimum of 3 m on top of the side drain or ramp.

Two construction deficiencies through the filter construction were associated with the placement of filter sand. Both of the deficiencies resulted from samples being too fine on the 900 µm sieve. In both cases the material was removed and replaced with new filter sand material meeting specifications.



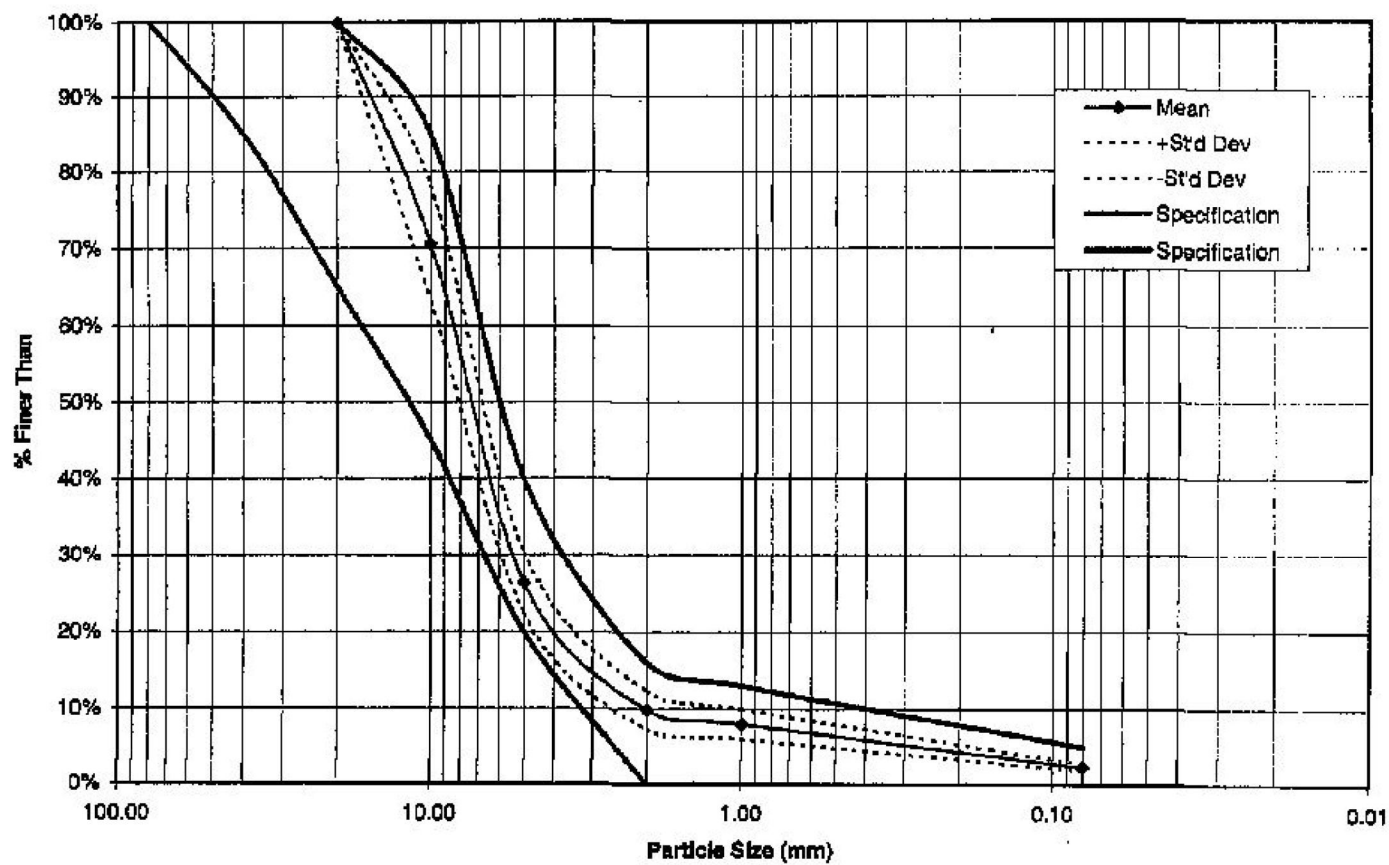
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FIGURE 2.3-28
JEB PIT TAILINGS MANAGEMENT FACILITY FILTER
GRAVEL GRADATION TEST LOCATIONS

TAILINGS MANAGEMENT TID





SOURCE:
McCLeAN LAKE PROJECT: JEB TAILINGS FACILITY CONSTRUCTION,
LICENSE ADDITIONAL INFORMATION APPENDIX VOLUME 1 APRIL 1998
APPENDIX 1 FIGURE 4.2-6

FIGURE 2.3-29

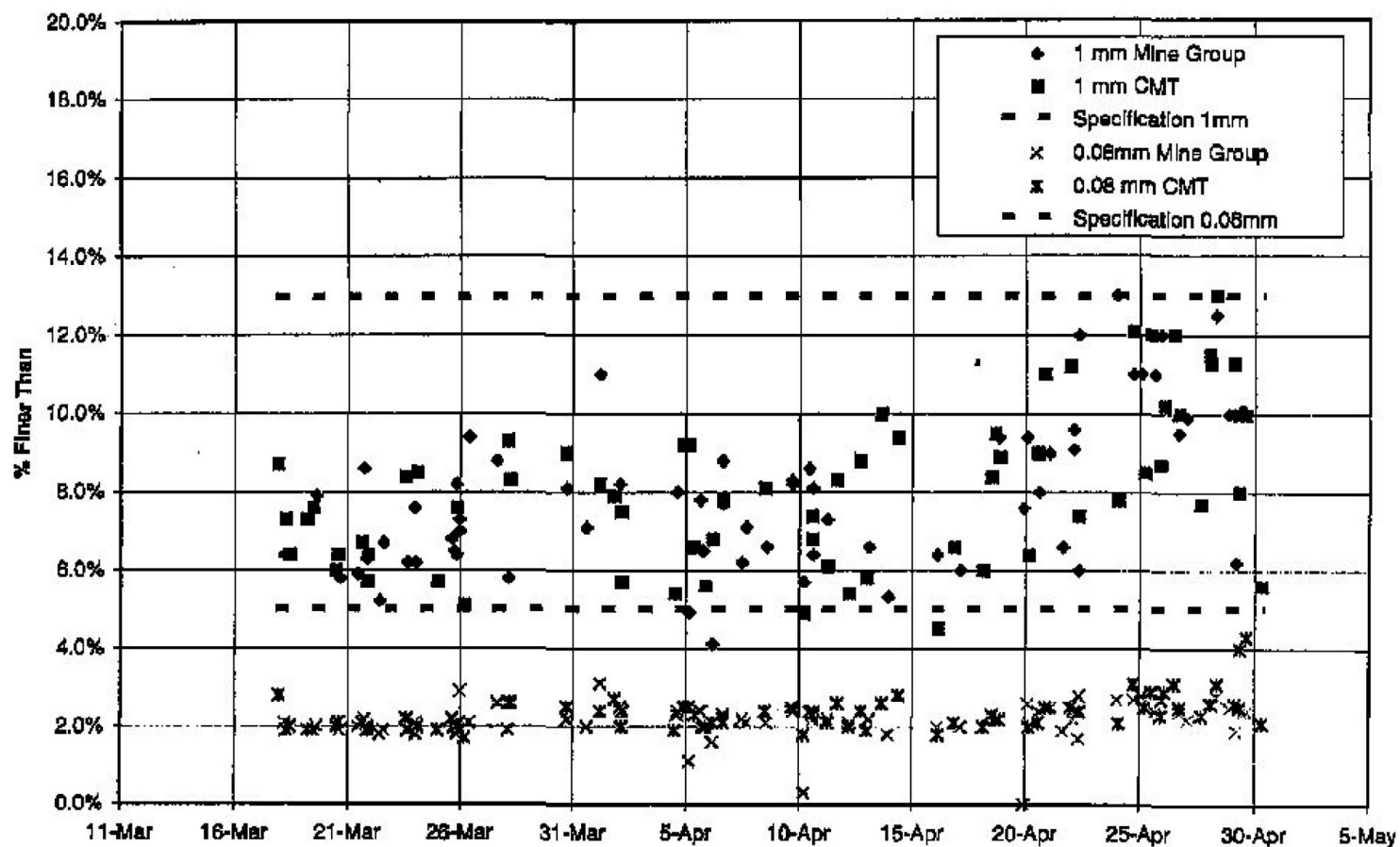
SUMMARY OF GRAIN SIZE TESTS PERFORMED
ON FILTER GRAVEL PLACED IN TMF

TAILINGS MANAGEMENT TID

Projection:
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LICENSE ADDITIONAL INFORMATION APPENDIX VOLUME 1 APRIL 1998
APPENDIX 1 FIGURE 4.2-7

FIGURE 2.3-30

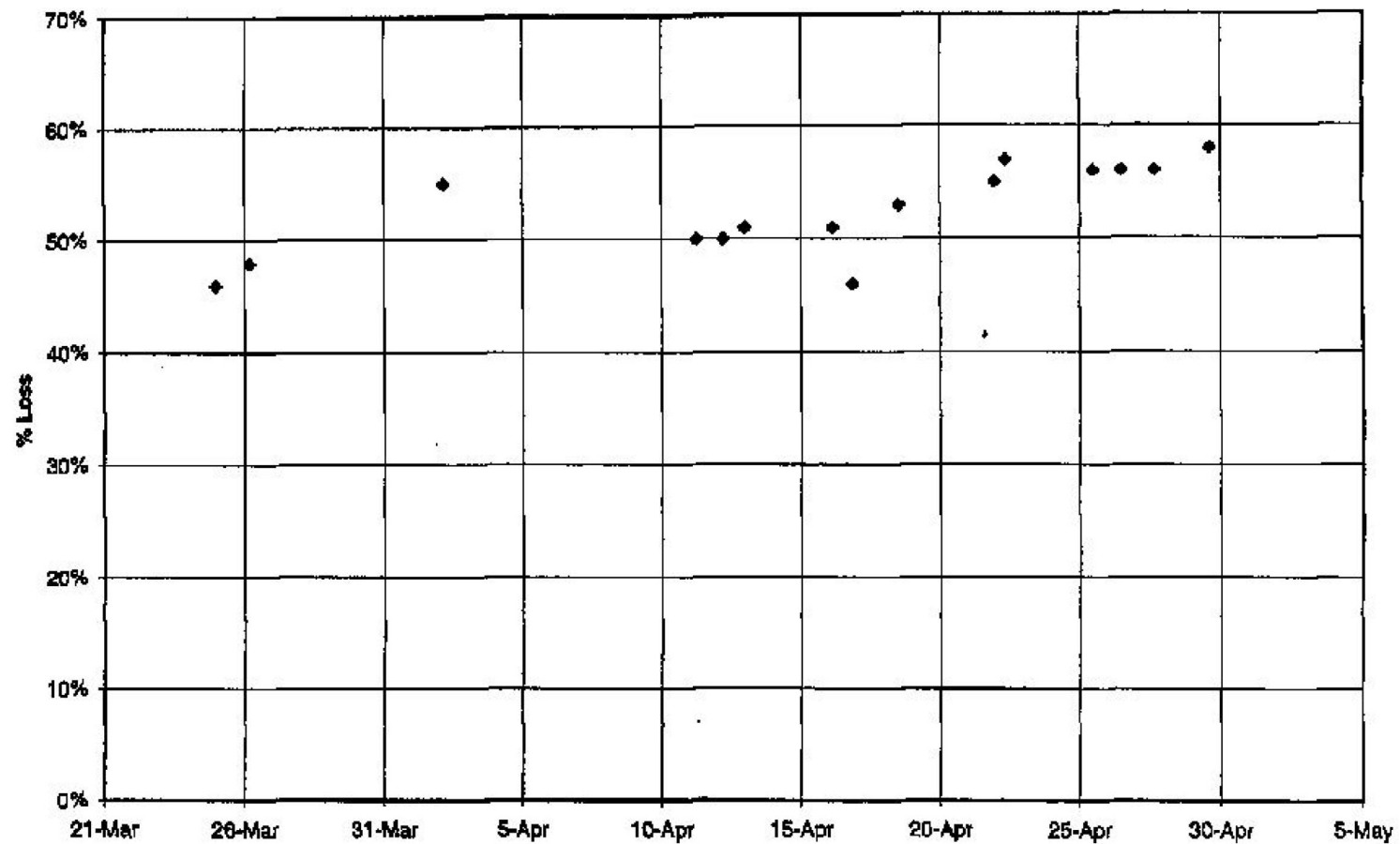
SUMMARY % PASSING 1MM AND 0.08MM SIEVE SIZES -
FILTER GRAVEL PLACED IN TMF FILTER

TAILINGS MANAGEMENT TID

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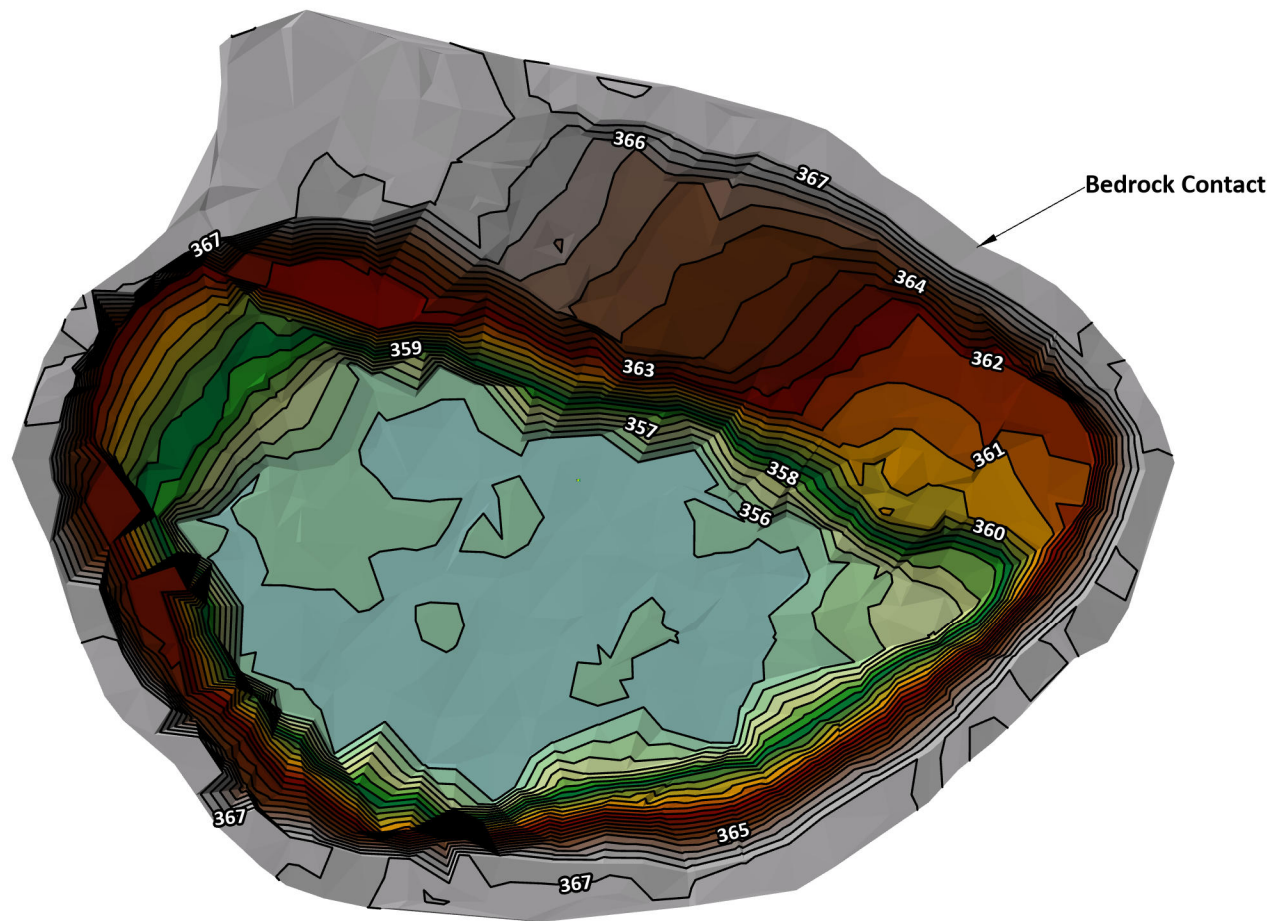
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FIGURE 2.3-31
 SUMMARY LOS ANGELES ABRASION TESTING
 GRADING C - FILTER GRAVEL PLACED IN TMF

TAILINGS MANAGEMENT TID

McCLEAN LAKE OPERATION





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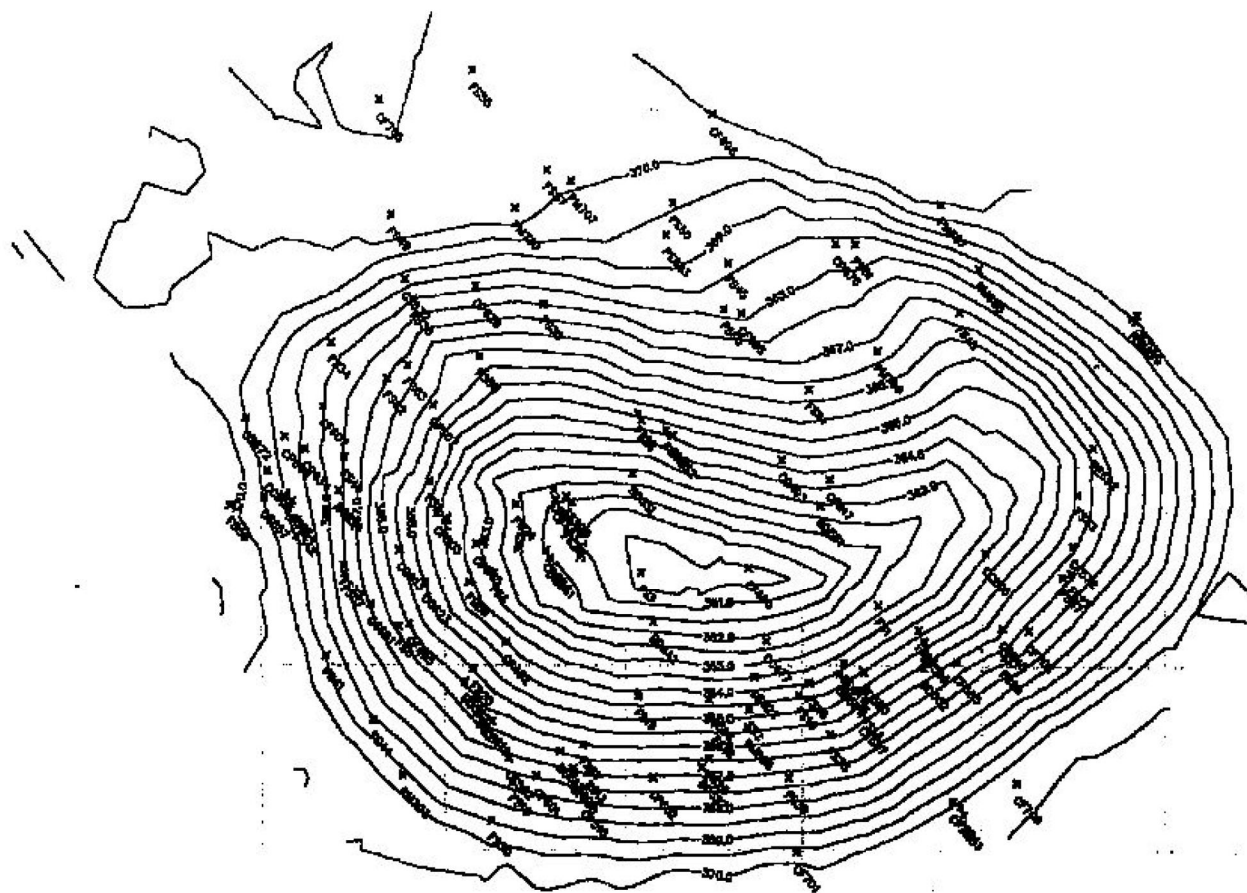
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FIGURE 2.3-32
 JEB PIT TAILINGS MANAGEMENT FACILITY FILTER
 GRAVEL SURFACE AS-CONSTRUCTED CONTOURS

TAILINGS MANAGEMENT TID

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APPENDIX 1 DRAWING JEB99-C009

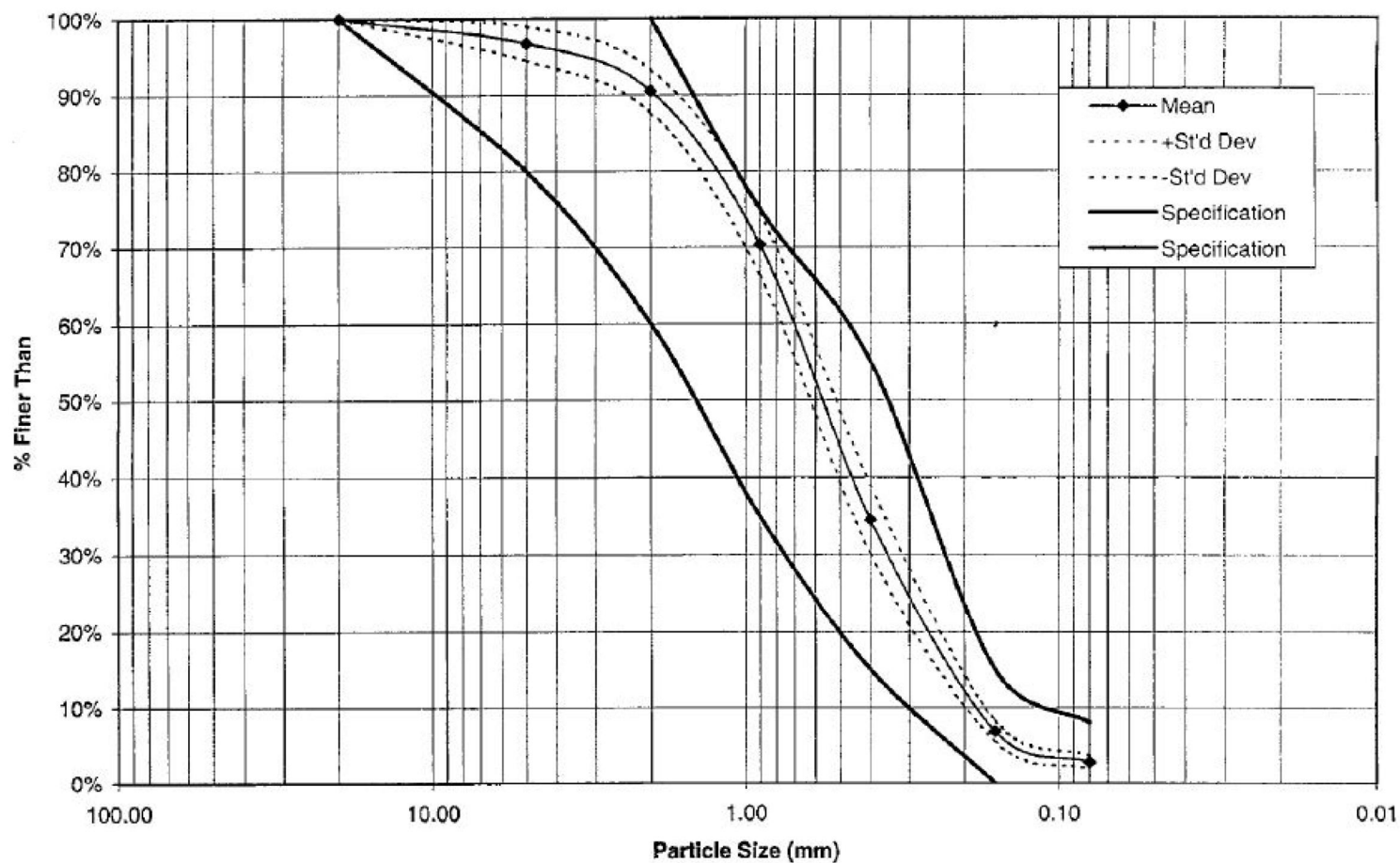
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Data Sources: ORANO Canada Inc.

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FIGURE 2.3-33
JEB PIT TAILINGS MANAGEMENT FACILITY
FILTER SAND SURFACE TEST LOCATIONS

TAILINGS MANAGEMENT TID





SOURCE:
 McCLEAN LAKE PROJECT; JEB TAILINGS FACILITY CONSTRUCTION,
 LICENSE ADDITIONAL INFORMATION APPENDIX VOLUME 1 APRIL 1998
 APPENDIX 1 FIGURE 4.2-9

FIGURE 2.3-34

SUMMARY GRAIN SIZE TESTS PERFORMED
 ON FILTER SAND PLACED IN TMF

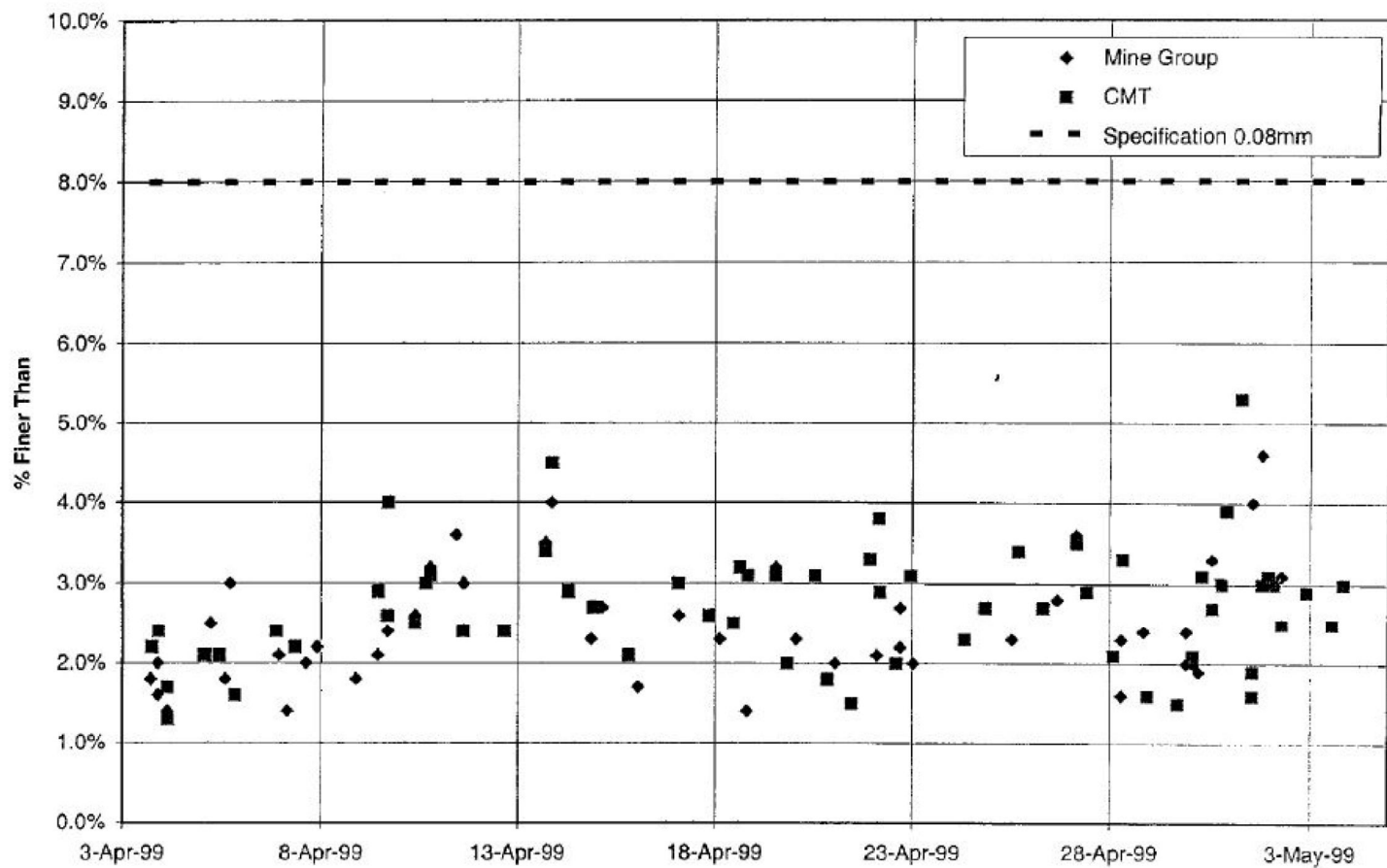
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TAILINGS MANAGEMENT TID





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APPENDIX 1 FIGURE 4.2-10

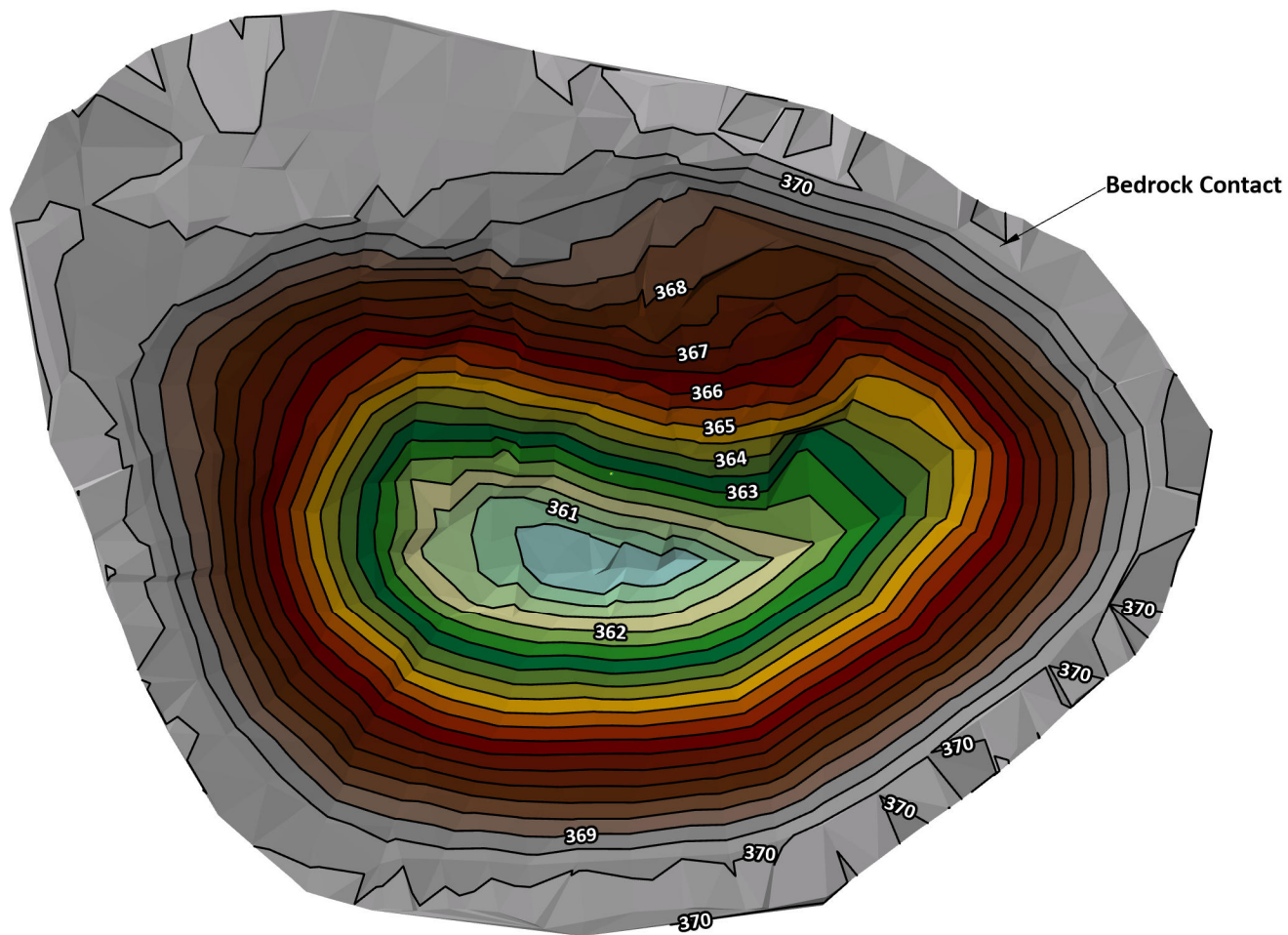
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Data Sources: ORANO Canada Inc.

McCLEAN LAKE OPERATION

FIGURE 2.3-35
SUMMARY % PASSING 0.08MM SIEVE
SIZE - FILTER SAND PLACED IN TMF FILTER

TAILINGS MANAGEMENT TID





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FIGURE 2.3-36
 JEB PIT TAILINGS MANAGEMENT FACILITY FILTER
 SAND SURFACE AS-CONSTRUCTED CONTOURS

TAILINGS MANAGEMENT TID



Rip Rap

Visual inspections were conducted throughout placement of the rip rap material. Figures 2.3-26 and 2.3-37 present the as-built geometry of the base filter. In all cases the placed material meets the design requirement of 0.5 m over the filter sand surface.

2.3.4.3 Pit Wall Stability

The JEB pit was excavated through overburden, sandstone, and regolith to achieve full-depth for recovery of the uranium ore. The stability of rock slopes, as well as the stability of the overburden slopes, in both the short- and long-term, were considered during construction. The following Sections outline the design of both the overburden slopes and the rock slopes, and provide an overview of the construction experience.

Overburden Slopes

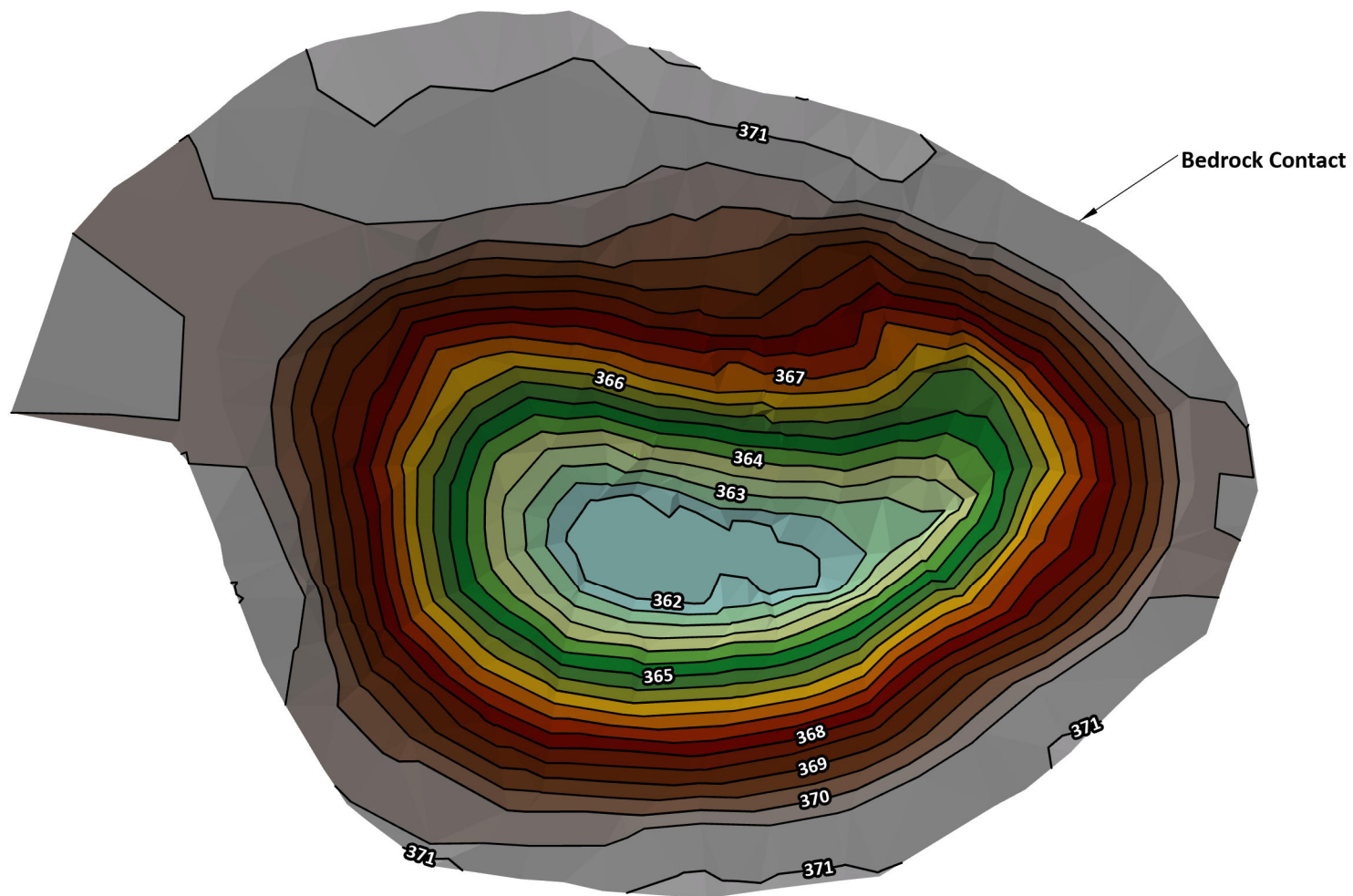
Although the depth of overburden was variable, cut slopes ranged as high as 20 m. Slope designs presented in Minatco (1991) specified a design angle of 27° (2H:1V) for overburden slopes.

An analysis of the overburden slope stability of the designed slopes is presented in Appendix B, Section A. The overburden layer was considered as a single soil layer with isotropic properties. The effective friction angle of the overburden was estimated from standard penetration tests in the drift. Values of 10 kPa effective cohesion and 40° for the effective friction angle were selected. For a condition with a groundwater table at surface, the estimated factor of safety of the overburden slopes was 1.5, which meets the largest long-term factor of safety of 1.25 with respect to slope stability.

Long-term drainage of the slope will improve the factor of safety, but this will be offset to some degree by potential softening which may reduce the cohesion intercept to zero in the long term. Nonetheless, the overburden slopes, as designed, were deemed to have an adequate factor of safety in both the short- and long-term.

The geometry of the excavated slopes in the overburden was controlled to a substantial degree by construction conditions. The overburden was excavated in an undrained condition, resulting in limitations on trafficability and some minor deviations in overburden slope geometry. The slopes were locally oversteepened to 45° by sloughing and ravelling, and while slumping of the highwall did occur over a short length (less than 50 m), the remainder of the overburden slopes were stable even at the steeper angles. The safety of the slopes was reinforced by the wide (22 m) safety berm at the top of the bedrock that safely contained any sloughing or slumped material.

As part of the JEB TMF Optimization and Expansion projects, overburden till slopes were flattened to a final slope of 3H:1V to provide a stable slope suitable for liner construction. Details are discussed further in Section 2.8.



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FIGURE 2.3-37
 JEB PIT TAILINGS MANAGEMENT FACILITY
 RIP RAP SURFACE AS-CONSTRUCTED CONTOURS

TAILINGS MANAGEMENT TID



Rock Slopes

The overall backwall design slope in the rock section is 45°. Structural measurements of the major joints (more than 3,000 measurements) have been collected over the full depth of the JEB pit and are presented in Appendix B, Section B. The structures were variously identified as joints or faults with the vast majority dipping at more than 70°. Most had limonitic stains. A few of the structures were described as chloritic or clay-coated. Details of the data collection and analysis of the rock slopes is included in Appendix B, Section C.

The poles of all structural measurements were plotted on stereonet in order to group the data into major joint sets. The concentrations of the poles were then contoured to define the more statistically prominent features. The contoured concentrations of the poles from the 421 to the 359 bench identified four structural features. They were:

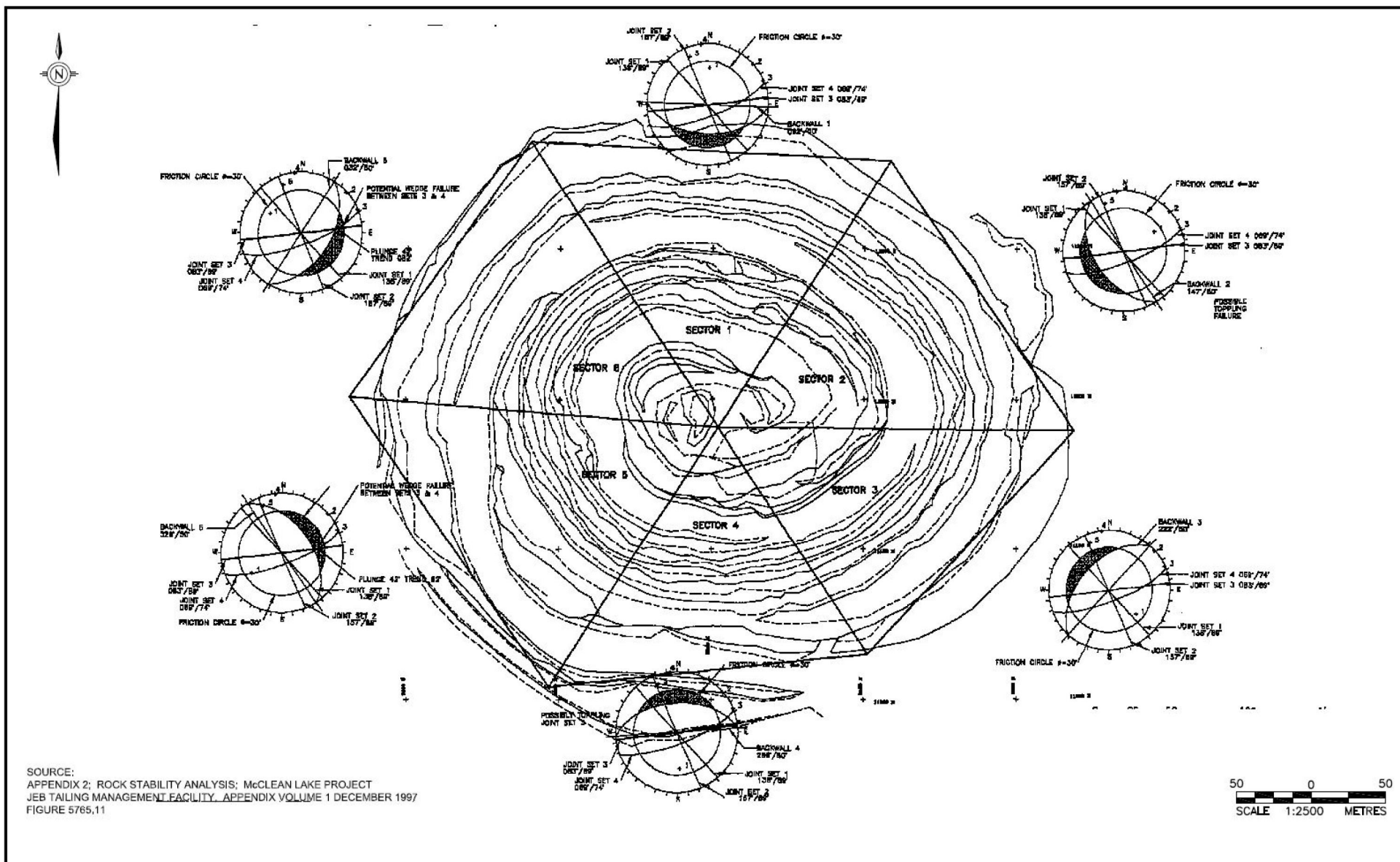
- a prominent northwest-southeast set ranging between 130° and 160°;
- a prominent northeast-southwest set ranging between 050° and 070°;
- a less prominent east-west set ranging between 080° and 090°; and,
- prominent horizontal partings parallel to bedding planes.

On the basis of this information, the pit was divided into six structural sectors, as illustrated in Figure 2.3-38. Each of the zones was subjected to a kinematic analysis to identify potential failure modes. Potential failure modes included:

- plane failures, where the strike of the structure was subparallel to the orientation of the back wall and the dip of the joint set was shallower than the overall back wall slope;
- toppling failure, when the joint set has a strike that was subparallel to the bench back wall and the dip was subparallel to the dip of the bench back wall;
- wedge failures, when two joint sets intersected at a plunge at an angle less than the overall slope but greater than the friction angle of the rock;
- stepped path failure, when the joint set intersected a subhorizontal plane such as a bedding plane or the unconformity;
- circular slip failure, where zones of weak or friable rock moved on the circular failure surface into the pit; and
- ravelling, where rock fell from the wall as a result of mechanical weathering or erosion.

All of these conditions were analyzed, including a limit equilibrium analysis of the identified critical section of the northeast section of the pit. The minimum factor of safety estimated on the basis of limit equilibrium was 1.24, which was acceptable.

None of the analyses identified unacceptable risk of major slope failures within the JEB pit, but indicated that some ravelling and minor toppling of the slopes could be expected. Scaling and inspection was recommended to control ravelling, including routine inspection and maintenance of the safety berms, as required, during the JEB TMF operating phase.



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FIGURE 2.3-38
KINEMATIC ANALYSIS

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Regular geologic mapping of the pit was conducted as mining progressed. The pit was constructed as designed but, locally, overbreak has caused some oversteepening on backwalls, and ravelling has encroached on the safety berms, reducing their width over short sections.

Given the abundance of subvertical structure evidenced in the measurements taken within the JEB pit, the relatively shallow overall design pit slope and the foregoing analysis, there is a low potential for major slope failures within the pit. There is a higher potential for minor plane failures when shallow dipping structures daylight on the backwalls. This was evidenced in the failure that occurred in July 1997. The proportion of shallow dipping structures was low (2% of the measured structures); therefore, it is not likely that large plane failures would occur.

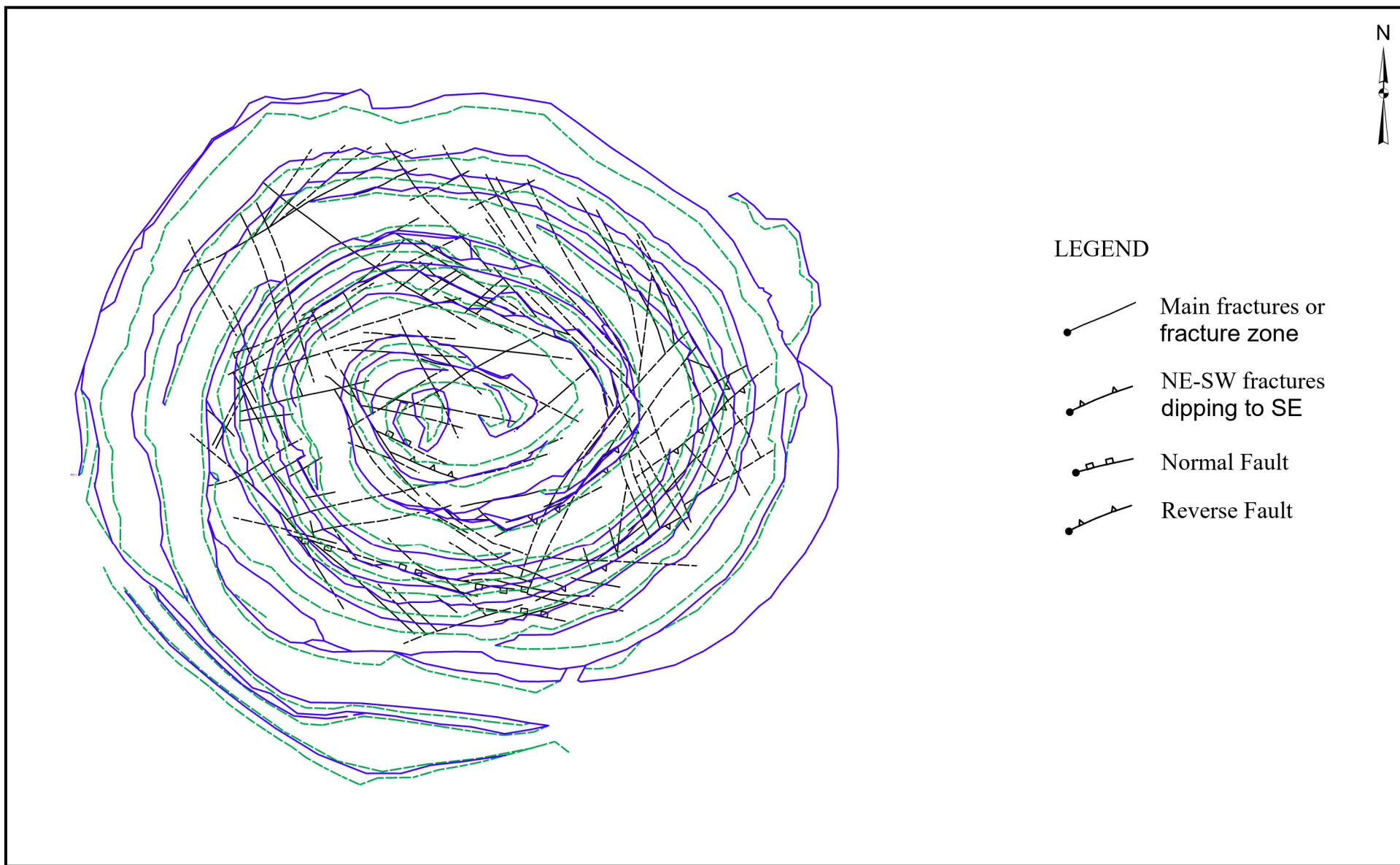
The stability of the pit walls discussed above was based on the pit walls being in a drained condition. Concerns regarding the stability of the pit walls were expressed in the event of failure of the dewatering wells and the potential detrimental effects of build-up of pore pressures on the stability of the wall. The nature of the sandstone observed during dewatering of JEB pit indicated that steep gradients into JEB pit will not occur. In the event that the water level in JEB pit and sandstone immediately surrounding JEB pit rise, it will occur at a near uniform rate. This will result in little or no hydraulic pressures being built up on the pit wall and will have a negligible effect on the stability of the pit wall.

2.3.4.4 Dewatering Drift and Raise Well Design

The dewatering drift and raise well are designed to manage water levels in and around the JEB TMF. Until 2014 hydraulic containment of the JEB TMF was originally controlled through a combination of pumping from the dewatering wells, which intercepted clean groundwater, and water pumping from the JEB TMF pond (reclaim) and base drain (raise). Hydrodynamic containment was maintained by ensuring that the hydraulic head at the dewatering well ring was greater than the JEB TMF pond elevation, which was greater than the hydraulic head in the base drain. This ensured that groundwater is always flowing into the JEB TMF, thereby preventing the escape of contaminated water. The method of hydrodynamic containment associated with the JEB TMF Optimization Project is discussed in Section 2.4.1. Regulatory requirements of hydraulic containment are discussed in Section 2.2.2 This Section presents the original design of the dewatering drift and raise well. A description of the decommissioned dewatering wells may be found in COGEMA, 2004, Section 2.

Dewatering Drift

The control of water levels in the filter drain at the base of the pit was accomplished through construction of a dewatering drift running from the bottom of the pit and connecting with vertical raise wells. The location of the drift with respect to the outline of the pit is shown on Figure 2.3-18. The orientation and location of the drift was selected based on the local geology; specifically, the location and nature of the fractures in the bedrock. The final report on the geologic mapping of the pit has been included as Appendix B, Section B. Detailed structural mapping of the JEB pit to identify the location and orientation of fractures and faults was performed after the mining of the pit was complete (see Figure 2.3-39).



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FIGURE 2.3-39
 STRUCTURAL MAP OF JEB PIT

TAILINGS MANAGEMENT TID

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The portal entrance is located at elevation 351 mASL. It was protected by rock bolting and mesh, as illustrated on Figure 2.3-40, to allow the drift to be constructed and backfilled. The rock bolting and mesh design was reviewed by the mining contractor, Procon Mining and Tunnelling Ltd., based on the pit wall structural mapping and was found not to require modification.

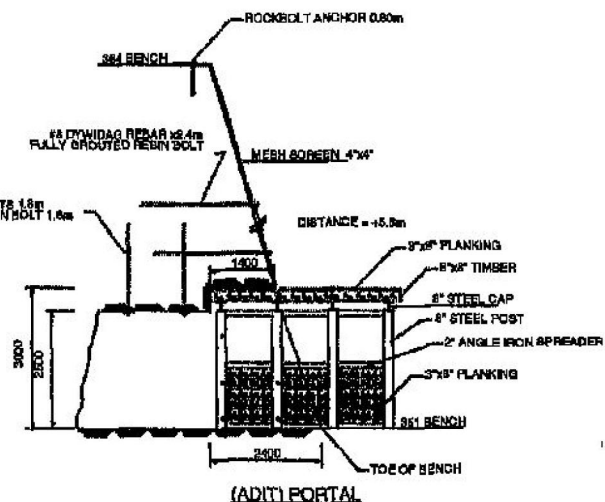
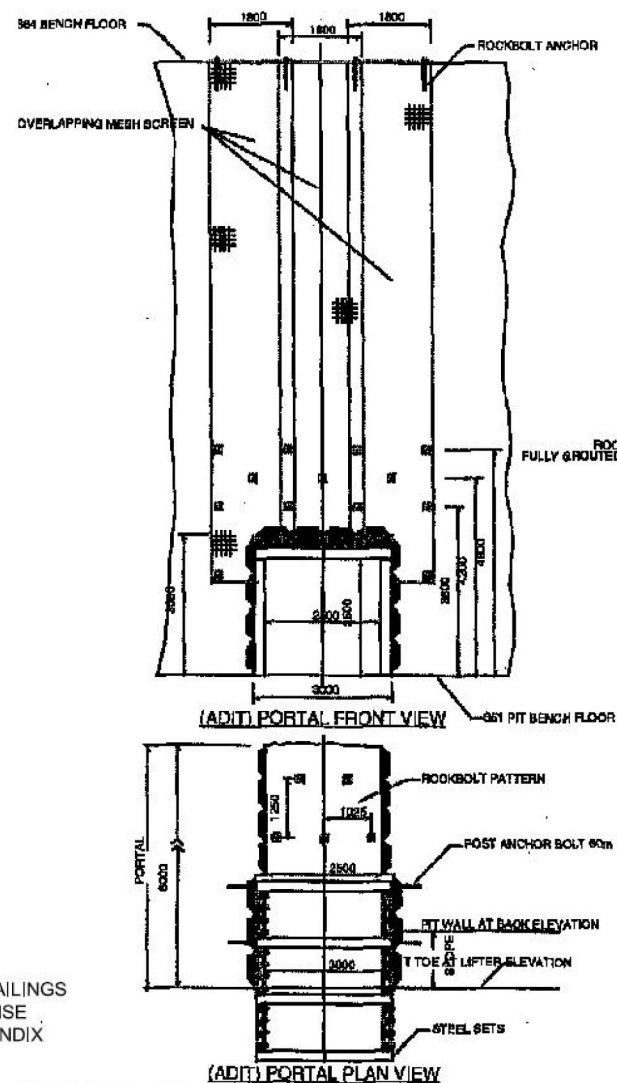
The drainage drift was approximately 230 m long and had a square cross-section with nominal dimensions of 2.5 m by 2.5 m. It was collared in the lowest level backwall and had a downward slope of about 4% towards the raise wells, as illustrated on Figure 2.3-41. This slope was selected to allow a greater pumping drawdown to provide operating flexibility (additional sump capacity) for the future, if required.

The drift ends in a drainage chamber that intersected the predrilled and cased raise wells. The well casings were checked to ensure they were intact and properly sealed. Stainless steel screens, extending to the chamber floor, were welded to the existing casings. The chamber was then backfilled with crushed sandstone with the gradation of 100% smaller than 150 mm and 5% smaller than 10 mm. When the chamber was backfilled, the entire drift was backfilled with special drain rock that had a gradation of 100% smaller than 300 mm and 5% smaller than 40 mm. It exhibited less than 50% Los Angeles abrasion loss and less than 2.5% loss in sodium sulfate soundness test. Details of the drainage chamber construction are provided on Figure 2.6-27. The characteristics required for the special drain rock were the same as outlined for the drain rock. Backfilling of the drift and pump chamber required about 3,000 m³ of material.

Suitable ground support in the drift was provided during construction. Continuous geological monitoring was conducted during the construction program to map ground conditions and secondary structure. Of particular interest were the mineralized zones, unstable ground conditions, or joint and fracture systems that produced water.

The co-ordinates of the portal and drift are as follows:

- Portal entrance 11,160.61 N 5,326.25 E;
- End of drift 11,024.41 N 5,516.14 E; and,
- Azimuth 127° 35' 39".



SOURCE:
McCLEAN LAKE PROJECT; JEB TAILINGS
FACILITY CONSTRUCTION, LICENSE
ADDITIONAL INFORMATION APPENDIX
VOLUME 1 APRIL 1998
APPENDIX 1 FIGURE 7

FIGURE 2.3-40
ADIT AND PORTAL DESIGN

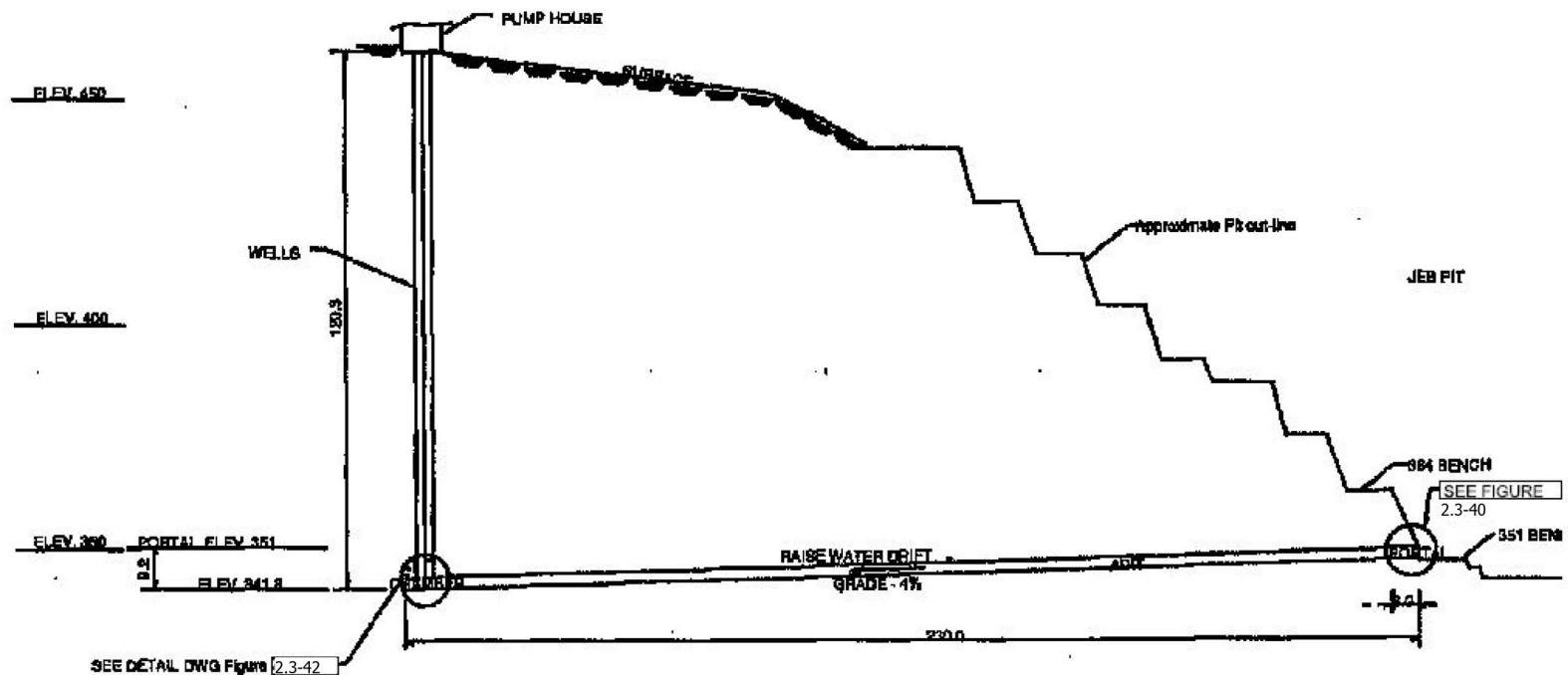
TAILINGS MANAGEMENT TID

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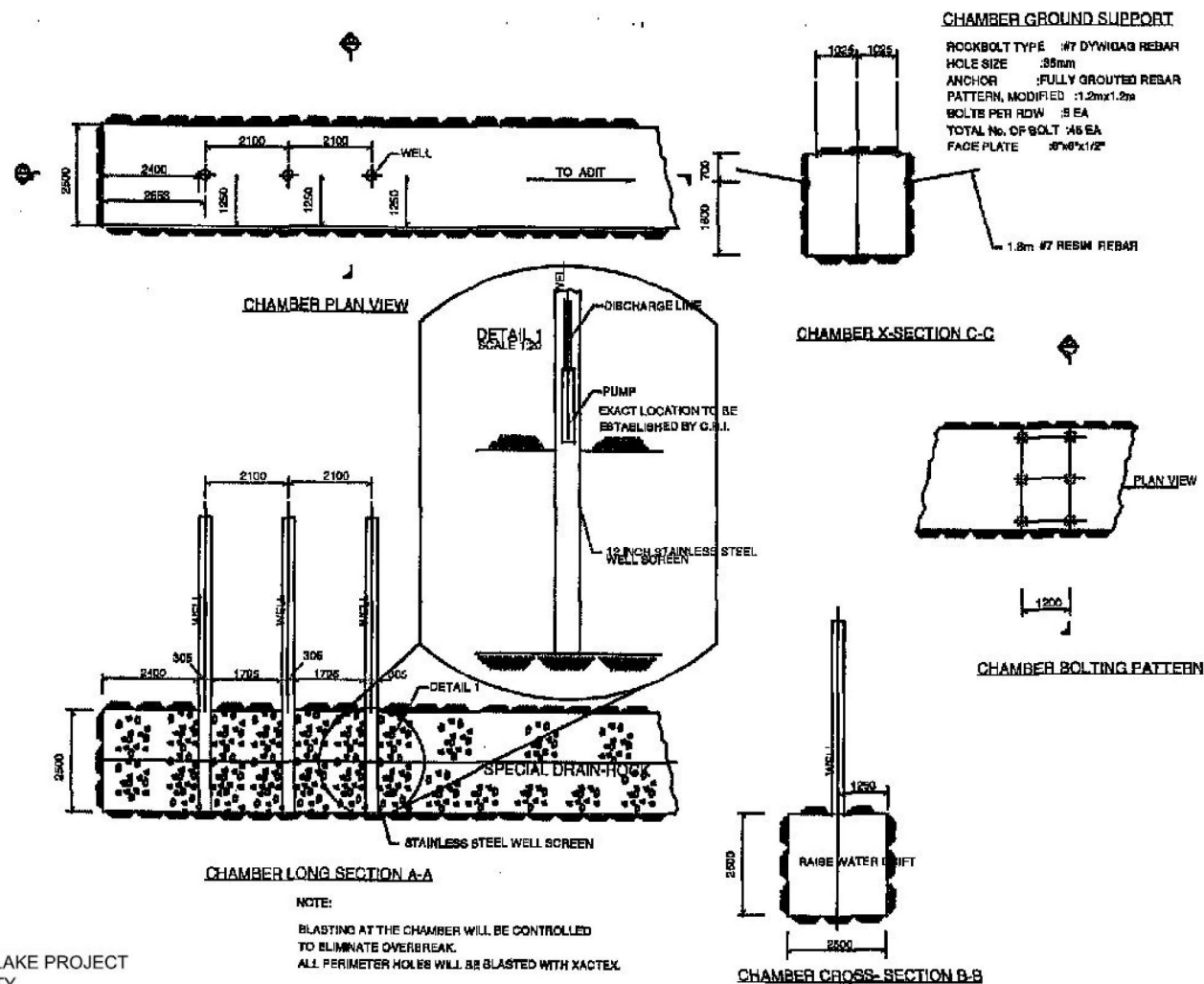
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FIGURE 2.3-41
 LONGITUDINAL PROJECTION

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CONSTRUCTION LICENSE ADDITIONAL INFORMATION
APPENDIX VOLUME 1 APRIL 1998
APPENDIX 1 FIGURE 9

FIGURE 2.3-42
DRAINAGE CHAMBER GROUND SUPPORT

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Raise Wells

Three raise water wells were constructed of 610 mm carbon steel well casing to an approximate depth of 20 m followed by a 300 mm diameter carbon steel casing extending down into the chamber of the dewatering drift. A seal was installed in the casing to the borehole annulus to seal off the well from the dewatering drift. A high strength stainless steel screen extending to the drift floor was welded to the casing when mining of the chamber was completed. A 50-hp submersible down hole pump was installed in each of the raise water wells, as illustrated in the schematic on Figure 2.3-43.

Drift Monitoring Well

A monitoring well was drilled into the drift from a surface location near the rim of the pit. This well was used to measure the water level in the base filter and to collect water samples. The drift monitoring well was constructed of 100 mm diameter polyvinyl chloride (PVC) or HDPE well casing in a 200 mm diameter borehole, with grout in the annulus. The casing extended into the dewatering drift. Once mining of the drift was completed, the bottom of the casing was cut square and a high strength, stainless steel screen was welded to the casing.

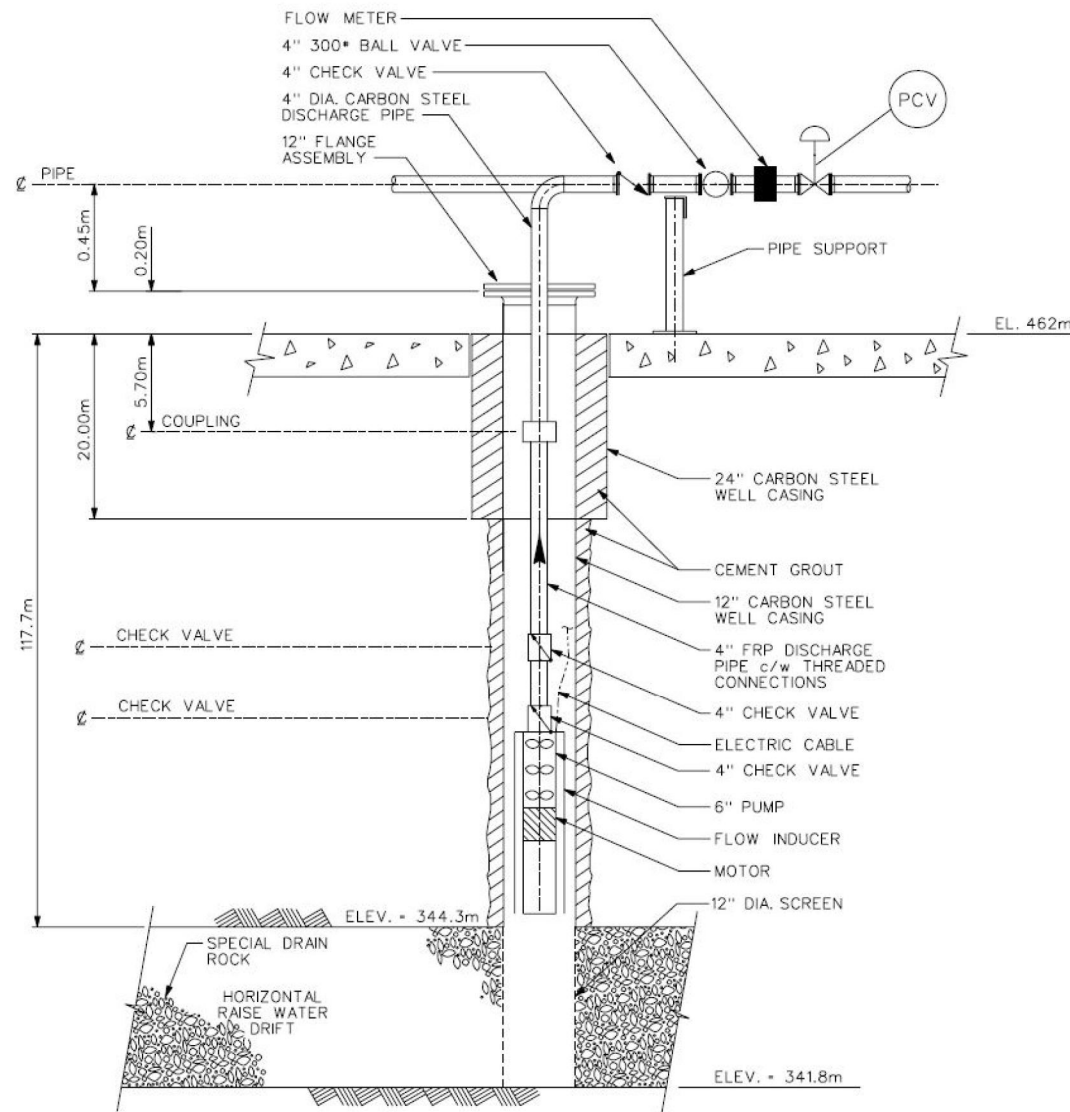
2.3.4.5 Raise Water System

Description

The objective of the raise water system is to maintain a downward hydraulic gradient from the tailings pond to the base filter and to maintain a consistent pond level. The raise water system removes water volumes daily to compensate for the impinging groundwater and, additionally, removes any pore water from the tailings that passes through the filter in the bottom of the JEB TMF. The water is collected by the raise water system and pumped to the mill and through an intermediate cooling loop in the leach circuit. The water then reports to the process water tank for recycling through the mill processes and excess is directed to the JEB WTP.

The raise water system is shown on the piping and instrument diagrams in Figures 2.3-44a, b and c and schematic 2.3-45

Three raise water wells were drilled down into the chamber at end of the drift as described in Section 2.3.4.4. Each well was equipped with a submersible pump to pump water from the drift to the surface where flows are combined into a single header. A schematic of the pumping system in each well is outlined on Figure 2.3-43. Each of the three wells contains a 100-mm diameter fibre-reinforced plastic (FRP) discharge piping, three check valves (one in the surface piping, a second near the mid-point of each well and a third immediately above the pump), an isolation valve and a flow meter. The flow from the pumps routes into a common header, which contains a pressure control valve to control the discharge pressure of all three pumps.



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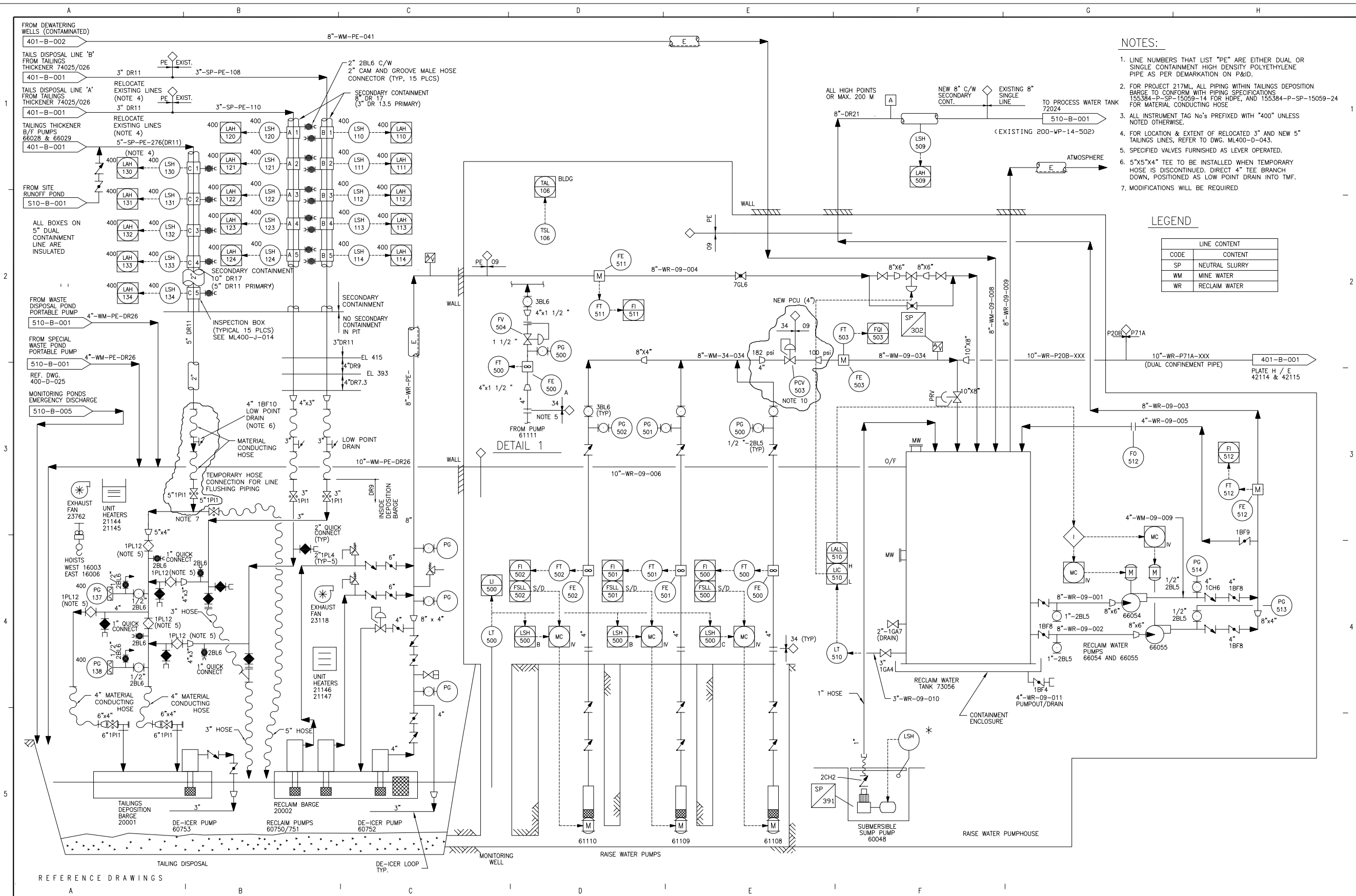
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FIGURE 2.3-43
 JEB OPEN PIT RAISE WELL SCHEMATIC

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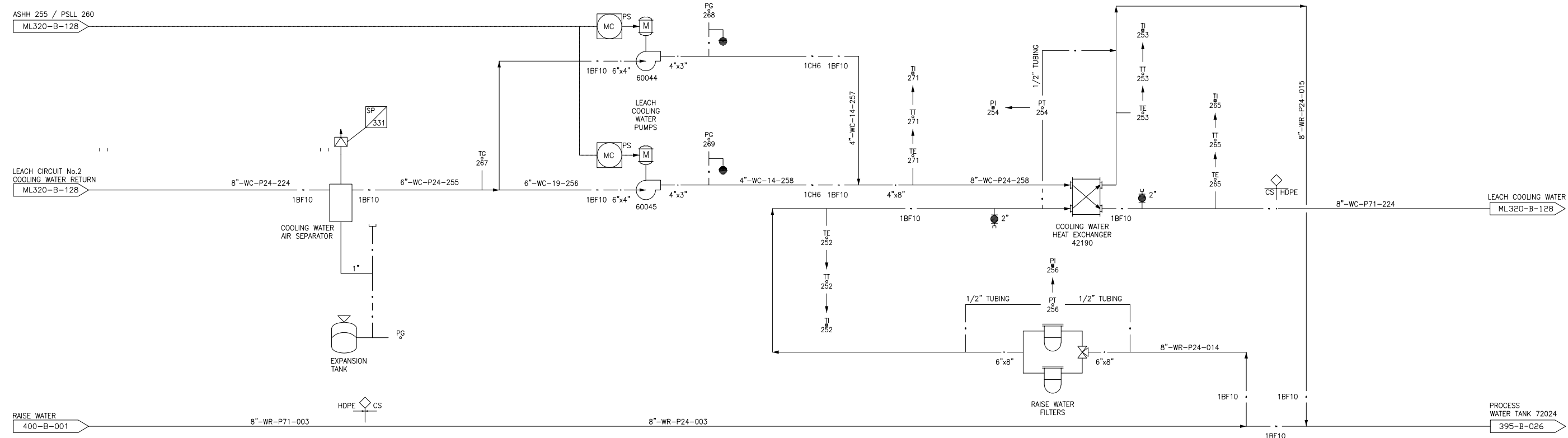


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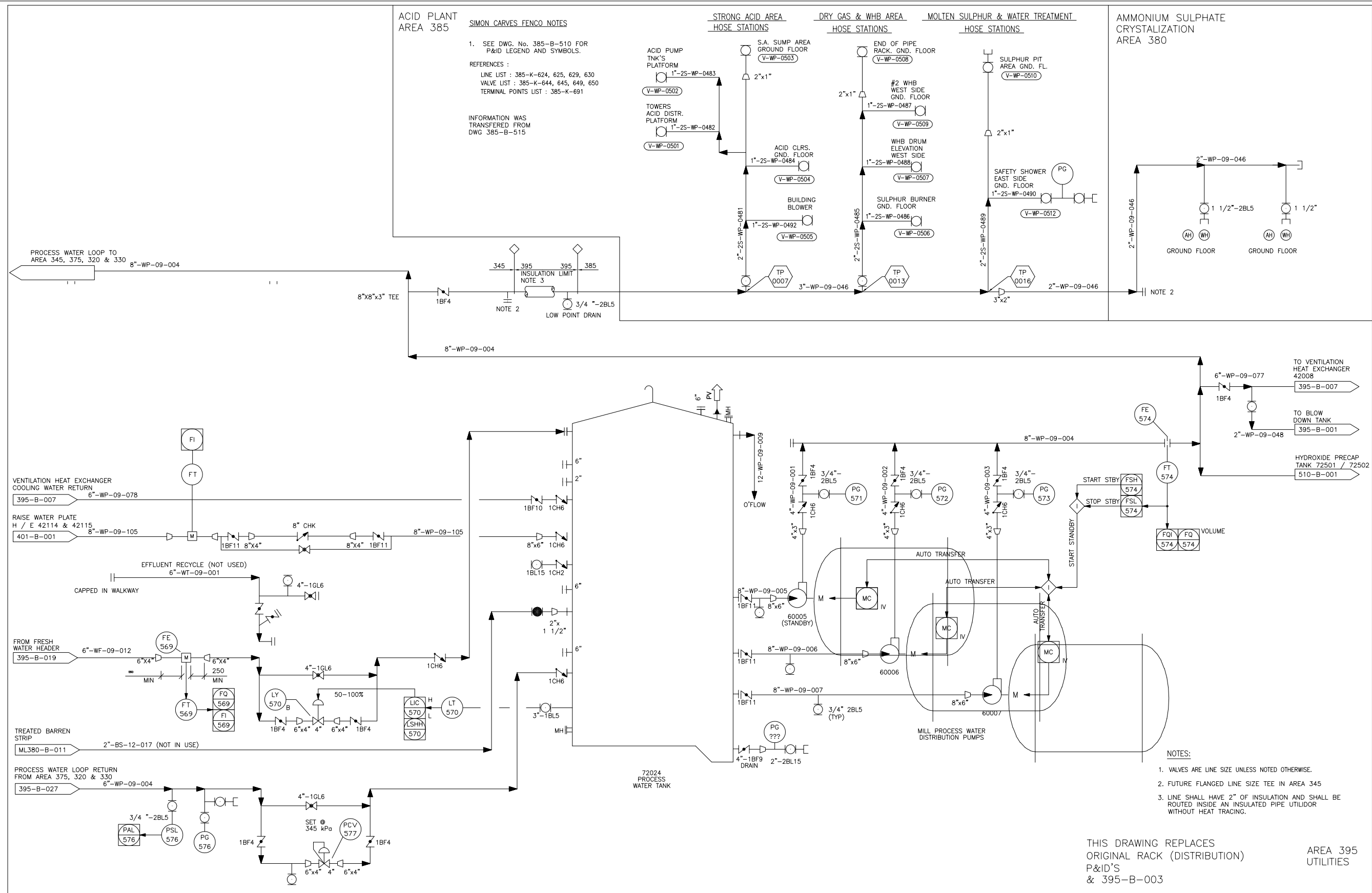
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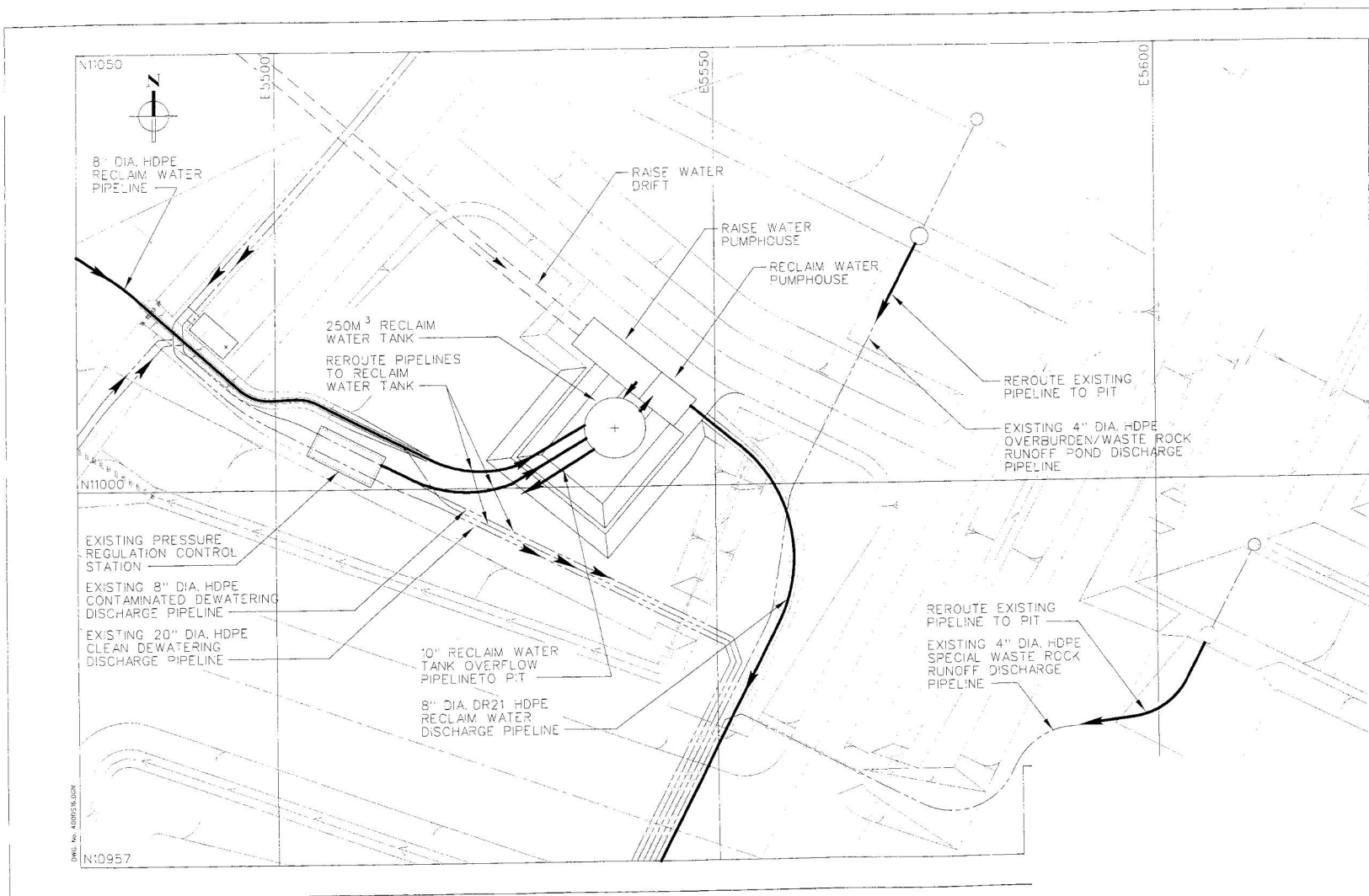
FIGURE 2.3-44a
MCCLEAN LAKE PROCESS PLANT TAILINGS DISPOSAL
PIPING AND INSTRUMENTATION DIAGRAM RAISE WATER PUMPING

FIGURE:
 REPORT: TAILINGS MANAGEMENT TID



1. ALL DRAIN VALVES SHALL BE 1/2" 2BL6 UNLESS OTHERWISE NOTED.
2. ALL PROCESS CONNECTIONS AT PRESSURE GAUGES & TRANSMITTERS (WITH OR WITHOUT DIAPHRAGM SEALS) SHALL BE 1/2" FNPT.
3. USE 1BF10 BUTTERFLY VALVES ONLY WHERE SPECIFICALLY NOTED.
4. * INDICATES LINES INSTALLED AS SCH 40S 316L MATERIAL.





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FIGURE 2.3-45

JEB TMF DEWATERING, RAISE WATER PIPELINES AND RECLAIM WATER PIPELINE

TAILINGS MANAGEMENT TID



After passing through the header, raise water is directed into the mill to the leach circuit where it passes through a heat exchanger and is used to cool the leach vessels. The warmer water moves to the process water tank, located within the mill facility, where the raise waters are further employed within the mill process. Excess water not used in the mill process is routed to the JEB WTP process, for treatment and release to the S/V TEMS.

The raise water pumphouse is a steel-clad, heated building with a concrete floor. The roof has been fitted with three removable roof hatches centred above the raise water pumps for pump maintenance. The raise water pumphouse has been provided with a temperature switch and alarm to alert the JEB WTP operator in case of a failure of the building heating system.

Raise System Water Level Control

Originally the water level in the raise system was maintained at or slightly below the tailings pond water in the JEB TMF but now is controlled relative to the level of Fox Lake as the primary method of hydraulic containment (Section 2.2.2). The water level in the drift is measured in a monitoring well drilled from the surface, near the rim of the pit, into the drift (well CM06). A level measurement instrument is located in the well to monitor the water level in the raise water system. This provides verification that the raise water pumps are maintaining the design water level in the drift. In the event of a discrepancy between the design and actual measurements, the raise water pumping rate is adjusted.

Tailings Pond Water Level Control

Pumping through the raise system originally served to maintain the pond water level and balance groundwater inflow into the JEB TMF, which occurs at approximately 90-100m³/hr, and currently is the primary control of hydraulic containment of the TMF (Section 2.2.2). Raise well pumping also serves to collect any pore water that is released from the deposited tailings aiding in tailings consolidation. The reclaim water system (Section 2.3.4.6) works in conjunction with raise water pumping to maintain the tailings pond at a relatively stable level. While the raise well pumping is maintained at a constant rate reclaim pumping is varied to account for the addition of tailings to the JEB TMF and any other inflows into the JEB TMF such as site runoff from precipitation events.

Previous to the expansion of the TMF capacity (described in detail in Section 2.4) the elevation of the water in the tailings pond was monitored with a graduated staff gauge immersed in the water next to the reclaim barge and compared to groundwater levels measured in monitoring well TW08. Extensions of the gauge were added as the water level increased. The gauge was surveyed periodically to confirm the reliability of the measurements. The level of the pond water was recorded daily and the gauge was protected from the ice by maintaining an ice-free condition next to the barge.

In August 2024, an automated survey system was installed to collect TMF pond elevations. The Trimble 4D control GPS records the pond elevation hourly then calculates an average daily elevation. Hourly readings allow for potential wave action and movement of the barge.

Spill Control and Secondary Containment

The reclaim water tank has a 255-mm diameter overflow line to direct any excess flow to the tailings pond. The tank was placed within the pumphouse so that the pumps and other equipment are protected from weather conditions. A sump is located in the building to collect any leakage from the tank or associated equipment. The sump pump directs any leakage back to the overflow line, which leads to the tailings pond. The pumphouse contains a concrete pad and a side wall of concrete. The containment structure in the pumphouse has sufficient capacity to retain 110% of the contents of the tank, to provide adequate spill protection in the event that there is a major spill in the pumphouse. Even if a rupture resulted in over-topping of the containment structure, the local topography is naturally sloped toward the JEB TMF so that any spillage will flow to the pit.

Secondary containment has been provided for the 200-mm diameter carrier pipeline by encasing it in a 300-mm diameter HDPE pipeline. The containment pipe has the same DR-21 specification as the carrier pipe. It is continuous without flanges or other fittings. Secondary containment has been provided along the entire 400 m length of pipeline from the pumphouse to the point where it is connected to the existing pipeline, in the vicinity of the mill site runoff pond. Downstream of the location where the new pipe connects to the existing pipeline, water from a break would flow to the mill site runoff pond and be contained.

The secondary containment system for the pipeline begins where the outlet pipe from each pump is combined into a single pipeline and exits the pumphouse wall. An end seal has been fusion-welded to both the carrier and containment pipes at each end of the pipeline. This provides an annulus for containment in case a leak develops in the carrier pipe.

The secondary containment pipeline is a dual containment system specially designed by PLEXCO engineering. It is identical to the tailings pipeline, except larger in diameter. The piping sections were fabricated in 12 m lengths, which consist of the containment pipe, the carrier pipe, and all internal fittings. A centralizer is fusion-welded to both pipes at each end of a 12 m piping section. The centralizer ensures that neither of the pipes would move during the fusion welding of two sections of pipeline plus it restricts any differential thermal expansion between the outer and the carrier pipe within each section. The centralizers consist of an HDPE disc with four holes, each with a diameter of 19 mm. The annulus between the containment pipe and the carrier pipe is maintained along the entire length of each piping section by the installation of “spiders” at intervals of about 1.2 m.

Two sections of dual containment piping were butt fusion-welded together using a special heating head which simultaneously heated the ends of the carrier and containment pipes of both sections before the pipes were forced together to provide a fusion joint. Fusion-welding was performed during winter months by placing a tent over the section to block out the wind and providing heat, normally to above 0°C, to ensure that the heated piping sections did not cool too quickly. The design of the secondary containment pipeline is shown in Figure 2.3-46.

Monitoring for Pipeline Leaks

The pipeline berm has a low point approximately 150 m from the raise water pumphouse. If a leak were to develop in the carrier pipe, the water will flow within the annulus to the low point. A piping tee was installed in the outer containment piping at the low point and contains a flanged cap. An ultrasonic, gap-type, level switch was installed at the tee to detect the presence of water in the annulus. Wires from the level switch were run through a separate conduit located outside of the dual containment piping back to the raise water pumphouse where the signals are transmitted to the mill control room via radio modem. An alarm would sound in the control room if a leak were detected in the pipeline. The level switches are easily tested by simply removing the cap on the tee, and immersing the switch in a liquid to initiate an alarm.

A pumpout nozzle was also installed in the carrier pipe at the low point to allow it to be pumped out if the system was not operating for a prolonged period during the winter months. The annulus provides sufficient insulation for the carrier pipe to prevent freezing during normal operation in the winter. The arrangement of the pumpout and monitoring connections are shown on Figure 2.3-46.

Repair of Secondary Containment

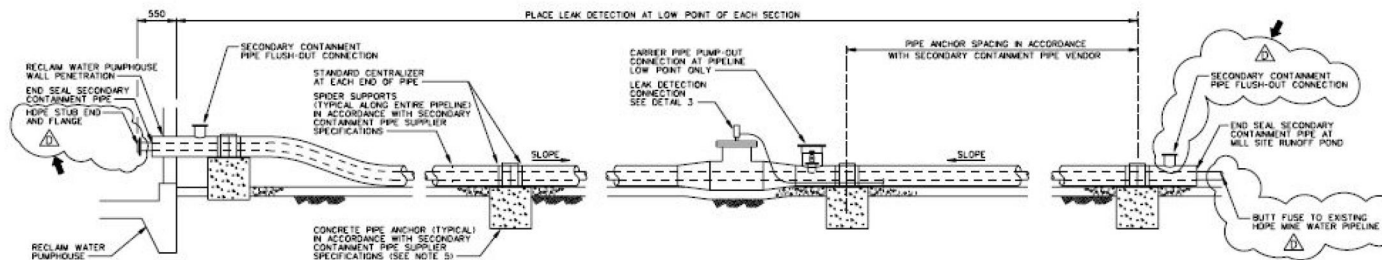
The dual containment system piping is easily repaired and provides excellent protection of the worker in the event of leakage of the carrier pipe. It is particularly well suited to contain any leakage from the carrier pipe within the annulus so that a spill does not occur.

If a leak in the carrier pipe were detected, the raise water and reclaim water systems would be shut down immediately. First, the pipeline would be depressurized by draining the reclaim water tank back to the tailings pond. Next, a plastic apron would be inserted under the tee containing the monitoring instrumentation to divert any leakage that occurs during opening of the system to a container beside the berm. The container to collect leakage has sufficient volume to store all water from the annulus. It would typically be a section of plastic pipe with a diameter of 24 to 36 inches and have end seals and nozzles fused onto it. Finally, the cap on the tee would be opened and any water in the annulus would be removed with a vacuum truck.

To detect the location of the leak, a pump at the reclaim water tank would be restarted and the leak located by listening on the outside of the pipeline with a stethoscope. The volume of flow would be controlled by partially closing the valve downstream of the pump. The leakage into the annulus would be collected at the tee either with a vacuum truck, by diverting it into a storage container (pipe) or piping it back to the reclaim water tank overflow line.

The design of the dual containment system allows one or more sections of 12 m of piping to be cut out and removed from the pipeline. Normally, the pipeline would be cut at a fusion weld, which is located either between two centralizers or between a centralizer and an end seal. The section of pipe can be removed and a new section butt fusion-welded into the location. If it were necessary to cut the pipe in an area where a centralizer is not located, a new centralizer would be fusion welded into each section of pipe using a special fusion head. The two sections of pipe would then be butt fusion-welded together as usual.

The leaking section of pipeline would be simply cut out of the line after the annulus and the carrier pipe are pumped out. Any minor leakage would be collected using a plastic apron. A new section of pipeline would be butt fusion-welded into the pipeline.



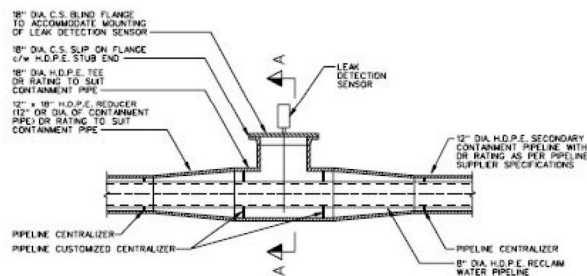
DETAIL 1
RECLAIM WATER / RAISE WATER PIPELINE
SECONDARY CONTAINMENT SYSTEM
CONCEPTUAL LAYOUT
N.T.S.

NOTES:

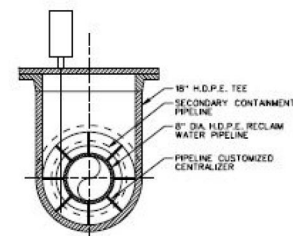
1. GRID SYSTEM IS CODEMA RESOURCE'S INC. MINING GRID BASED ON UNIVERSAL TRANSVERSE MERCATOR, NORTH AMERICAN DATUM (NAD27). CODEMA Q N IS UTM 563000N CODEMA Q E IS UTM 563000E
2. ALL CO-ORDINATES ARE IN METRES.
3. ALL ELEVATIONS ARE GEODETIC DATUM IN METRES AND DECIMALS THEREOF.
4. ALL DIMENSIONS ARE IN MILLIMETRES, UNLESS NOTED OTHERWISE.
5. NEW DISCHARGE PIPELINE RESTRAINTS AND CONCRETE PIPE ANCHORS WILL BE PLACED INDEPENDANT OF EXISTING SUPPORTS WHERE REQUIRED. PIPE RESTRAINT AND CONCRETE PIPE ANCHOR DESIGN TO BE IN ACCORDANCE WITH PIPE SUPPLIER SPECIFICATION.

LEGEND

NEW FACILITY OUTLINE.....
EXISTING FACILITY OUTLINE.....



DETAIL 3
LEAK DETECTION SYSTEM
CONCEPTUAL PROFILE
N.T.S.



SECTION A-A
N.T.S.

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McCLEAN LAKE OPERATION

FIGURE 2.3-46
RAISE WATER SYSTEM CONCEPTUAL PIPING LAYOUT SECTIONS AND DETAILS

TAILINGS MANAGEMENT TID



2.3.4.6 Reclaim Water System

Reclaim Pipeline

The road ramp leading to the bottom of the JEB pit ends at the edge of the tailings pond. A barge is located about 15 m from shore to pump pond water back to the JEB WTP.

The reclaim barge contains two 100-hp vertical turbine pumps (sized to pump 130 m³/h), with one on standby, to pump water from the surface of the pond through an eight-inch HDPE pipeline up to a reclaim water tank located at the rim of the pit, beside the raise water pumphouse. A butterfly valve and a check valve were installed on both discharge lines from the pumps to allow them to be isolated or operated either independently or in series. The piping and instrument diagram for this system is shown in Figure 2.3-44a.

A safety berm is located along the inside edge of the JEB TMF ramp to ensure that vehicles cannot fall into the pit. The pipeline is routed on top of the berm to the point where it formerly followed the top bench to the reclaim water tank. The reclaim water tank was bypassed in 2021 due to failure of the tank (Approval PC21-161 Reclaim Water Bypass, Merkowsky to Huffman September 30, 2021). The system now consists of piping through the raise well house where the reclaim tank was formerly located. Flow meters and a throttle valve are located in-line of the reclaim piping in the raise well pump house. Beyond the raise well pump house to the JEB water treatment plant, the piping remains unchanged.

In the JEB WTP, a connection was provided to an existing line leading to the process water tank to allow recycling of a maximum amount of this water.

The layout of the former reclaim water tank, pumphouse, and associated pipelines is shown in Figure 2.3-45. A berm was constructed to allow for the pipeline to run straight across to the mill site.

Reclaim Barge

The barge for the pumps and associated mechanical and electrical equipment is 4.3 m wide and 8.5 m long. The suction from the two vertical turbine pumps was inserted into an internal sump located along the centre of the barge, between the pontoons on each side.

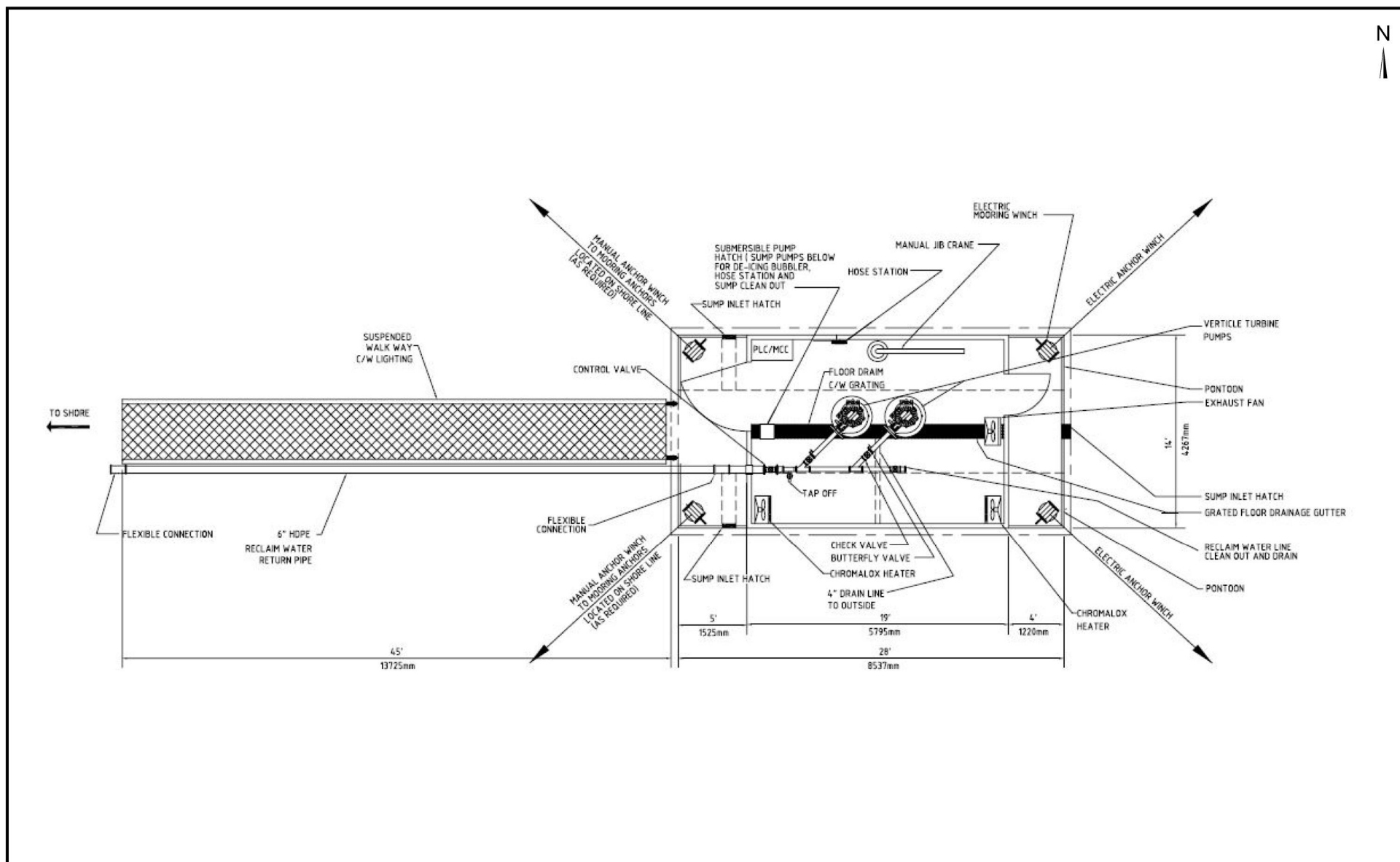
The pond water flows into an internal sump through three screened hatches: one at the end and one on each side near the walkway end. The hatches contain a gate to control the location of the decantation to near the surface of the pond to minimize the solids content. The gate is also used to seal off the sump to allow it to be cleaned out.

The pumps and equipment are located inside a steel-clad building with approximate dimensions of 5.8 m in length, 4.3 m in width and 3.3 m in height. The walls of the building contain fibreglass insulation to minimize heat loss. A door was installed at each end of the building to allow access to both ends of the barge and to transport equipment into and out of the building. A manual jib boom crane is located in the building to assist

with maintenance of the equipment. A detailed layout of the barge, building, and equipment is shown on Figures 2.3-47 to 2.3-50.

The barge is anchored about 15 m from shore and walkway from shore allows access to the barge. The entire barge and walkway system is anchored to various concrete blocks along the shore of the TMF, depending on the location of the barge. The walkway layout is shown on Figure 2.3-51

The eight-inch discharge pipeline and the electrical cable for the equipment on the barge are routed along the walkway leading to the barge.



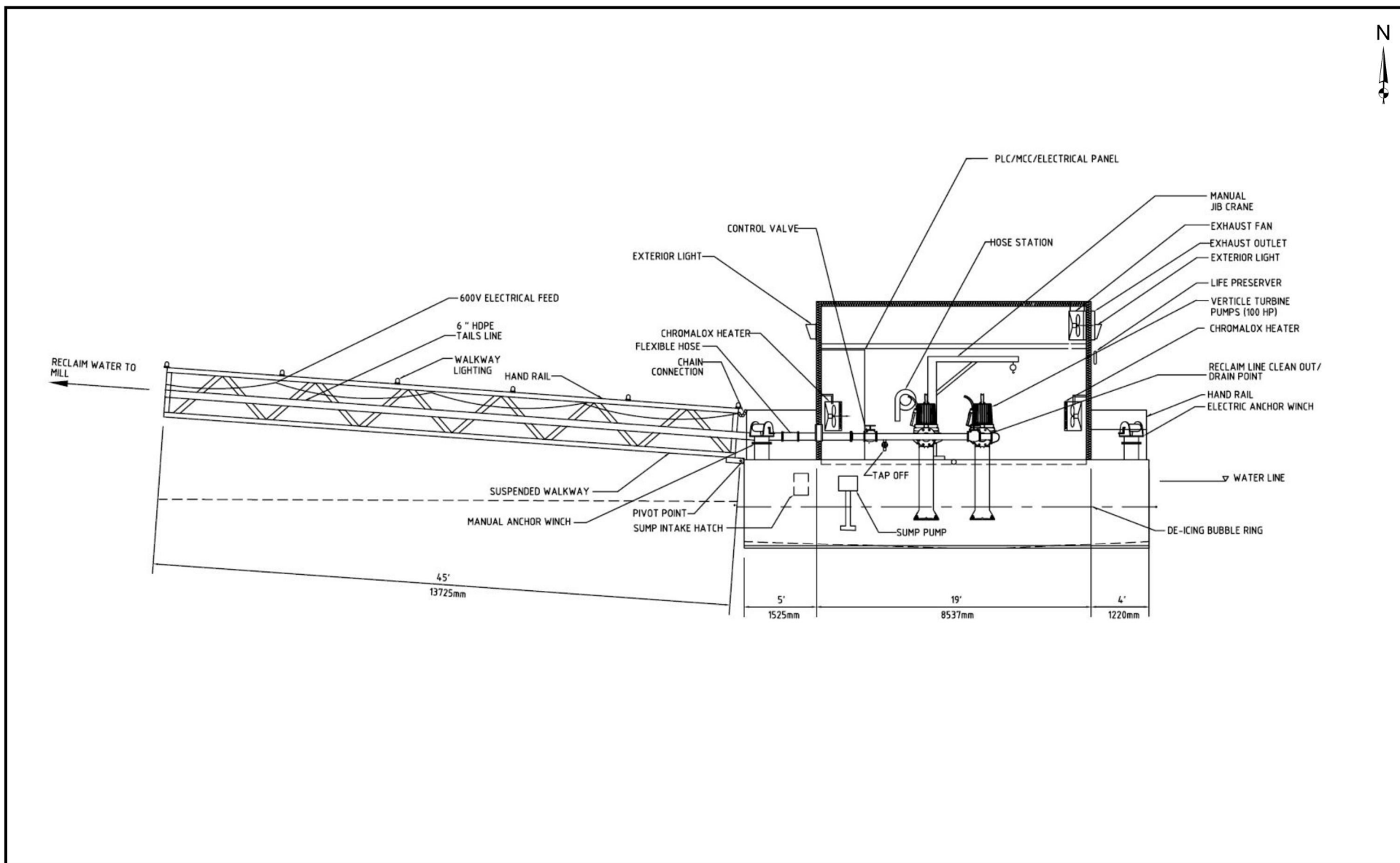
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 Topographic Database, ORANO Canada Inc.

McCLEAN LAKE OPERATION

FIGURE 2.3-47
 TAILINGS WATER RECLAIM BARGE - BARGE PLAN VIEW

TAILINGS MANAGEMENT TID





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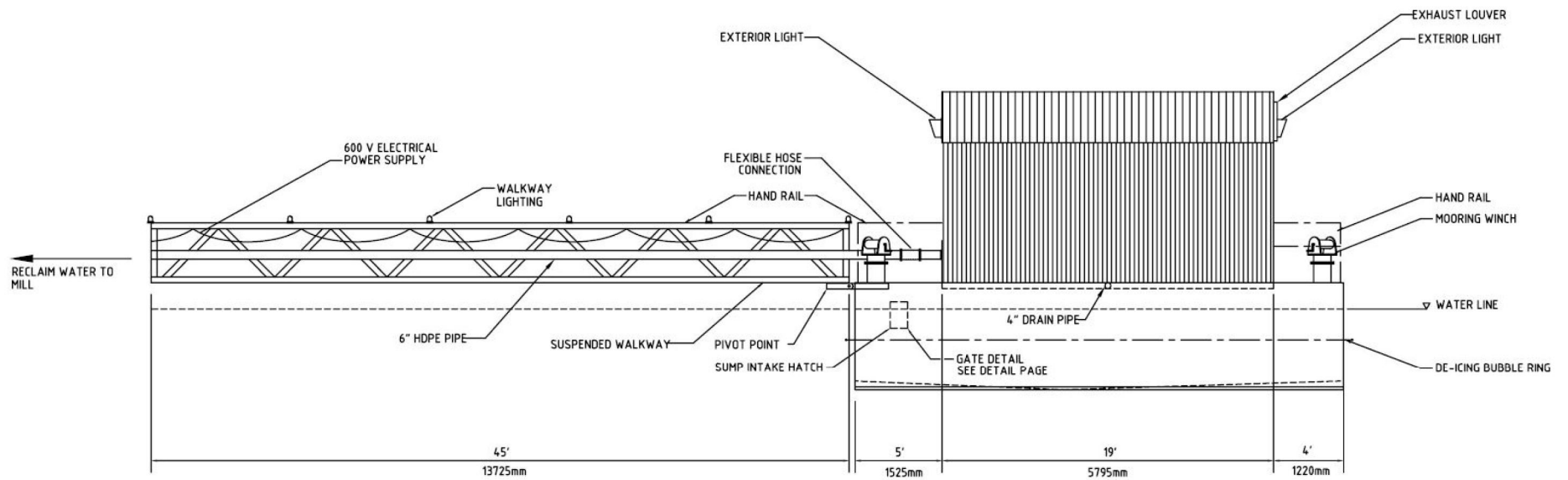
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FIGURE 2.3-48
 TAILINGS WATER RECLAIM BARGE - CROSS-SECTION

TAILINGS MANAGEMENT TID

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FIGURE 2.3-49
 TAILINGS WATER RECLAIM BARGE - PROFILE

TAILINGS MANAGEMENT TID



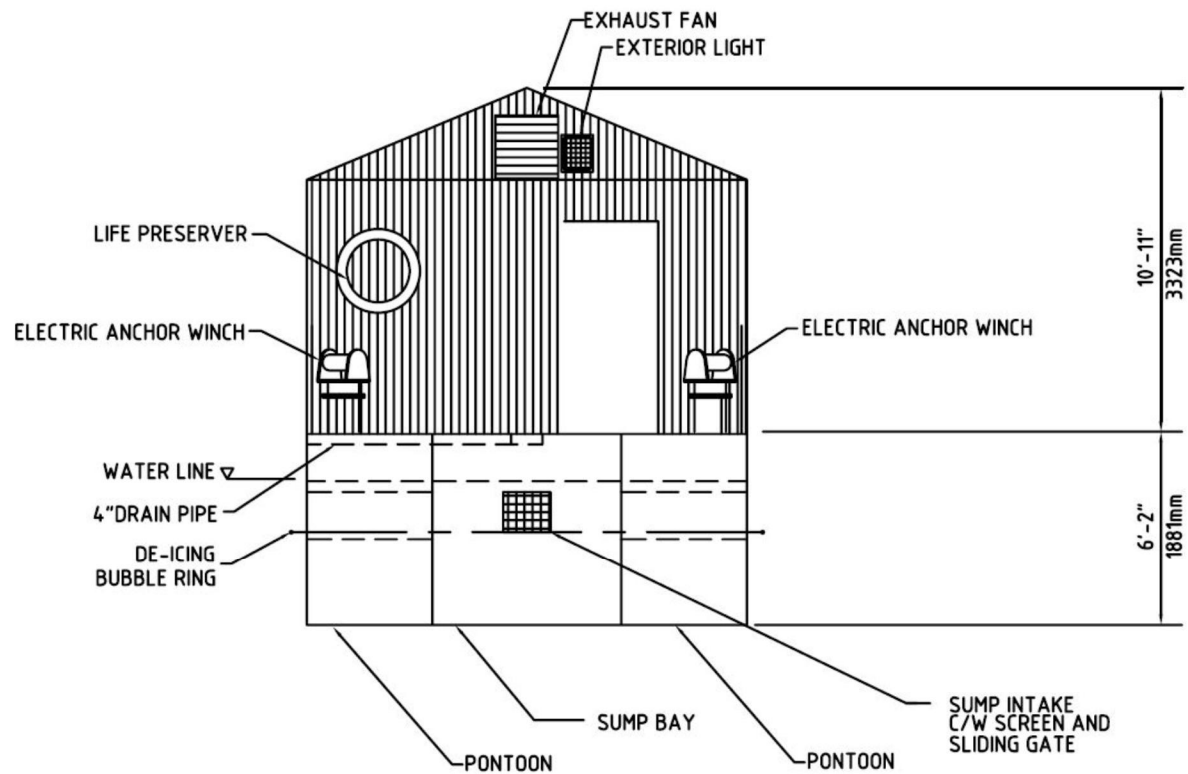


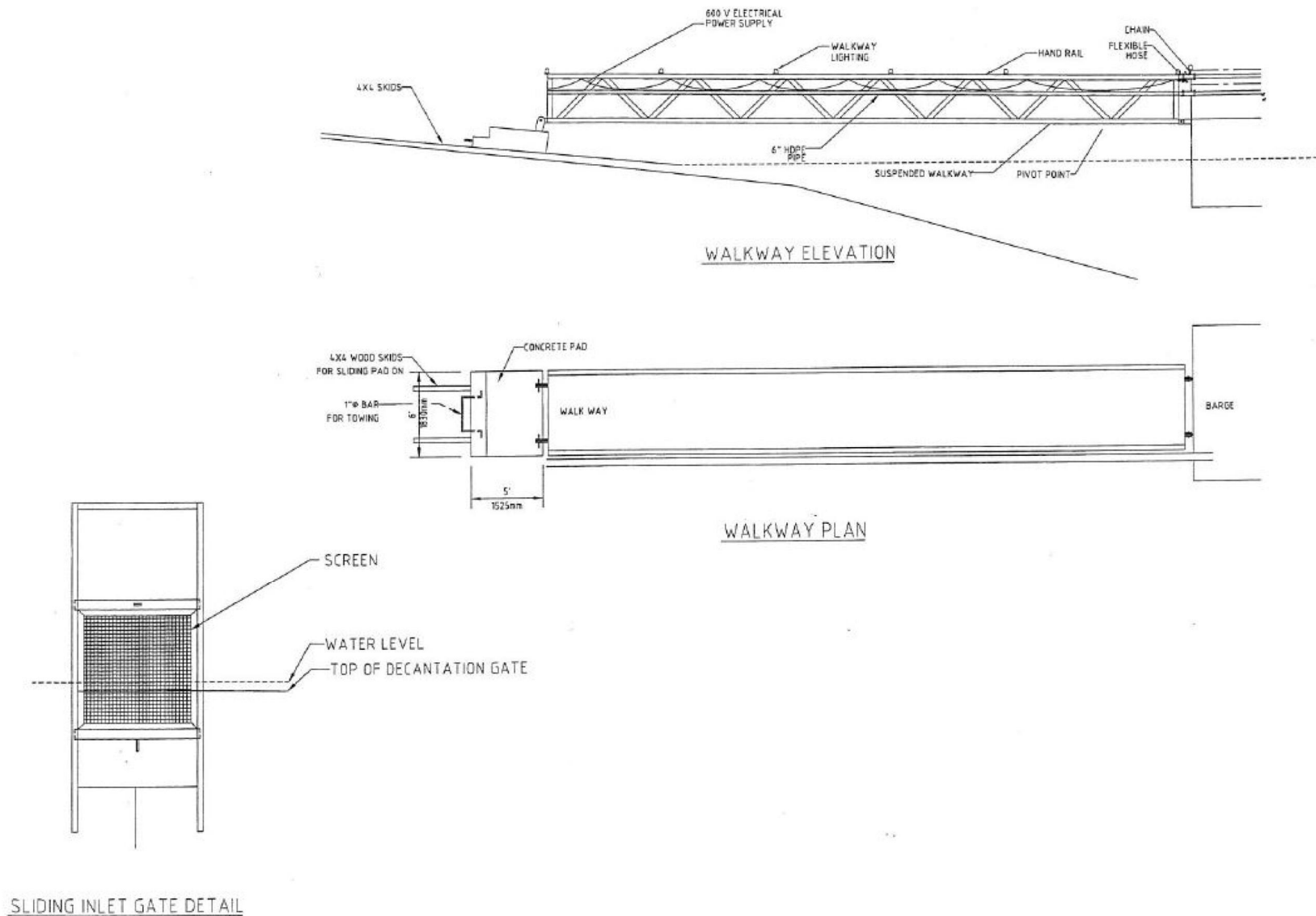
FIGURE 2.3-50
TAILINGS WATER RECLAIM BARGE - END ELEVATION

TAILINGS MANAGEMENT TID

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FIGURE 2.3-51
TAILINGS WATER RECLAIM BARGE - WALKWAY DETAILS

McCLEAN LAKE OPERATION

TAILINGS MANAGEMENT TID



2.3.5 Tailings Deposition System

Two three-inch tailings lines run from the mill down the TMF ramp and terminate at the bottom of the TMF near the edge of the tailings pond water. From this point, sections of three-inch HDPE pipe on the walkway are joined using flanged connections and flexible hose.

Until September 2018, tailings were deposited using a placement barge at the end of the walkway and a shallow injection tremie method. In September 2018, the tailings placement method was changed to incorporate multiple subaqueous deposition points along the walkway, while preserving the flexibility to use the previous tremie method if needed (Orano 2018a). The alternate subaqueous deposition method was implemented in order to make more efficient use of the remaining space in the TMF, and avoid barge moves in the winter.

In October 2021, the tailings deposition system was modified with two single-line horizontal subaqueous tailings deposition pipes extended and supported by a buoy and anchor technique (Orano 2021a). At this time the use of the tremie and subaqueous deposition systems was discontinued. Consequently, in 2023, the tremie barge and the flexible walkway associated with subaqueous deposition were removed from the TMF. (Braithwaite to Akerman August 2023) Additionally, a portion of the walkway connecting the header barge to the former tremie barge was dismantled at that time. Details of the former configuration including walkway, tremie deposition system, and subaqueous deposition system, as well as the current subaqueous tailing line extension system are outlined below.

In 2024 the deposition system was slightly modified to have the deposition lines float on the pond surface and continue to discharge subaqueously. This allows for flexibility in relocating deposition points and increases the ability to reach previously underutilized portions of the TMF, making more efficient use of space in the TMF.

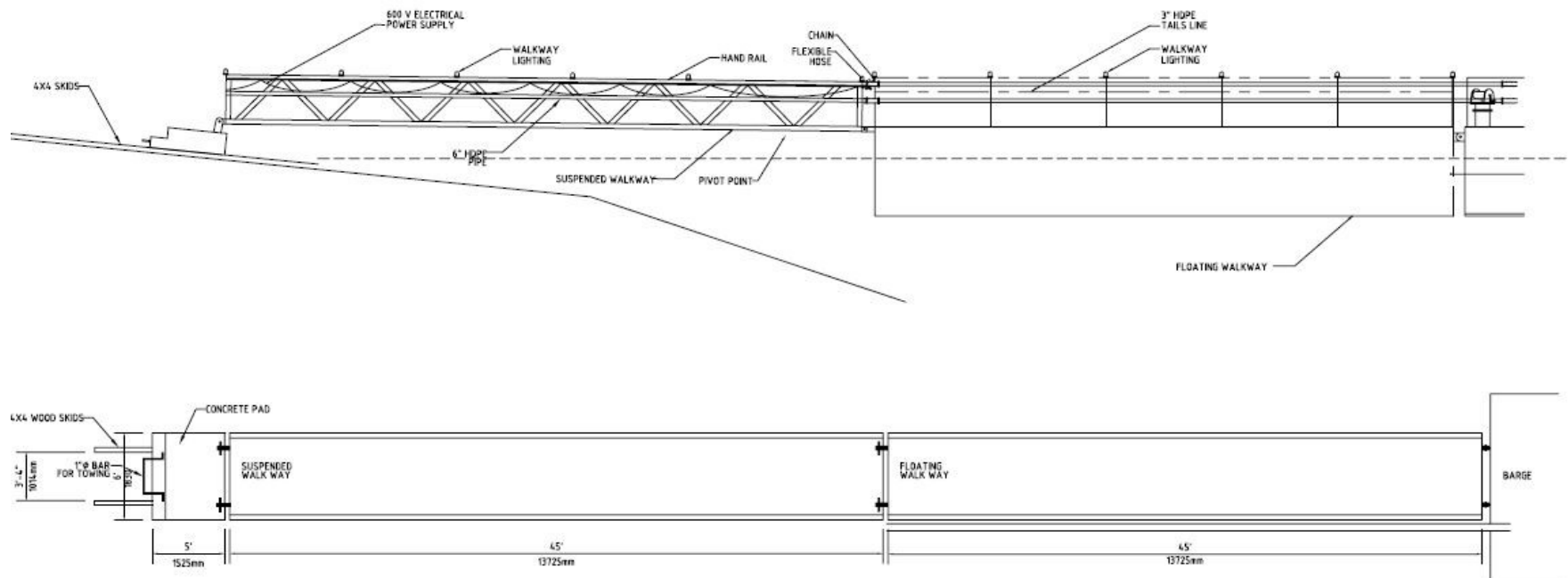
2.3.5.1 Infrastructure

Deposition Walkway

The floating walkway had been constructed in typical sections of 9-12 m in length and 2 m in width. Each section of the walkway was constructed using the square pontoon arrangement illustrated in Figure 2.3-52. In 2023, sections of the floating walkway from the header barge to the former tremie barge were disconnected and removed from the TMF. The remaining floating walkway is connected to shore using a cantilevered section of walkway attached to a concrete anchor block on shore. As the tailings pond water level increases, the shore anchor is re-located using a crane and/or loader. A boom-type coupling is used at each end of the cantilevered walkway which allows it to swivel in the upward or downward direction to accommodate increases or decreases in the water level (Figure 2.3.52).

The remaining reclaim barge is powered by a 600V cable which runs along the remaining walkway to provide power for equipment and lighting (the former tremie barge was powered in a similar way). All electrical and control components are located in the barge, and flood lights are installed to illuminate the floating walkway.

The pipeline sections on the walkway are connected using flexible hose and HDPE piping (rated for the design pressure), and flange connections. The walkway sections are connected to each other and to the barges using a pin arrangement so it was easier to disconnect and allow for differential movement between the sections of walkway.



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FIGURE 2.3-52
 TAILINGS DEPOSITION BARGE - WALKWAY DETAILS

McCLEAN LAKE OPERATION

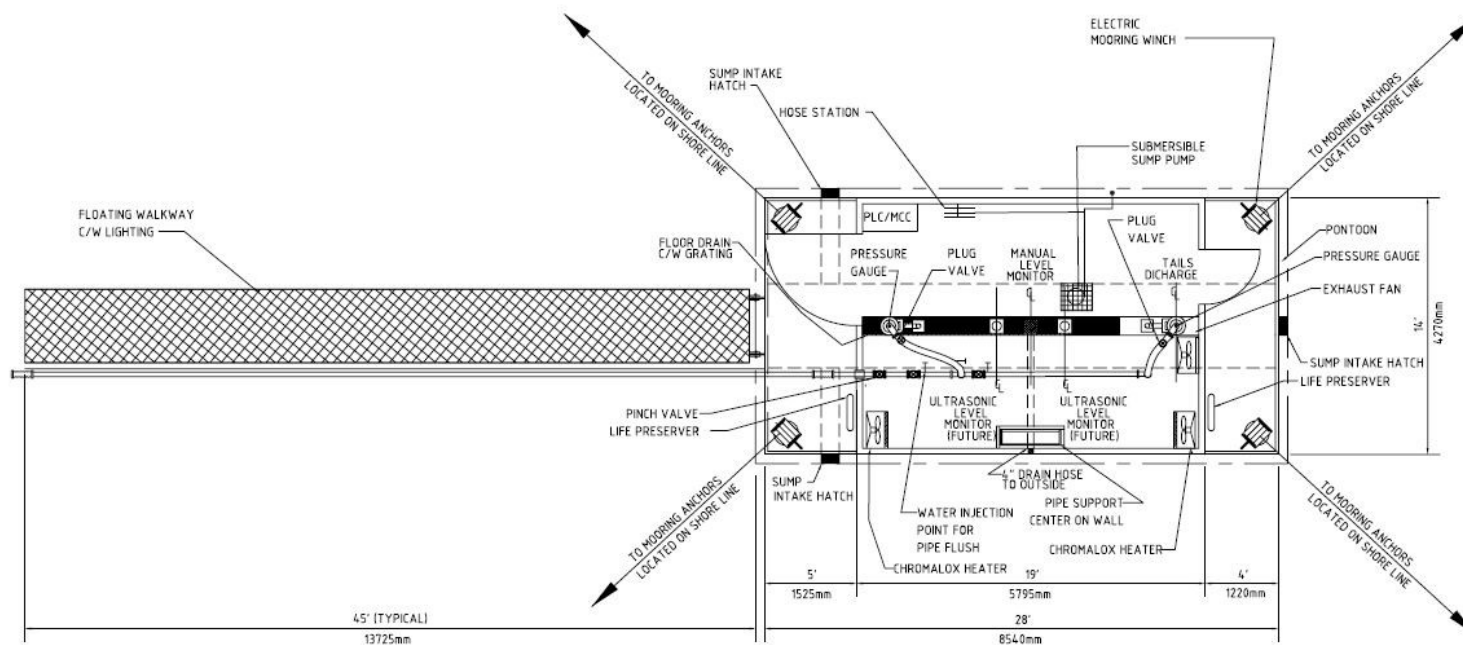
TAILINGS MANAGEMENT TID



Tremie Deposition System

The tremie system had rarely been used after the installation of the subaqueous deposition system in fall 2018 and was previously kept as a contingency to provide additional tailings placement capacity. Orano had maintained the flexibility to operate both deposition systems as required. However, with the implementation of the two single-line subaqueous deposition system, use of the tremie barge discontinued in 2021, and was decommissioned and removed from the TMF in 2023.

When the tremie system was in use, the tailings were routed along the TMF walkway to a floating barge located at the end of the walkway. The floating barge design is outlined in Figures 2.3-53 through 2.3-56 and a description of the full tremie deposition system can be found in the 2020 Tailings Management TID, (Orano 2020b, Appendix A).



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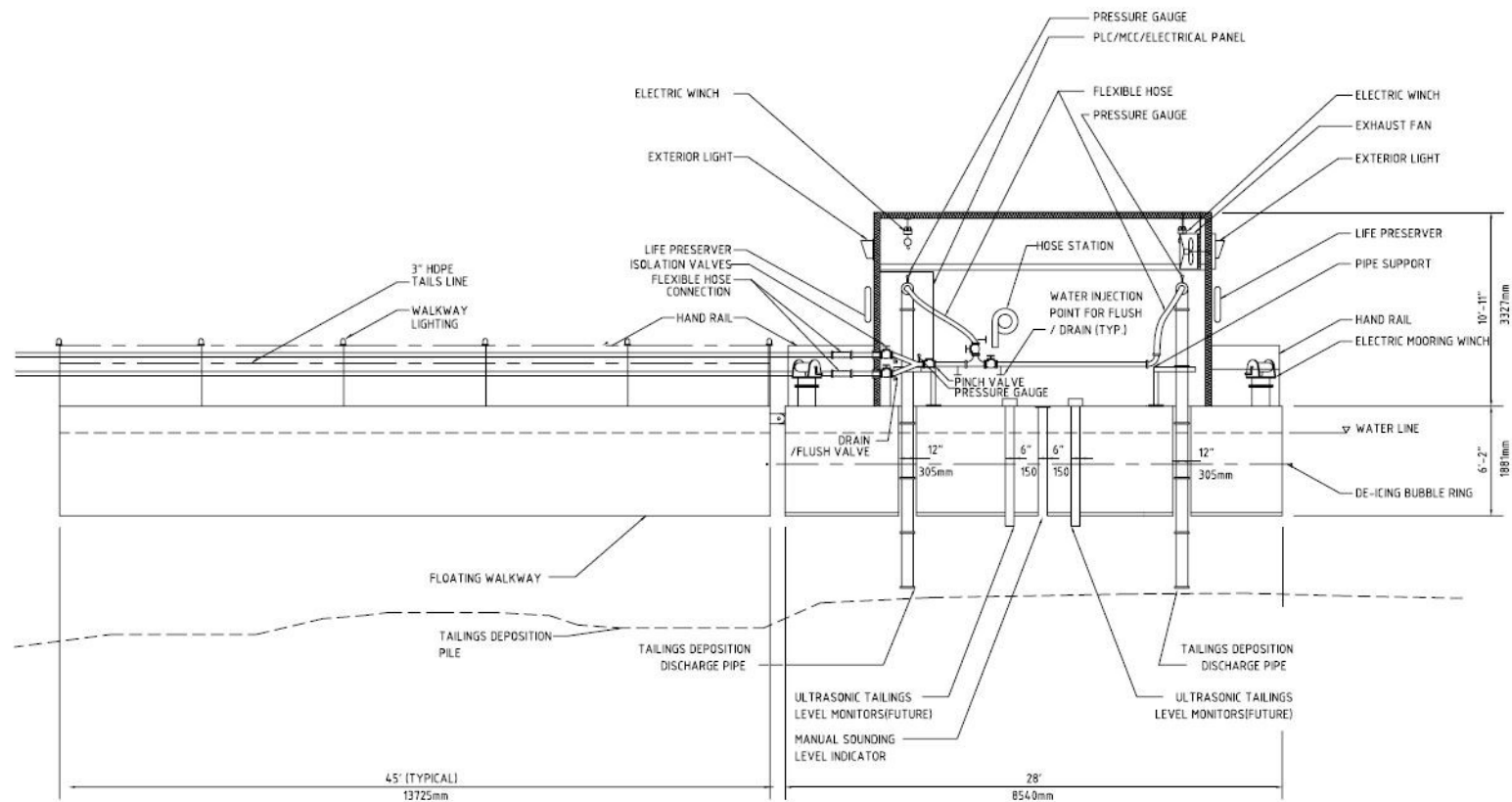
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FIGURE 2.3-53
 TAILINGS DEPOSITION BARGE - PLAN VIEW

McCLEAN LAKE OPERATION

TAILINGS MANAGEMENT TID





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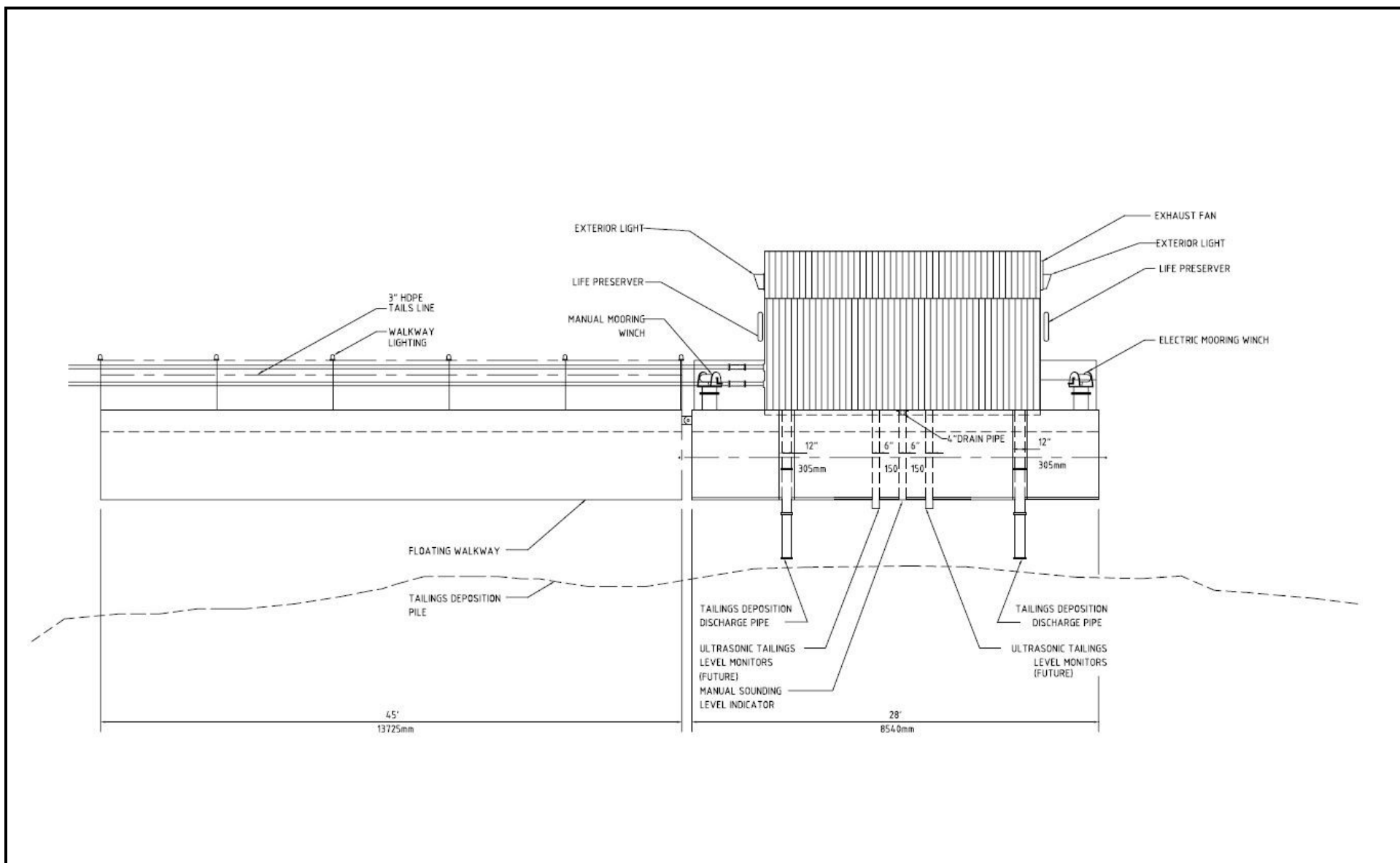
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FIGURE 2.3-54
TAILINGS DEPOSITION BARGE - CROSS-SECTION

TAILINGS MANAGEMENT TID

McCLEAN LAKE OPERATION





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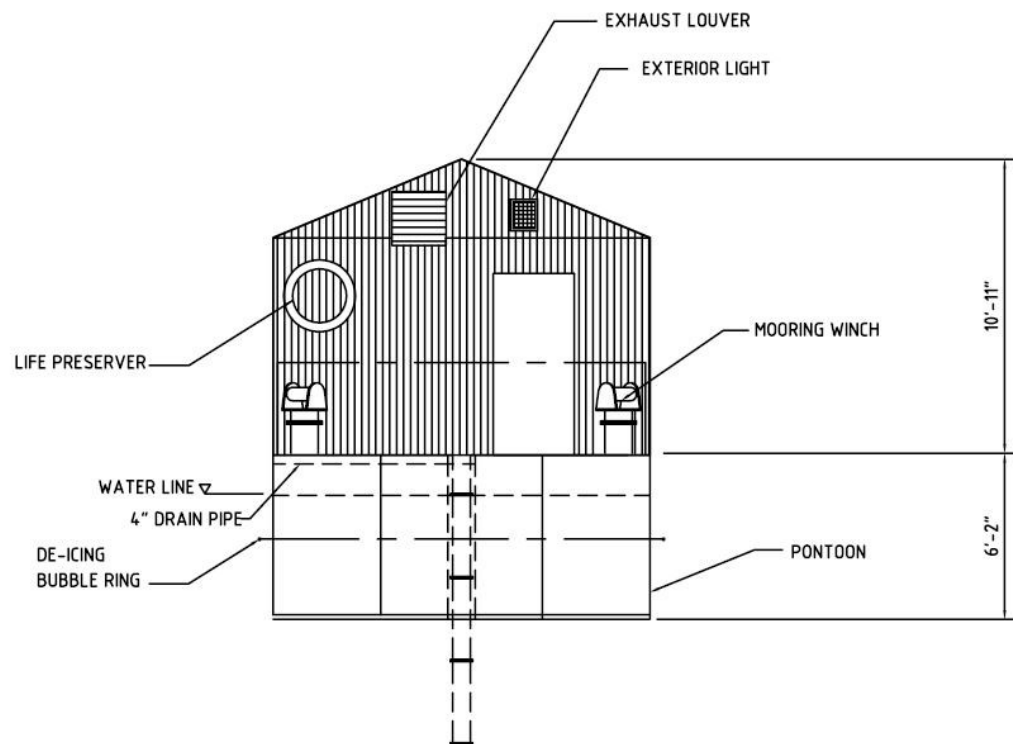
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FIGURE 2.3-55
 TAILINGS DEPOSITION BARGE - PROFILE

TAILINGS MANAGEMENT TID

McCLEAN LAKE OPERATION





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FIGURE 2.3-56
 TAILINGS DEPOSITION BARGE - END ELEVATION

TAILINGS MANAGEMENT TID

McCLEAN LAKE OPERATION



Subaqueous Deposition Systems

Flexible Walkway with Five Deposition Points

From 2018 to 2021 a subaqueous deposition system was used as the primary method of tailings deposition. A system of flexible walkways connected to the main walkway described earlier in this section. There were five deposition points each with an associated length of flexible walkway. This configuration is illustrated in Figure 2.3-57. A schematic of the piping enclosure (header barge) is shown in Figure 2.3-58. The former anchoring block design for the walkways and barges is shown on Figure 2.3-59. Figure 2.3-60 shows a schematic of the piping arrangement at each deposition point. Use of this system was discontinued in 2021 and the infrastructure was decommissioned and removed from the TMF in 2023. A complete description of the system may be found in the previous Tailings Management TID (Orano 2020b, Appendix A).

Two Single-line Horizontal Subaqueous Deposition

Figure 2.3-61 shows the layout of the subaqueous deposition system installed in 2021. The system included two single extended deposition lines, and was initially installed along the former subaqueous deposition 3.5 m flexible walkways connected to the main walkway described earlier in this section. The 3-inch HDPE pipe (Line “A”) for Tailings Thickener Underflow (TTUF) and the 3-inch HDPE pipe (Line “B”) for either Tailings Thickener Overflow (TTOF) or TTUF connected to existing deposition 3 and deposition 4 piping were submerged approximately 3 m below the surface of the TMF pond water to a 90-degree joint. The pipe was then directed horizontally and parallel to the flexible walkway, attached to the extended subaqueous 3-inch HDPE pipe using a buoy and anchor system, as shown in Figure 2.3-62.

The subaqueous 3-inch HDPE pipe was secured by a series of floats and anchors (anchor assembly) at varying depths, depending on the elevation of the tailings surface. Pipe clamps connected by cable thimbles and cable clamps were secured by a serrated flange to hold the 3-inch HDPE pipe in position at the desired depth of 1.5 m below the water surface. This anchor assembly, as displayed in Figure 2.3-63 was repeated approximately every 6 m along the extension to the deposition point. The 3-inch HDPE pipe transitions to a 6-inch IPS HDPE DR11 pipe to slow discharge velocity. The discharge at each deposition location was horizontal to the surface of the TMF pond.

As mentioned in previous sections, the tremie barge, five subaqueous flexible walkways, and main walkway past the header barge were removed from the TMF in 2023. At that time the “A” and “B” lines were flushed and then disconnected from deposition walkway 3 and 4. The remaining walkway, reclaim, and header barge were relocated, and two new tailings line extensions were installed as shown in Figure 2.3-64 Line “A” and Line “B” outlets from the header barge are connected via flex pipe flanges to corresponding 3-inch S1242 Goodflex flex hoses approximately 7.62 m in length. Each Goodflex flex hose is connected to the corresponding tailings 3-inch IPS DR11 PE4701 pipe extension as illustrated in Figure 2.3-65. Each tailing line extension was fitted with a typical float and anchor system separated approximately 6.1 m apart and floated approximately 2 m below the water surface. At each deposition location, the 3-inch HDPE pipe transitions to a 6-inch IPS HDPE DR11 to slow discharge velocity. The typical design of the tailing extension float and anchor system is detailed in Figure 2.3-66.

Between 2021 and 2023 the deposition lines were replaced annually during the shut-down period to maintain efficient use of space filling in the low-lying areas of the TMF, while ensuring capacity at a particular location is not compromised.

In 2024 this system was modified slightly to have the 3-inch TTUF lines floating on the pond rather than anchored to the tailings surface. The discharge end of the lines has a slight bend and maintains subaqueous discharge. The discharge end is anchored by synthetic winch rope to at least three concrete anchors on the TMF embankment. This system does not require intensive annual replacement activity and can be moved in a simplified manner when required during the ice-free seasons.

2.3.5.2 Monitoring Program

For both former deposition methods, the depth to tailings was measured multiple times daily on active deposition points. The depth was measured weekly on inactive deposition points. Monitoring of the tailings depth identified the need to change deposition points. The current deposition method cannot be measured on a daily basis since there is no walkway or permanent platform above the active deposition.

Tailings surface surveys are conducted semi-annually to annually, generally coinciding with spring thaw and fall shutdown. The surveys are an important input to tailings deposition modelling, and provide validation of tailings deposition predictions and placed densities.

Dredge sampling is also conducted semi-annually to annually, generally coinciding with barge moves. The samples inform assessments of segregation, which are discussed further in Section 5.6.2.

2.3.5.3 Anchoring and Movement

The existing deposition system is secured by synthetic winch ropes to an anchor point. Several anchor points for the remaining barge and walkway are provided around the perimeter of the tailings pond along the crest of the liner bench elevation. Land anchor points consist of a steel frame structure containing two concrete blocks and a winch mechanism providing an anchoring mass of approximately 5,200 kg each (Figure 2.3-59). The anchor blocks around the pit are located on platforms constructed of rip rap. As new stages of soil-bentonite liner are constructed, new platforms for the anchor blocks are also constructed at higher elevations and the positions of the anchor blocks are adjusted as the pond level rises.

NOTES:

1. ALL DIMENSION IN MILLIMETERS U/N

CODES AND STANDARDS:

2. ALL WORK SHALL CONFORM TO THE LATEST EDITION OF THE FOLLOWING CODES, STANDARDS AND REGULATIONS.
 - THE NATIONAL BUILDING CODE OF CANADA (NBC)
 - CAN/CSA S16 AND CSA W59 AND W59.2
 - PROJECTS SPECIFICATIONS AND DESIGN CRITERIA
 - OCCUPATIONAL HEALTH AND SAFETY REGULATIONS
 - THE MINES REGULATIONS
 - MANUFACTURER'S PROCEDURES AND RECOMMENDATIONS

MATERIAL:

ALL ROLLED SECTIONS TO BE 6061-T6 ALUMINUM U/N
 ALL PLATE TO BE 5052-H32 ALUMINUM U/N
 ALL PIPE TO BE 6061-T6 ALUMINUM
 ALL BOLTS TO BE ZINC PLATED GR5 TO ASTM F1941 U/N
 ALL LAG BOLTS TO BE HOT DIPPED GALVANIZED TO ASTM A123

ESTIMATED WEIGHTS:

- XROSSWATER FLOATING WALKWAY SECTION = 1100 LBS (INCLUDES SIDE WINGS)
- PERMANENT EXISTING WALKWAY = 2000 LBS

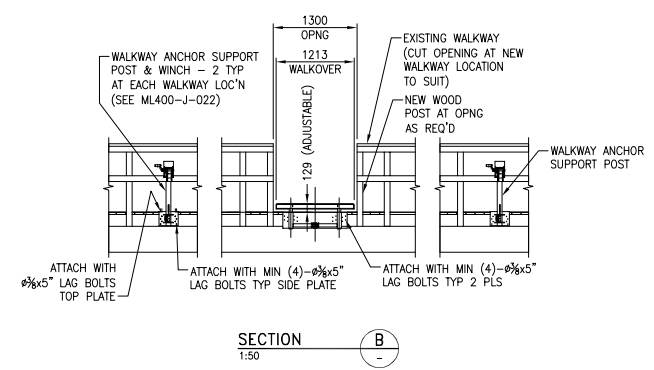
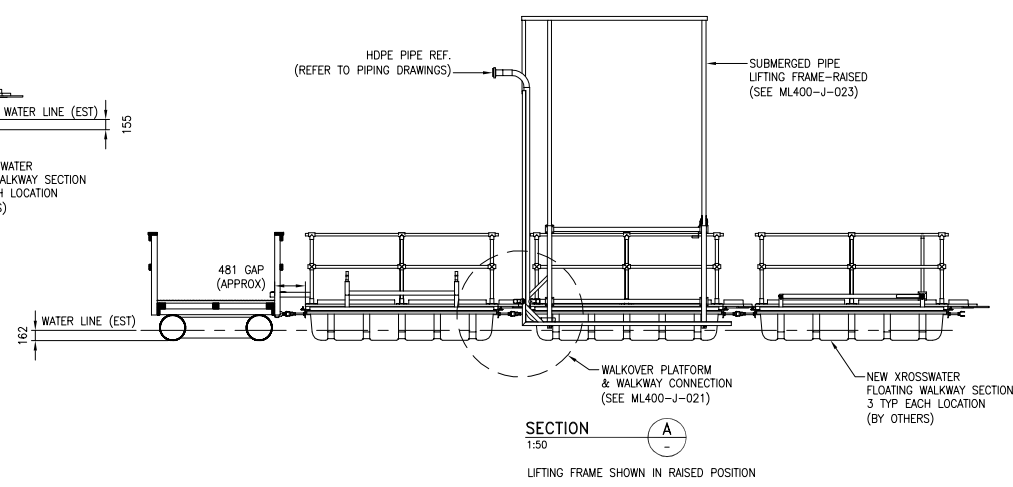
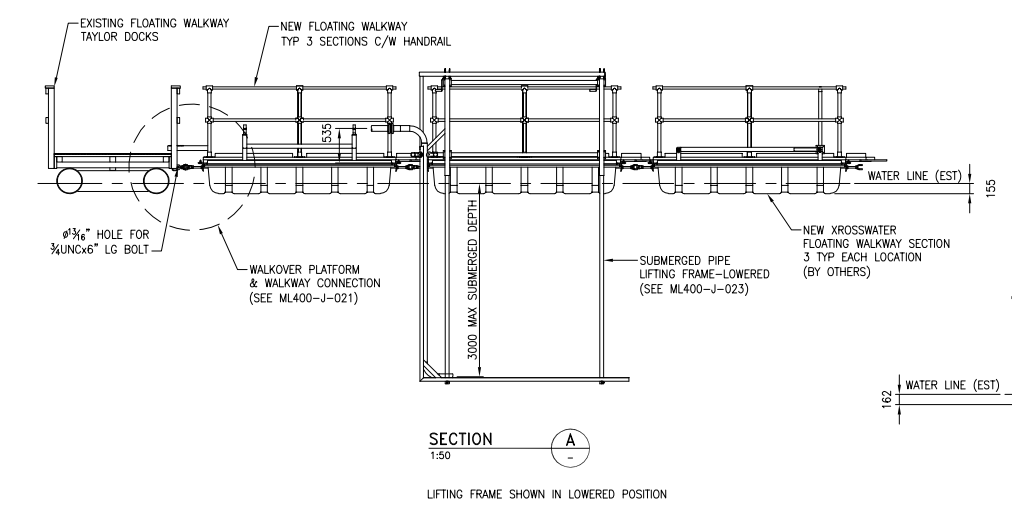
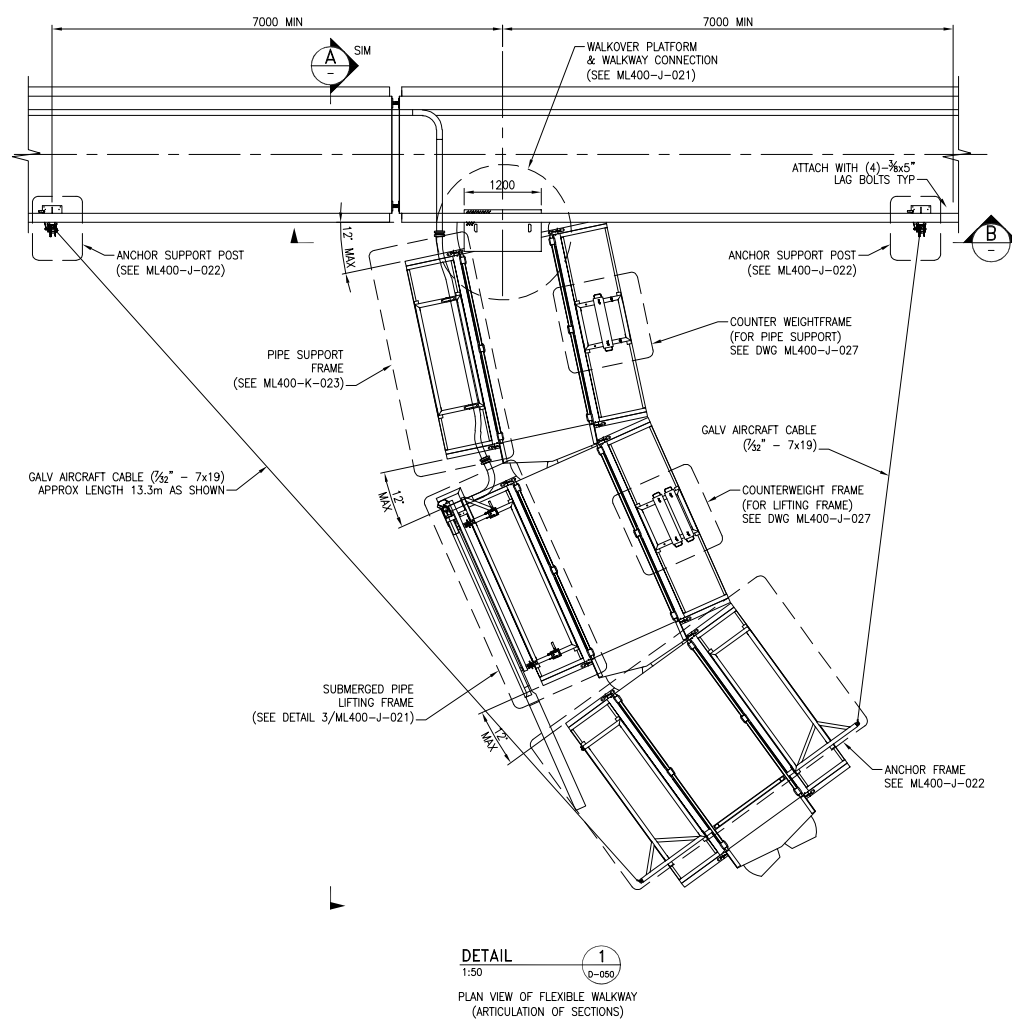
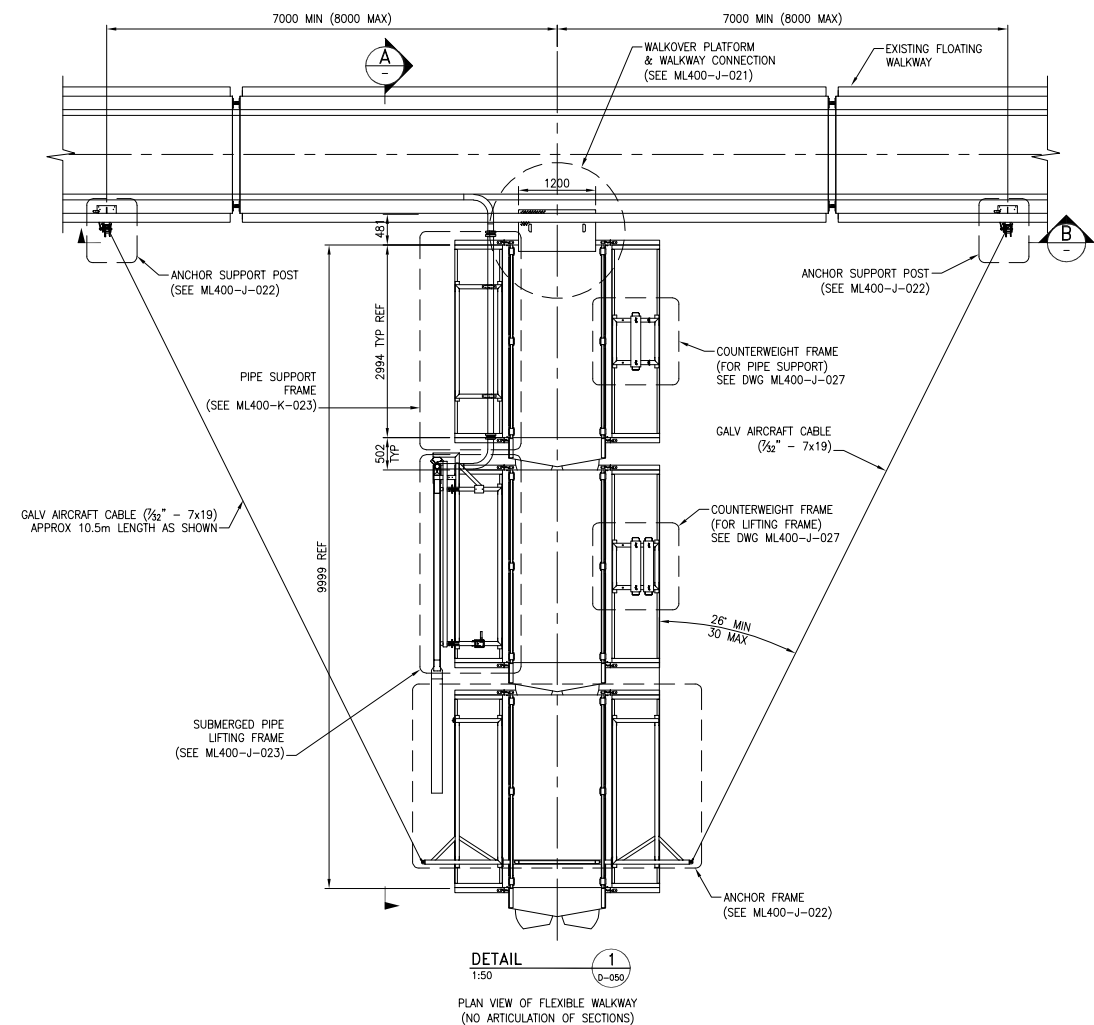
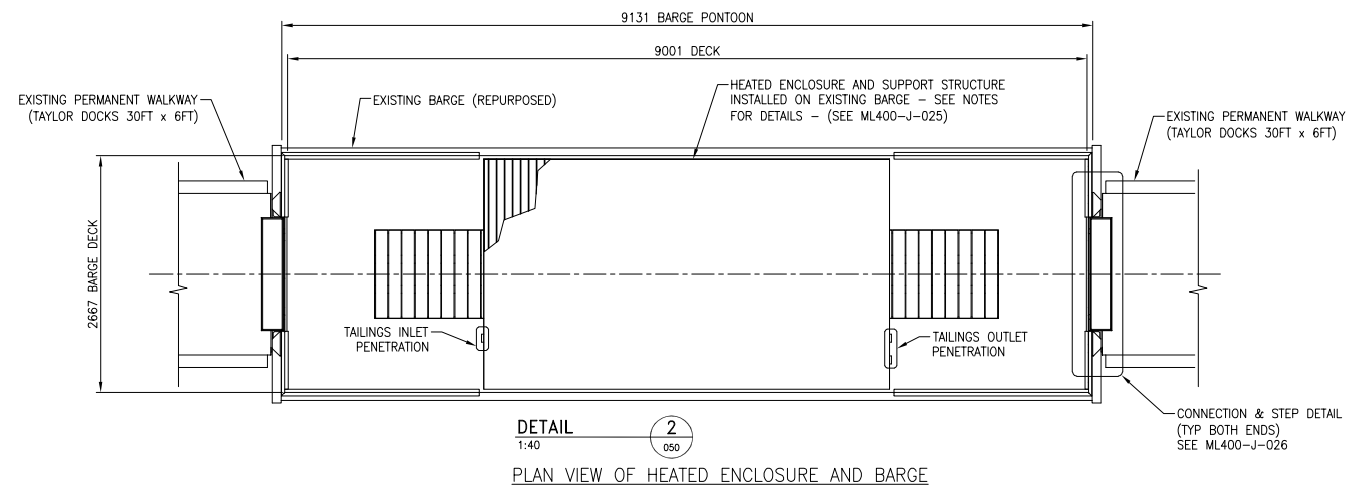


FIGURE 2.3-57
SUBAQUEOUS TAILINGS DEPOSITION FLEXIBLE WALKWAY PLANS, SECTIONS AND DETAILS
 FIGURE:
 REPORT: TAILINGS MANAGEMENT TID



NOTES:

1. ALL DIMENSION IN MILLIMETERS U/N

CODES AND STANDARDS:

2. ALL WORK SHALL CONFORM TO THE LATEST EDITION OF THE FOLLOWING CODES, STANDARDS AND REGULATIONS.
- THE NATIONAL BUILDING CODE OF CANADA (NBC)
 - CAN/CSA S16 AND CSA W59 AND W59.2
 - PROJECTS SPECIFICATIONS AND DESIGN CRITERIA
 - OCCUPATIONAL HEALTH AND SAFETY REGULATIONS
 - THE MINES REGULATIONS
 - MANUFACTURER'S PROCEDURES AND RECOMMENDATIONS

MATERIAL:

ALL ROLLED SECTIONS TO BE G40.21-50W
ALL PLATE AND CHECKER PLATE TO BE G40.21-44W
ALL HEX BOLTS TO BE ZINC PLATED GR5 TO ASTM F1941
ALL LAG BOLTS TO BE HOT DIPPED GALVANIZED TO ASTM A123

HEATED ENCLOSURE CONSTRUCTION

- INSULATED METAL PANELS SUPPLIED AND INSTALLED BY OTHERS (CF-42 MESA INSTALLED VERTICALLY C/W WITH TRIM & FLASHING). MANDOR installed both ends.
- FOR SUPPORT STRUCTURE (SEE ML400-J-025)

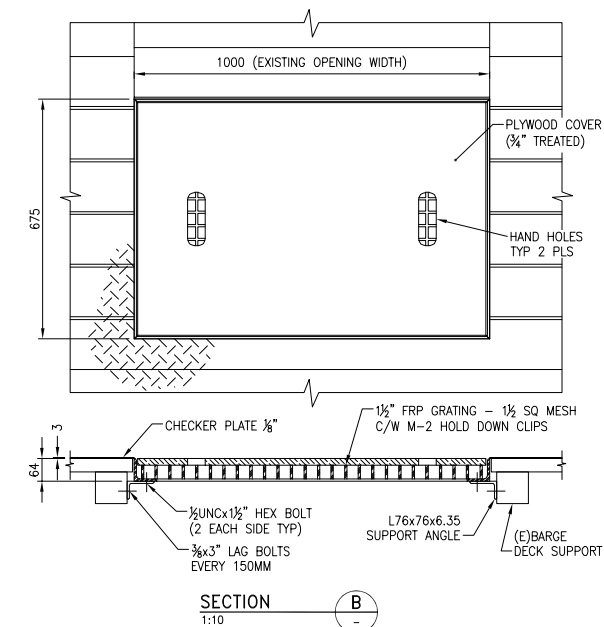
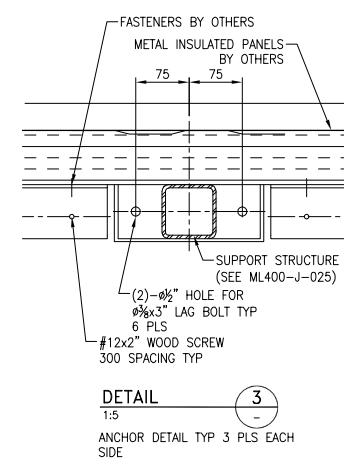
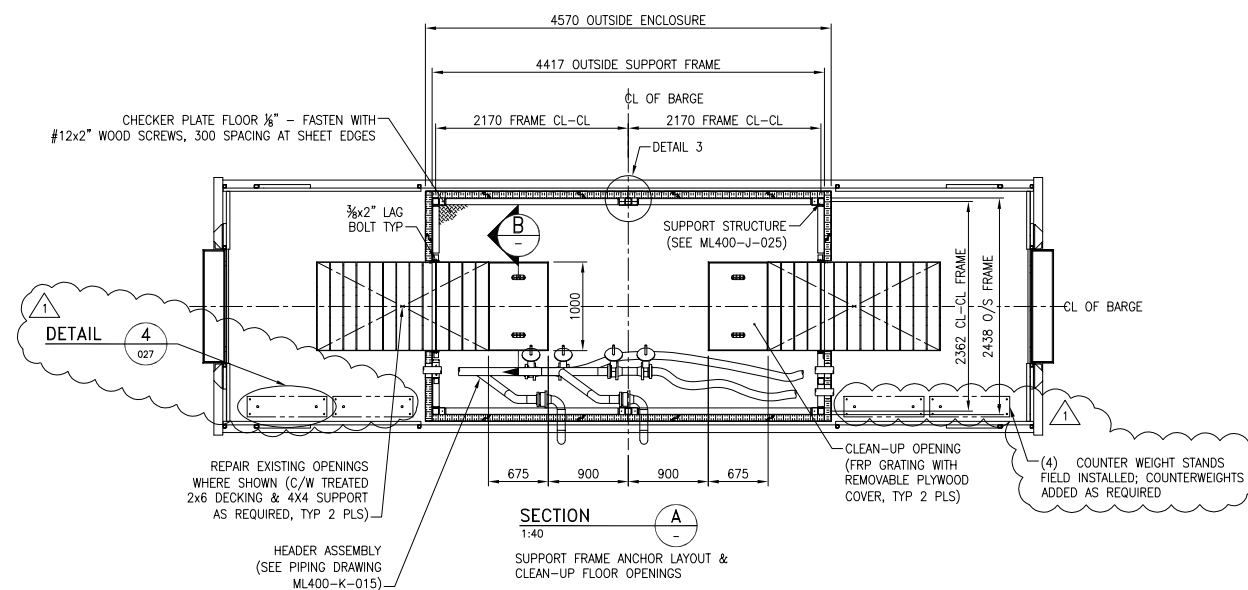
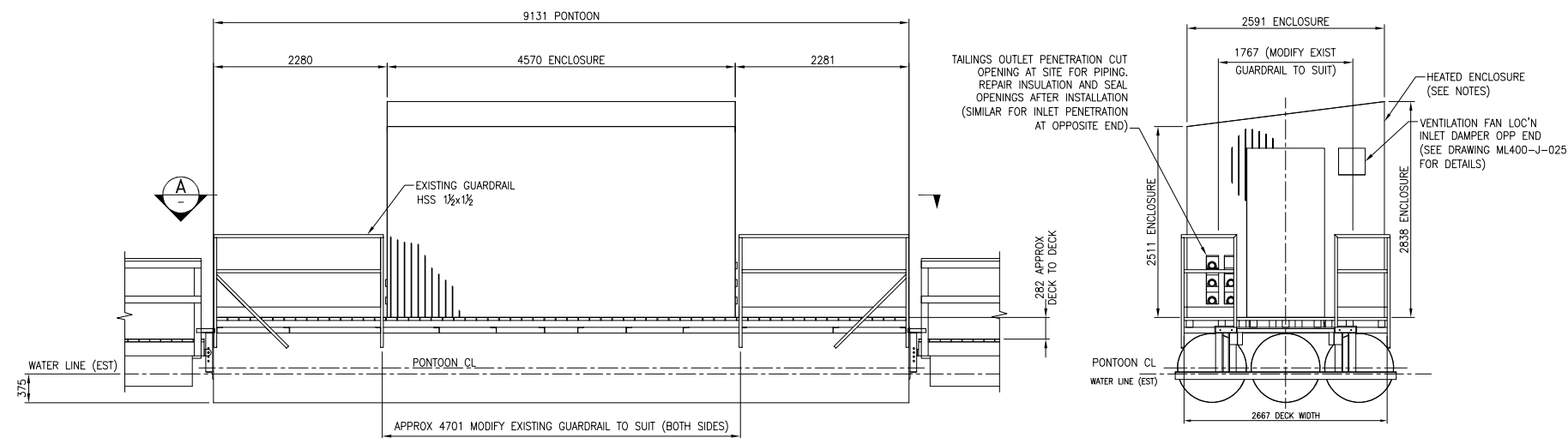
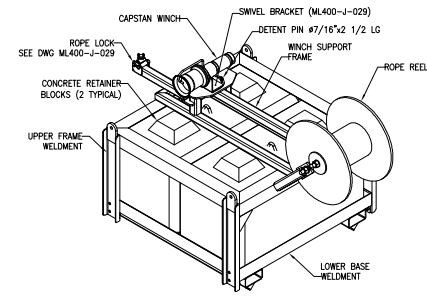
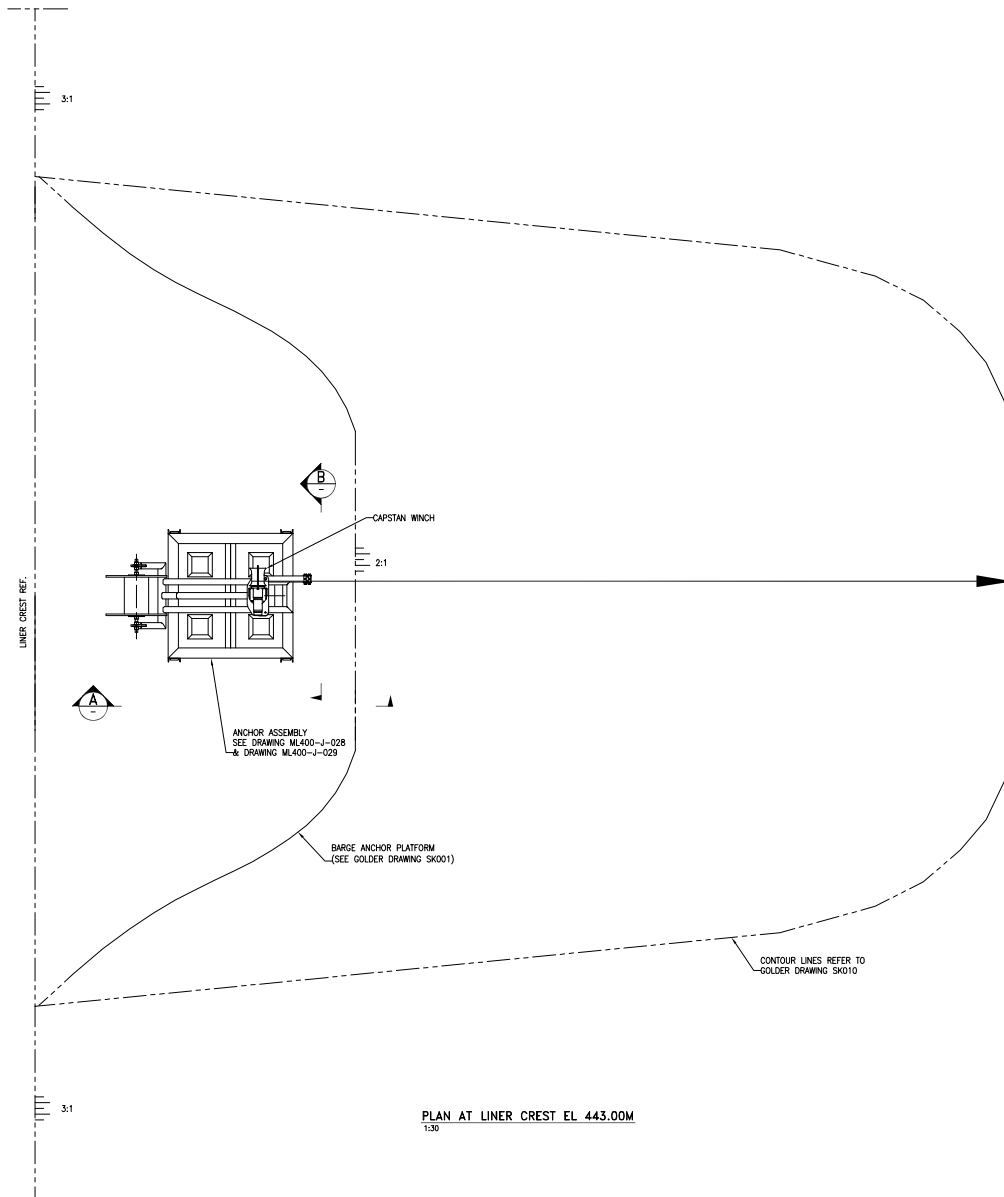
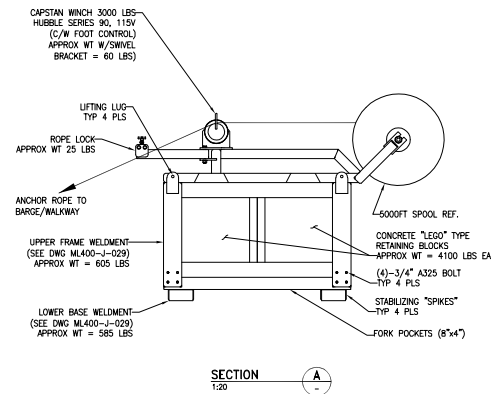


FIGURE 2.3-58
SUBAQUEOUS TAILINGS DEPOSITION EXISTING BARGE DECK MODIFICATIONS PLANS, SECTIONS AND DETAILS

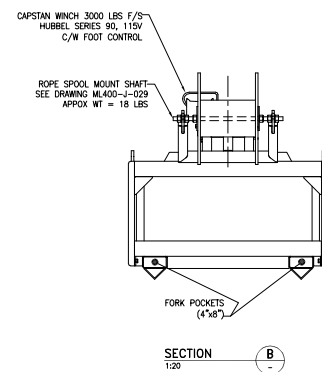
FIGURE:
REPORT: TAILINGS MANAGEMENT TID



ISOMETRIC VIEW
CAGE ASSEMBLY



SECTION A-A
1:20



SECTION B-B
1:20

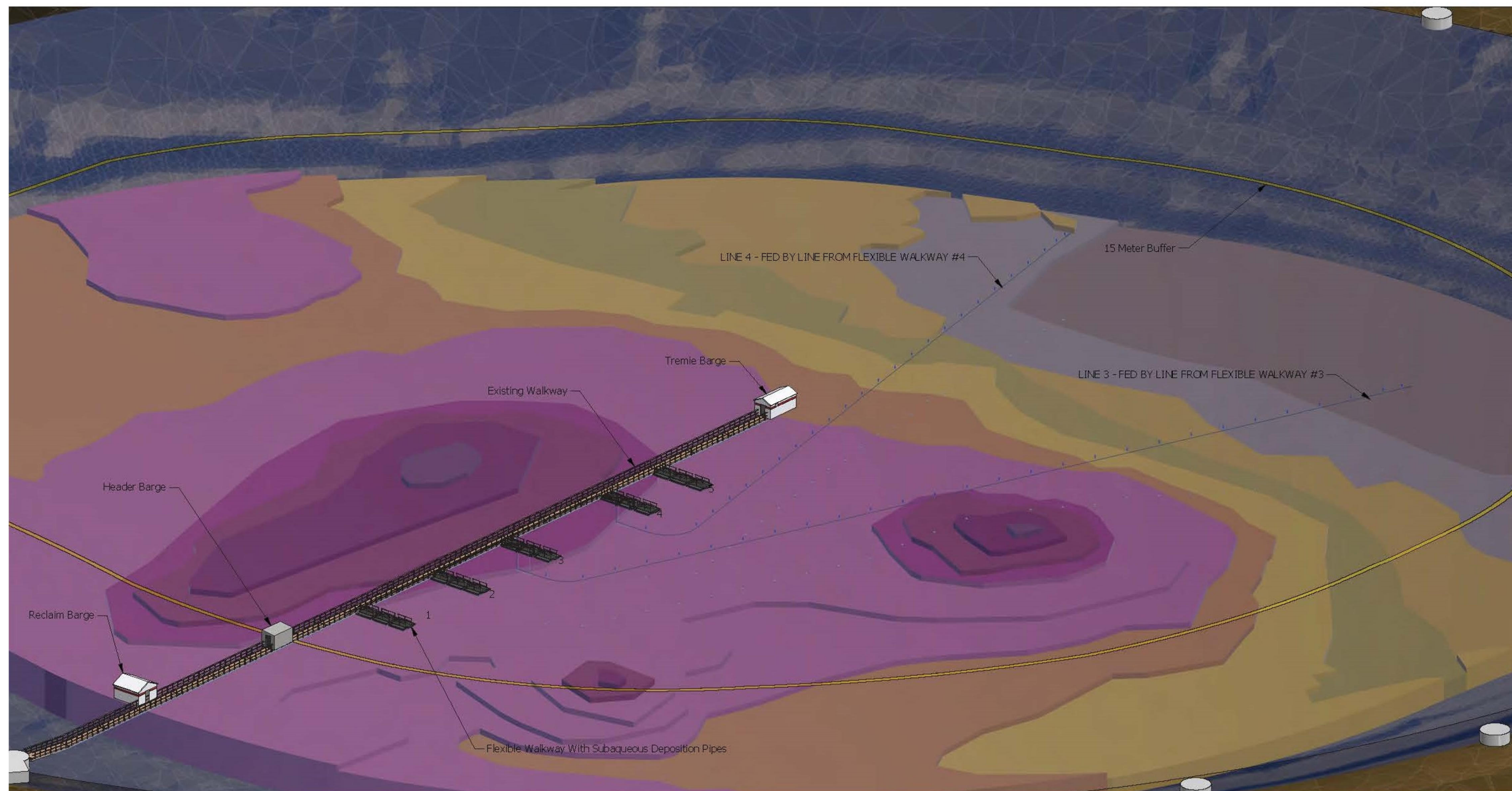
- NOTES:
1. ALL DIMENSION IN MILLIMETERS U/N
 2. ALL WORK SHALL CONFORM TO THE LATEST EDITION OF THE FOLLOWING CODES, STANDARDS AND REGULATIONS:
 - THE NATIONAL BUILDING CODE OF CANADA (NBC)
 - CAN/CSA S16 AND CSA W59 AND W59.2
 - PROJECTS SPECIFICATIONS AND DESIGN CRITERIA
 - OCCUPATIONAL HEALTH AND SAFETY REGULATIONS
 - THE MINES REGULATIONS
 - MANUFACTURER'S PROCEDURES AND RECOMMENDATIONS
- MATERIAL:
- ALL ROLLED SECTIONS TO BE G40.21-350W U/N
ALL PLATE TO BE G40.21-300W U/N
ALL HEX BOLTS TO BE ZINC PLATED GR5 TO ASTM F1941
- APPROX TOTAL WEIGHT:
INCLUDING CONCRETE BLOCKS, UPPER FRAME WELDMENT, LOWER BASE WELDMENT, WINCH SUPPORT FRAME AND WINCH = 11,250 LBS
(NOT INCLUDING SPOOL WEIGHT)

Projection:
Compiled:
Date: 4/9/2020
Data Sources:

Drawn:
Scale:

FIGURE 2.3-59
SUBAQUEOUS TAILINGS DEPOSITION
BARGE ANCHOR
FIGURE:
REPORT: TAILINGS MANAGEMENT TID





Projection:
 Compiled:
 Date:
 Data Sources: RMD Engineering (24344-01-0001)

Drawn: RMD Engineering Inc.
 Scale:

McCLEAN LAKE OPERATION

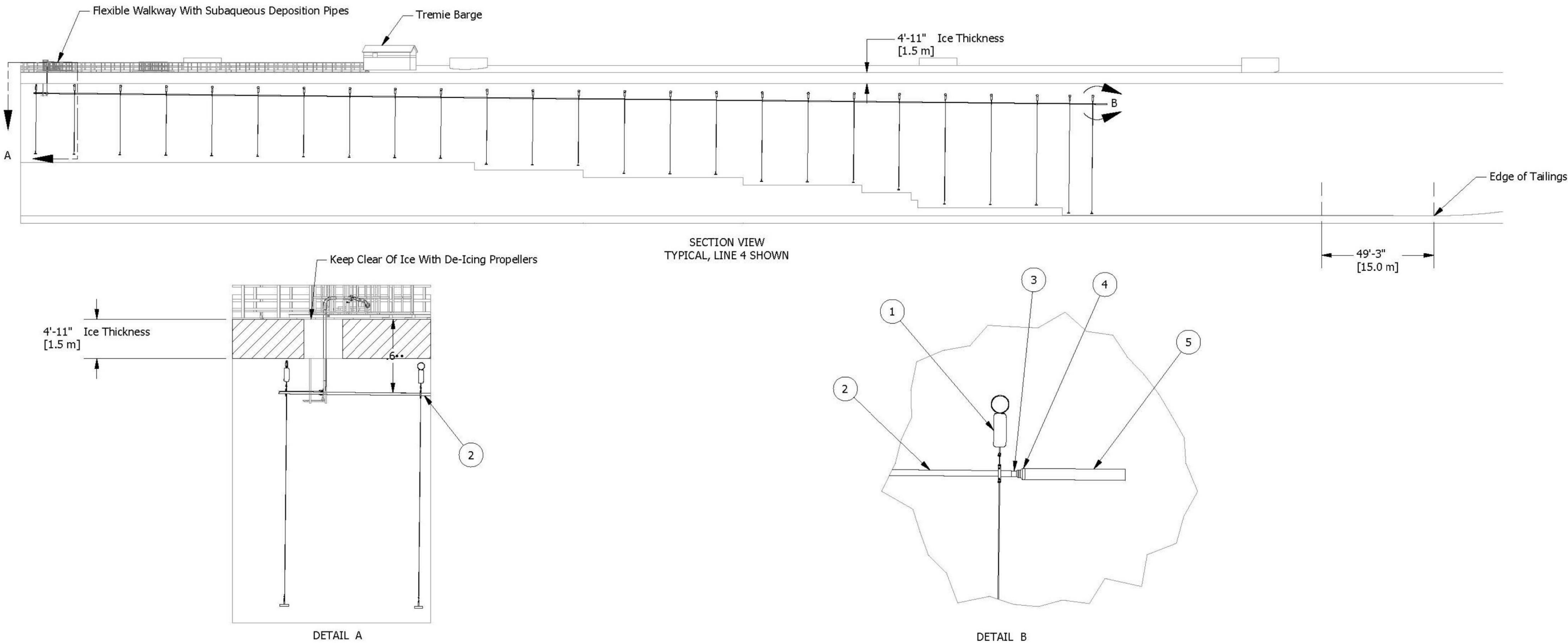
FIGURE 2.3-61
 TWO-SINGLE LINE SUBAQUEOUS DEPOSITION LAYOUT

TAILINGS MANAGEMENT TID



PARTS LIST		
ITEM	QTY	DESCRIPTION
1	53	Anchor Assembly
2	1	3"IPS HDPE DR11 Pipe
3	2	4"IPS x 3"IPS DR11 Concentric Butt Fusion Reducer
4	2	6"IPS x 4"IPS DR11 Concentric Butt Fusion Reducer
5	2	6" IPS HDPE DR11 Pipe

Water 1000 kg/m••	Water Weight Per Linear Foot Of Pipe (• 3.5" OD)= 4.164 Lbs.	Calculations:	
Water 1000 kg/m••	Water Weight Per Linear Foot Of Pipe (• 2.826" ID)= 2.715 Lbs.	Pipe full of slurry	(1.382 Lbs./Ft. + 3.741 Lbs./Ft.) - 4.164 = .959 Lbs./Ft.
HDPE 950 kg/m••	Pipe Weight Per Linear Foot = 1.382 Lbs.	Pipe full of water	(1.382 Lbs./Ft. - 2.715 Lbs./Ft.) = 4.097 Lbs./Ft. (4.164-4.097 = .067 Buoyant)
Slurry 1375 kg/m••	Slurry Weight Per Linear Foot Of Pipe(• 2.82" OD)= 3.741 Lbs.	Empty Pipe	4.164 Lbs./Ft. - 1.382 Lbs./Ft. = 2.782 Lbs./Ft. (Buoyant)
		If Pipe Is Empty (Full Of Air), Weight Required to Hold Down	(2.782 Lbs./Ft. X 20 ft.) + 30 Lbs. = 85.64 Lbs.
		Buoyancy Required To Support Full Pipe	.959 Lbs./Ft. X 20 Ft. =19.18 Lbs.



Projection:
 Compiled:
 Date:
 Data Sources: RMD Engineering (24344-01-0001)

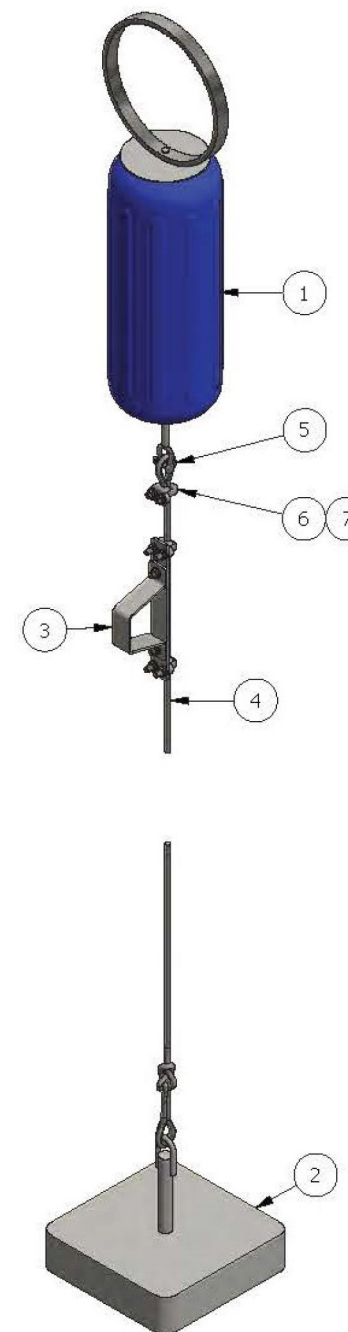
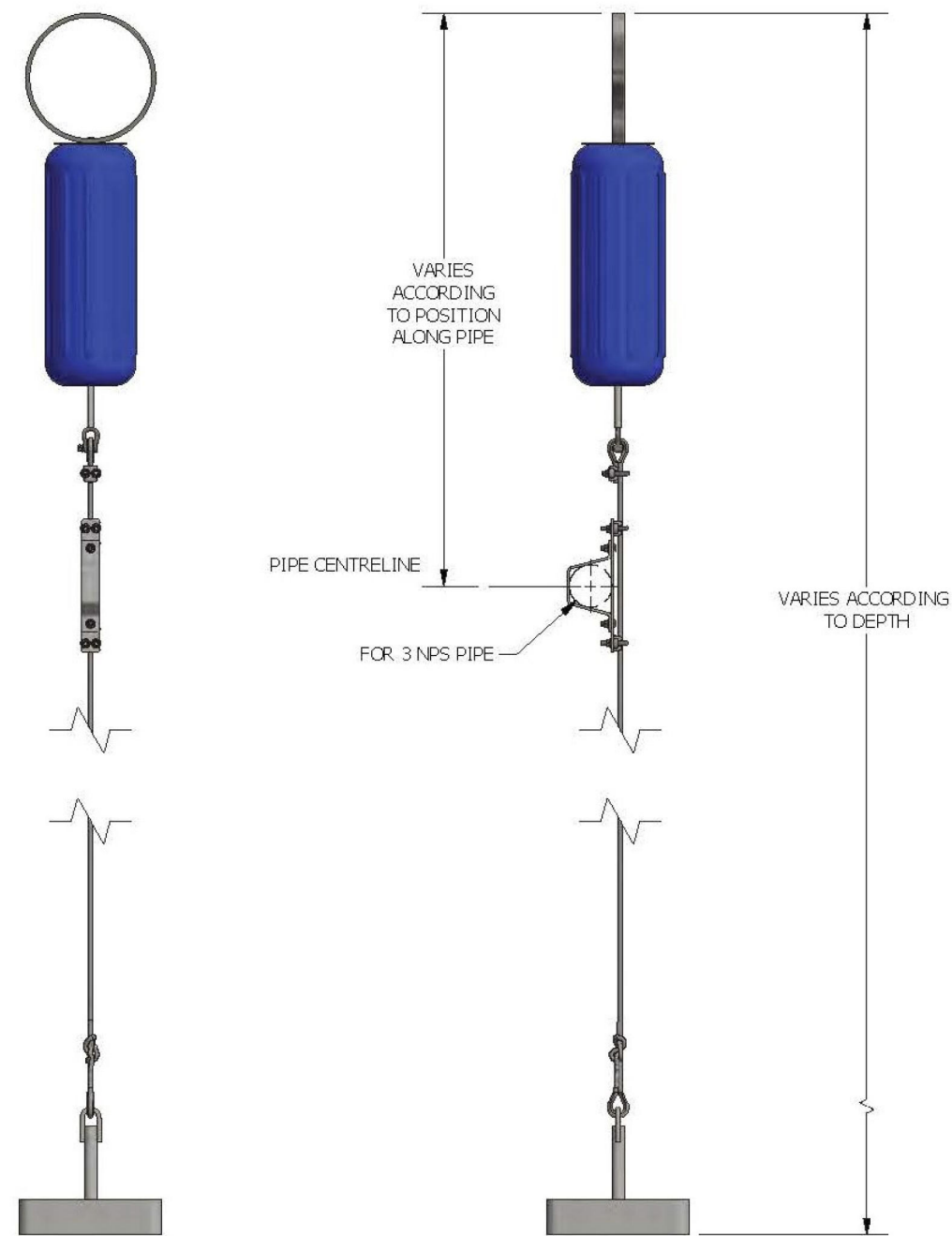
Drawn: RMD Engineering Inc.
 Scale:

McCLEAN LAKE OPERATION

FIGURE 2.3-62
 TWO-SINGLE LINE SUBAQUEOUS DEPOSITION
 BARGE AND ANCHOR SYSTEM LAYOUT

TAILINGS MANAGEMENT TID





PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	24344-01-0008	Float Assembly
2	1	24344-01-0010	Anchor
3	1	24344-01-0015	Pipe Clamp Assembly
4	1	24344-01-1025	Anchor Line Rope, 3/8" Polyester
5	1	STDTS4-038	3/8 ST Cable Thimble
6	1	SPAS-516S6	5/16 SS Cable Clamp
7	2	NFCZ38	Flange Nut Serrated, 3/8-16 UNC Gr 2

Projection:
Compiled:
Date:
Data Sources: RMD Engineering (25884-01-0006)

Drawn: RMD Engineering Inc.
Scale:

FIGURE 2.3-63
FLOAT COLLAR ANCHOR ASSEMBLY

McCLEAN LAKE OPERATION

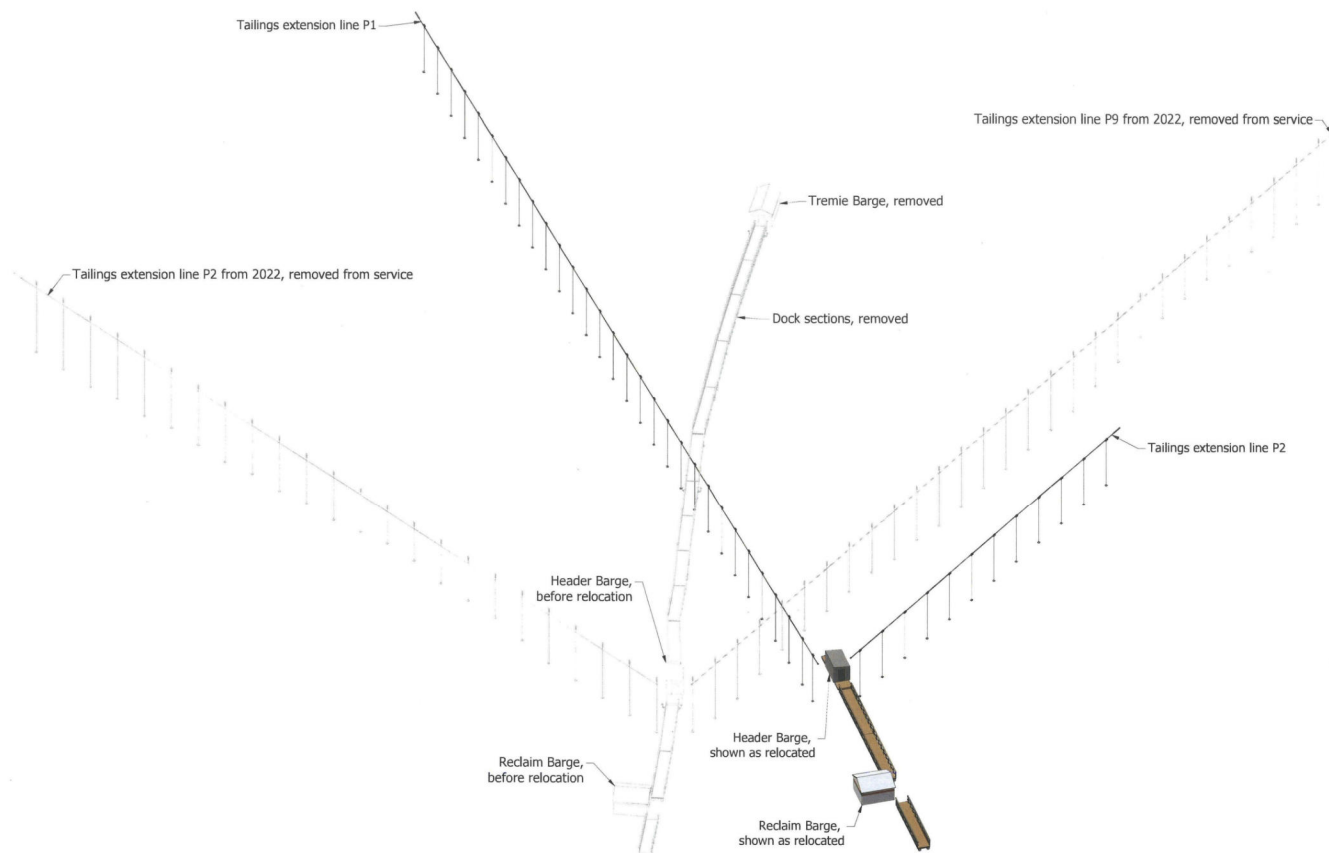
TAILINGS MANAGEMENT TID



orano

NOTES:

1. Horizontal pipe length for line P1 from the flange of the flex hose to the end of the discharge is approximately 181.4 m (595 ft).
2. Quantity of floats for line P1 is 29.
3. Horizontal pipe length for line P2 from the flange of the flex hose to the end of the discharge is approximately 72.8 m (239 ft).
4. Quantity of floats for line P2 is 12.



Projection:
 Compiled:
 Date:
 Data Sources: RMD Engineering (25884-01-0006)

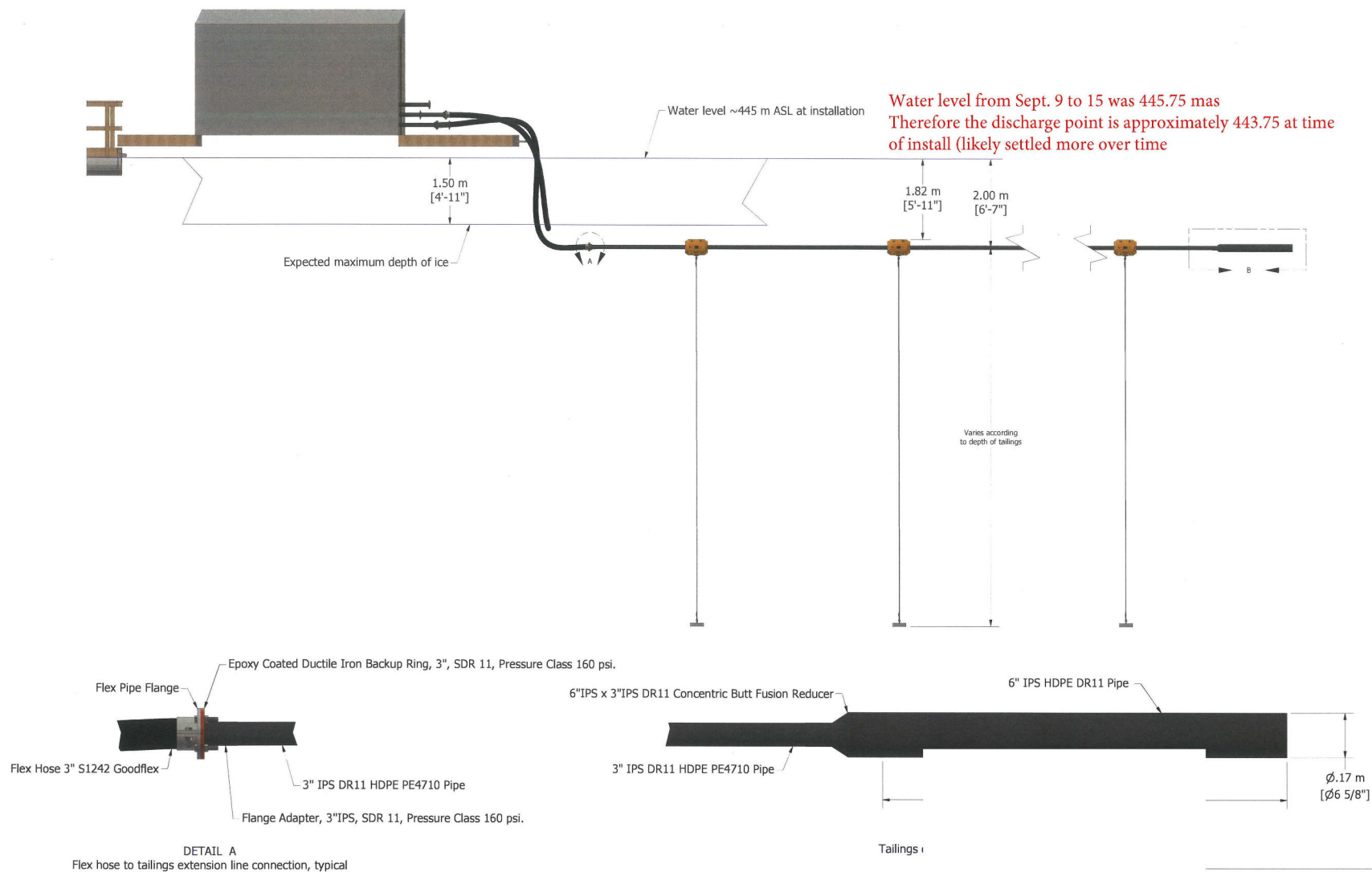
Drawn: RMD Engineering Inc.
 Scale:

McCLeAN LAKE OPERATION

FIGURE 2.3-64
 TAILING LINE RELOCATION AND BARGE REMOVAL DIAGRAM - 2023

TAILINGS MANAGEMENT TID





Projection:
 Compiled:
 Date:
 Data Sources: RMD Engineering (25884-01-0006)

Drawn: RMD Engineering Inc.
 Scale:

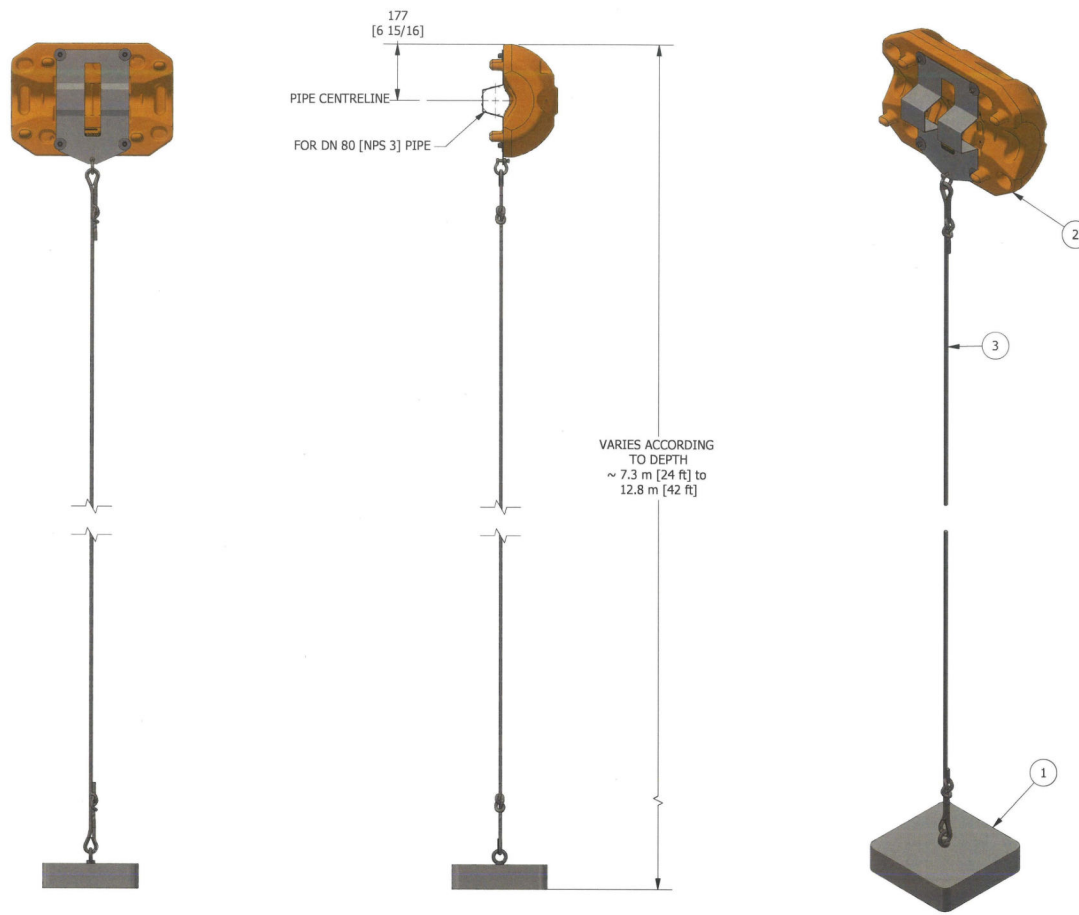
McCLEAN LAKE OPERATION

FIGURE 2.3-65

TYPICAL TAILING LINE EXTENSION CONNECTION AND DEPOSITION DISCHARGE DIAGRAM

TAILINGS MANAGEMENT TID





PARTS LIST				
ITEM	QTY	PART NUMBER	DESCRIPTION	MASS
1	1	25884-01-0011	Anchor	117.12 lbmass
2	1	25884-01-0012	Pipe Float Assembly	10.85 lbmass
3	1	25884-01-1025	Anchor Line Rope, 3/8" Polyester	1.48 lbmass

Projection:
Compiled:
Date:
Data Sources: RMD Engineering (25884-01-0010)

Drawn: RMD Engineering Inc.
Scale:

McCLEAN LAKE OPERATION

FIGURE 2.3-66
TYPICAL DESIGN OF TAILING LINE FLOAT AND ANCHOR SYSTEM

TAILINGS MANAGEMENT TID



2.3.5.4 Special Operating Conditions

Special operating considerations are required in certain conditions, such as winter and extreme weather events.

Winter Conditions: During the winter, prior to freeze up, the current single two-line deposition system is positioned at a location with sufficient depth to accommodate tailings placement throughout the winter months. With the exception of the area immediately adjacent to the reclaim barge an ice cover forms over the JEB TMF pond during the winter restricting the movements of the deposition lines.

2.3.5.5 Tailings Deposition Modelling

In order to effectively manage the remaining space in the TMF, Orano implemented tailings deposition modelling beginning in 2018. The software MUCK3D, created by MineBridge, is used to complete the modelling. Inputs to the model include the tailings angle of repose, tailings density, projected tailings tonnages, and surveyed tailings surfaces. The deposition model is used to inform both short and medium term deposition planning, and inputs to the model are continually reviewed and validated against field data.

2.4 TMF Capacity Optimization and Expansion

In 2010 Orano initiated a series of activities to optimize and expand the JEB TMF facility.

In 2010, Orano obtained an approval for the JEB TMF Optimization Project from the provincial and federal regulators. The project intent was to ensure slope stability and pond water containment during the operation of the JEB TMF within its original assessed capacity (i.e. storage of consolidated tailings to 434 mASL). It involved re-sloping and construction of a soil bentonite liner to 443 mASL. The optimization allowed unconsolidated tailings placement up to 439 mASL, with a 3 m of water cover and 1 m of freeboard on top. Upon decommissioning, after cover placement, tailings would consolidate to the approved and assessed level of 434 mASL. These optimization activities were completed in two stages in 2012-2013 (Stage 1) and in 2018 (Stage 2). The details of the JEB Optimization Project are discussed in section 2.4.1.

In 2011, Orano first submitted a project description for the JEB TMF Expansion Project. The JEB TMF Expansion Project was subjected to a few revisions and changes, but ultimately Orano has been authorized by the CNSC to modify the outer perimeter of the JEB TMF for expansion up to 468 mASL and to accommodate disposal of tailings up to a consolidated tailings elevation of 462 mASL. Following SMOE approval in 2019, Orano progressed with the TMF Expansion Project by constructing an embankment to an elevation of 457.5 mASL in 2021 and by placing the liner to increase the soil bentonite liner crest elevation from 448.0 mASL to 452.5 mASL in 2023. Over the course of 2027-2035 JEB TMF facility will be further expanded to the approved embankment elevation of 468 mASL. The TMF Expansion Project is discussed in Section 2.4.2.

2.4.1 JEB TMF Optimization Project

2.4.1.1 Design Criteria

Details regarding the design criteria assessed for the JEB TMF Optimization Project are summarized below and records of construction may be found in Appendix B, Section D.

Till Slopes: Based on the results of additional till material characterization and analysis performed to evaluate stability conditions of the JEB TMF till slopes and potential modification of the pit slope geometry, the following conclusions have been made:

- The laboratory test results indicated that there was not a significant difference in the geotechnical properties between the two till overburden units;
- The side slope of the proposed optimized TMF sections should be 3H:1V, extending from the till/sandstone contact to either elevation 440 mASL for Stage 1 construction, or elevation 443 mASL for Stage 2 construction. The side slope above elevation 440 mASL (Stage 1) and 443 mASL (Stage 2) could be as steep as 1.5H:1V; and,
- Some maintenance activities would be required on an annual basis as a result of surficial erosion.

Pond Containment: The primary purpose of the liner system is to maintain containment of the JEB TMF pond water throughout operations. With no liner in place, the containment of the pond water cannot be assured by pumping from the base drain alone, particularly when the natural variability of the till units is considered (Golder, 2009a).

JEB TMF Liner Alternatives: As part of the JEB TMF Optimization Project, to make optimum use of the assessed JEB TMF capacity, the unconsolidated tailings and subsequently the pond water, would be temporarily placed above the sandstone/till contact, prior to consolidation to the elevation approved at the time of 434 mASL. As a result, during operations and prior to cover placement and tailings consolidation, the pond water elevation would ultimately reach 442 mASL, which is approximately 8 m above the sandstone/till contact at the JEB TMF perimeter.

To achieve an operational pond water elevation of 442 mASL, it was necessary to improve the slope stability conditions and incorporate pond containment in the till layer at the JEB TMF. A number of potential liner materials were evaluated for the construction of the JEB TMF containment system, including: i) synthetic flexible membrane liner (FML) such as polyvinyl chloride, polyethylene and butyl rubber; ii) admixed materials such as asphalt, concrete, and soil asphalt; iii) compacted native materials such as till and crushed sandstone and iv) native soil/rock material potentially amended with bentonite. There were advantages and disadvantages identified for each of the liner type materials; Table 2.4-1 presents a comparison of the potential options considered.

Table 2.4-1: Comparison of Liner Options

Liner Options	Advantage	Disadvantage
i) Membrane Liner	Contain a wide range of waste fluids High resistance to chemical and bacterial deterioration Very low hydraulic conductivity if there is no leak through the liner	Requires high quality field seaming during installation Prone to puncture For staged construction, the quality of the seam for expansion will be difficult Operation of pond will require operating procedure for inspection to ensure no puncture or seam separation
ii) Admixed Materials	Universal availability and versatility of materials	Do not offer very low permeability Structure subject to cracking Difficult to provide good seal between liner portions constructed at different stages
iii) Compacted native materials such as till and crushed sandstone	Use local materials which can be amended as necessary Hydraulic conductivity can be lowered using amendment material such as bentonite Easy to construct, superior seal between liner portions constructed at different stages Material inertness to degradation and leaching History of success High performance system Provide good buffer for retardation of solute contaminant	Does not achieve the targeted hydraulic conductivity value
iv) Compacted native material such as till and sandstone, amended with bentonite	Use local materials which can be amended as necessary Hydraulic conductivity can be lowered using amendment material such as bentonite Easy to construct, superior seal between liner portions constructed at different stages Material inertness to degradation and leaching History of success High performance system Provide good buffer for retardation of solute contaminant	Material must be processed: till must be screened to remove large size cobble and rocks, or sandstone must be crushed to produce enough fine content Potential effects of wetting drying, and freeze-thaw cycles For bentonite amended material, mixing/blending and method of compaction are critical

Preferred Option: Compacted native soil liners have the longest record of successful performance based on thousands of years of uses and inherent characteristics of soils (Kays 1977). Where suitable native materials are available, the use of native soil as part of the liner material is preferable to a membrane liner or admixed material. Analysis conducted with respect to the JEB TMF has indicated that a native soil liner, alone, would not achieve the required hydraulic conductivity level. Therefore, the hydraulic conductivity level of the native materials is lowered by amendment with bentonite. In comparison with the synthetic FML, the bentonite amended soil liner has the following major advantages: i) self-sealing capabilities, ii) material inertness to degradation and leaching, iii) low permeability nature of the amended material, iv) less extensive to construct, and v) lower construction cost (Liao 1989). Because the construction of the liner was to be undertaken in various stages for the JEB TMF Optimization Project, the bentonite amended soil option would provide much more flexibility in construction and superior seal between liner portions constructed at different stages.

Liner Material Characterization: The characterization of potential liner materials was conducted for the till and sandstone available on site. The results of the characterization program indicated that without any amendment, neither screened till or crushed sandstone has a sufficiently low hydraulic conductivity (i.e. 10^{-9} m/sec) to contain pond water within the JEB TMF. To produce a hydraulic conductivity of 10^{-9} m/sec or less it was necessary to amend the till and crushed sandstone with bentonite. The test results indicated that either blended bentonite and crushed sandstone, or blended bentonite and screened till could be used as a liner material for the JEB TMF (Golder, 2009a).

Hydraulic Conductivity: Based on the analysis results (Golder, 2009b), the following conclusions were made regarding the soil liner thickness and calculated flux through the liner:

- A liner was required to contain pond water during the operations with the pond raising above the sandstone/till contact elevation;
- For a hydraulic conductivity of 1×10^{-9} m/s, a liner crest width of 4 m (or 1.3 m thick) would limit the wetting front in the liner and resulted in sufficiently low flux (less than 5% compared to the unlined conditions) through the liner during both Stage 1 and Stage 2 operations. Considering specific site conditions and construction conditions, a liner with a 6 m crest width (e.g. 1.92 m thick on 3H:1V side slope) was used for the optimization of the JEB TMF.
- With the same liner thickness, the saturated hydraulic conductivity of the liner had the most significant effect in the calculated flux through the liner. The calculated flux for the liner with a hydraulic conductivity of 1×10^{-10} m/s or less would be insignificant, but there was a marked increase in the calculated flux thru the liner when the liner hydraulic conductivity was higher than 1×10^{-8} m/s.
- The design crest width of the liner was based on constructability considerations.

Liner Protection: A wave analysis was conducted to calculate the freeboard requirement, and determine the size and thickness required to protect the liner slope from wave action. The following conclusions were made regarding freeboard requirement and liner protection:

- A freeboard of 1 m would be sufficient for both Stage 1 and Stage 2 operations; and

- A rip rap layer of 0.5 m thick, a mean diameter of approximately 0.26 m would be sufficient to provide erosion protection for the liner material for both Stage 1 and 2 operations.

2.4.1.2 Construction

The optimization of the JEB TMF was compared to the design objectives described in the 2004 Tailings Management TID and found to meet the assessed concept of the JEB TMF (COGEMA, 2004b). There were no changes identified which would have an environmental impact not considered in the existing approval.

Throughout operations, the design of the JEB TMF Optimization Project was consistent with the approved JEB TMF; there were no changes in the operating philosophy of maintaining hydraulic containment through operations. The flattened slopes and addition of a bentonite-amended soil liner through the till portion of JEB TMF walls enhanced wall stability and hydraulic containment by limiting outward flow from the operating pond. The liner facilitated maintaining hydraulic containment by pumping from the pond and base filter.

The JEB TMF Optimization Project was demonstrated to be consistent with the conceptual decommissioning plan outlined for the JEB TMF and integrated in the approved Preliminary Decommissioning and Financial Assurance Plan (AREVA 2017b). The expected long-term performance of the JEB TMF would not be affected by the capacity optimization.

The JEB TMF Optimization Project was approved by the CNSC under Licence UMOL-MINEMILL-McClean.00/2017 condition 3.1 on September 30, 2010 (AREVA 2010c). An Approval to Construct, Alter or Extend a Pollutant Control Facility was issued by the SMOE on November 18, 2010 (AREVA 2010d). The work completed for Stages 1 and 2 was constructed under the Saskatchewan Ministry of Environment Approval to Construct No. PC10-165 (File No. S25020-50/ML/03) dated November 18, 2010 and the Canadian Nuclear Safety Commission letter (File No. 2.04 ML-A) dated September 30, 2010. The two stockpiling areas were prepared under the Ministry of Environment Aquatic Habitat Protection Permit #12PA040 dated May 14, 2012 and Forest Product Permit #2821H dated May 14, 2012.

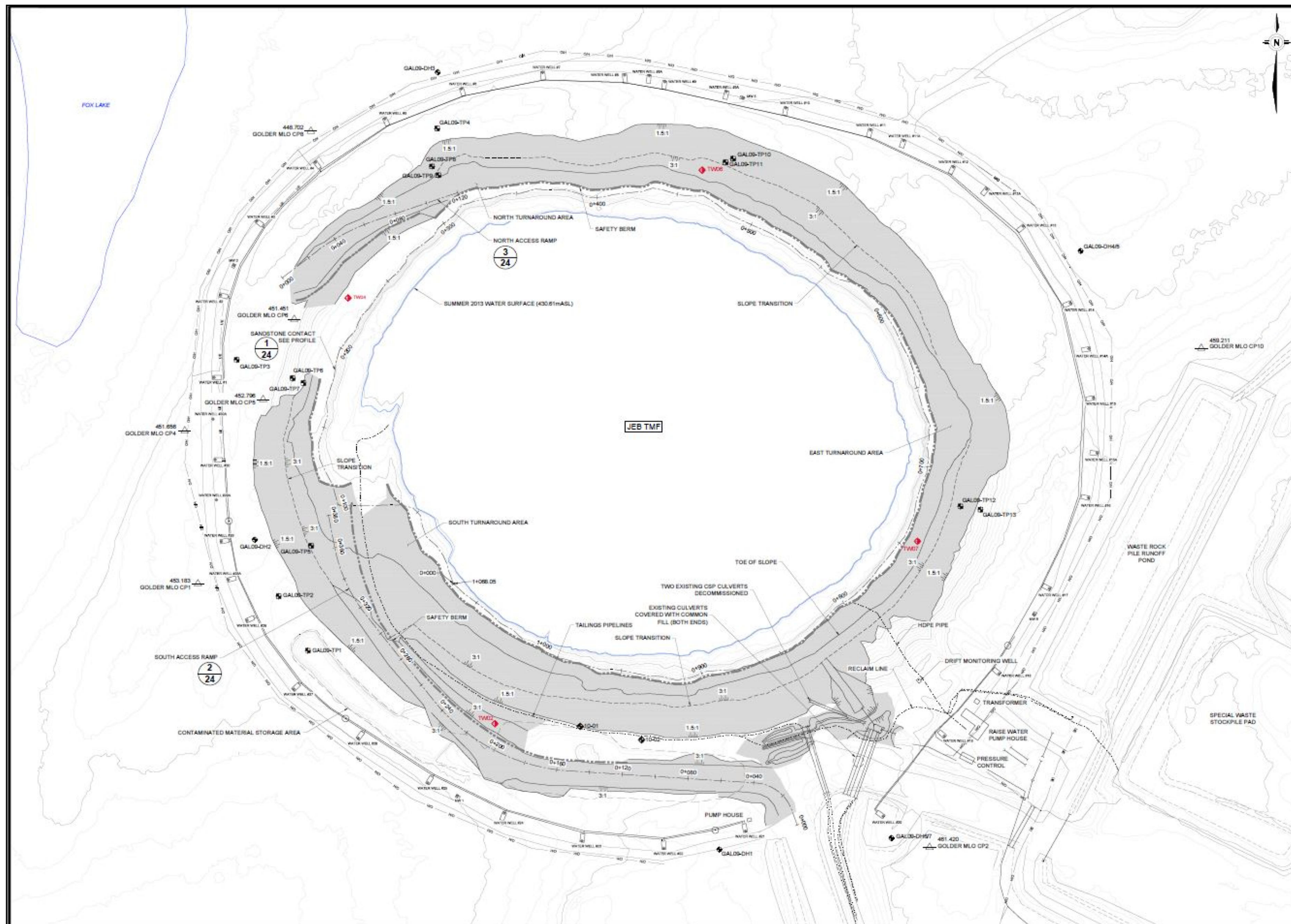
This Project was undertaken in two stages:

- Stage 1 – Slope stability work and construction of a liner along the slope in till to elevation 439 mASL (Figures 2.4-1 to 2.4-3) to allow tailings deposition to 435 mASL. Stage 1 was completed in September 2013 (Golder 2013).
- Stage 2 – Slope stability work and final construction to extend the liner to elevation 443 mASL to allow tailings deposition to elevation 439 mASL, assuming a conservative consolidation settlement value of 5 m (Figures 2.4-4 to 2.4-6). Stage 2 was completed in October 2018 (Golder 2019a).

The slope of the optimized JEB TMF sections is 3H:1V, extending from the sandstone/till contact to 440 mASL for Stage 1 construction and 443 mASL for Stage 2 construction. As part of the Stage 2 construction, the slope stabilization was completed to the crest of the TMF, to allow for future construction of the TMF expansion (described in Section 2.4.2).

For both stages of the JEB TMF Optimization Project, liner soil material was produced by blending crushed sandstone and till to meet the technical specification. An untreated Wyoming sodium bentonite was used to amend the liner soil material in a pugmill at a minimum of 5% by weight. Prior to each stage of liner construction, a test pad was constructed to confirm that the contractor's construction methodology would produce a soil bentonite liner with the properties specified in the design. A conservative fraction of 5% (by mass) bentonite addition was used to produce the liner. A third-party representative provided QA/QC testing throughout construction.

Soil bentonite liner was constructed within the JEB TMF with a crest width of approximately 6 m that achieved the minimum thickness and compaction specifications. Laboratory hydraulic conductivity tests were completed on 35 samples of liner material and 7 field hydraulic conductivity tests were conducted. The laboratory hydraulic conductivity test results ranged from 1.2×10^{-10} m/s to 4.0×10^{-11} m/s with a mean value of 7.4×10^{-11} m/s. Field hydraulic conductivity results ranged from 1×10^{-10} m/s to 7×10^{-11} m/s with a mean value of 2.5×10^{-10} m/s. QA/QC test results demonstrate that the constructed liner achieved the specified maximum of 1×10^{-9} m/s. Detailed as-built information is provided in the record of construction submissions referenced above. As-built records of construction for each stage of the JEB TMF Optimization Project were submitted to regulatory agencies following completion of construction stages (Stage 1: Richards to Bourhis and Gunning, December 28, 2013; and Stage 2: Laniece to Lung and Akhter, November 2, 2018).



- NOTES
1. CONTOURS GENERATED FROM LIDAR SURVEY (2008).
 2. CONTOURS SHOWN AT 1m INTERVAL.
 3. ELEVATIONS ARE REFERENCED TO GEODETIC DATUM: NAD83, ZONE 13.
 4. NORTHINGS AND EASTINGS REFERENCED TO LOCAL MINE COORDINATE SYSTEM.
 5. AS-BUILT SURFACES SHOWN WERE OBTAINED FROM AS-BUILT SURVEYS COMPLETED BY GOLDER ASSOCIATES IN 2013 (VARIOUS DATES).

- LEGEND
- ORIGINAL GROUND CONTOURS
 - BOREHOLE LOCATION
 - TEST PIT LOCATION
 - INNER TRENCH WALLS
 - SAFETY BERM LOCATION
 - OVERHEAD POWERLINE
 - POWER POLE
 - EXISTING CSP CULVERT
 - CONTROL POINT

CONTROL POINTS	DESCRIPTION	NORTHING	EASTING	ELEVATION
GOLDER MLO CP1		11199.626	9040.221	410.183
GOLDER MLO CP2		10949.172	3485.530	481.428
GOLDER MLO CP4		11202.765	9032.194	451.599
GOLDER MLO CP8		11231.760	8370.880	462.706
GOLDER MLO CP9		11270.627	5949.761	451.451
GOLDER MLO CP9		11345.156	3103.850	446.702
GOLDER MLO CP10		11253.060	9950.665	456.211

SCALE 1:1000 METERS

THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:1000 etc) ARE BASED ON 24"X36" FORMAT DRAWINGS



Association of Professional Engineers & Geoscientists of Saskatchewan
CERTIFICATE OF AUTHORIZATION
Golder Associates Ltd.
 Number: C0230
 Permission to Consult held by:
 Discipline: Sk. Reg. No. Signature: *[Signature]*



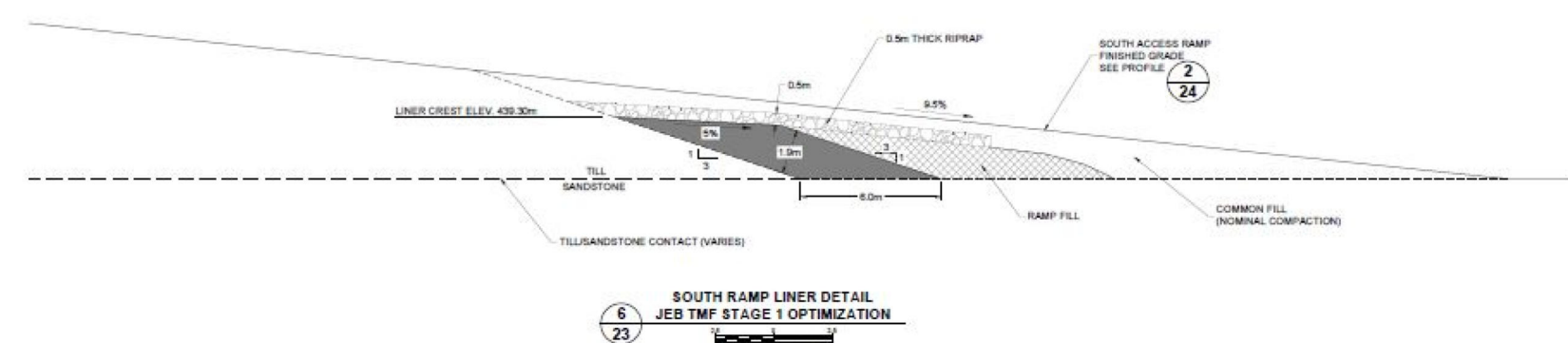
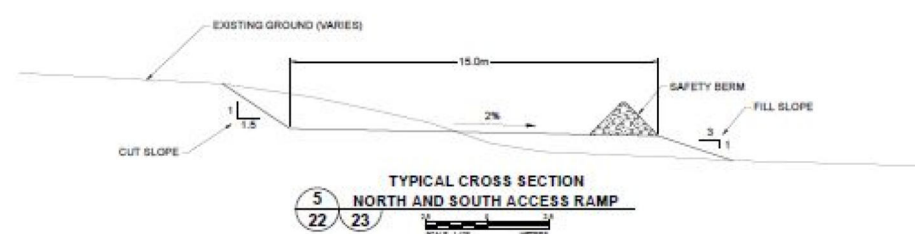
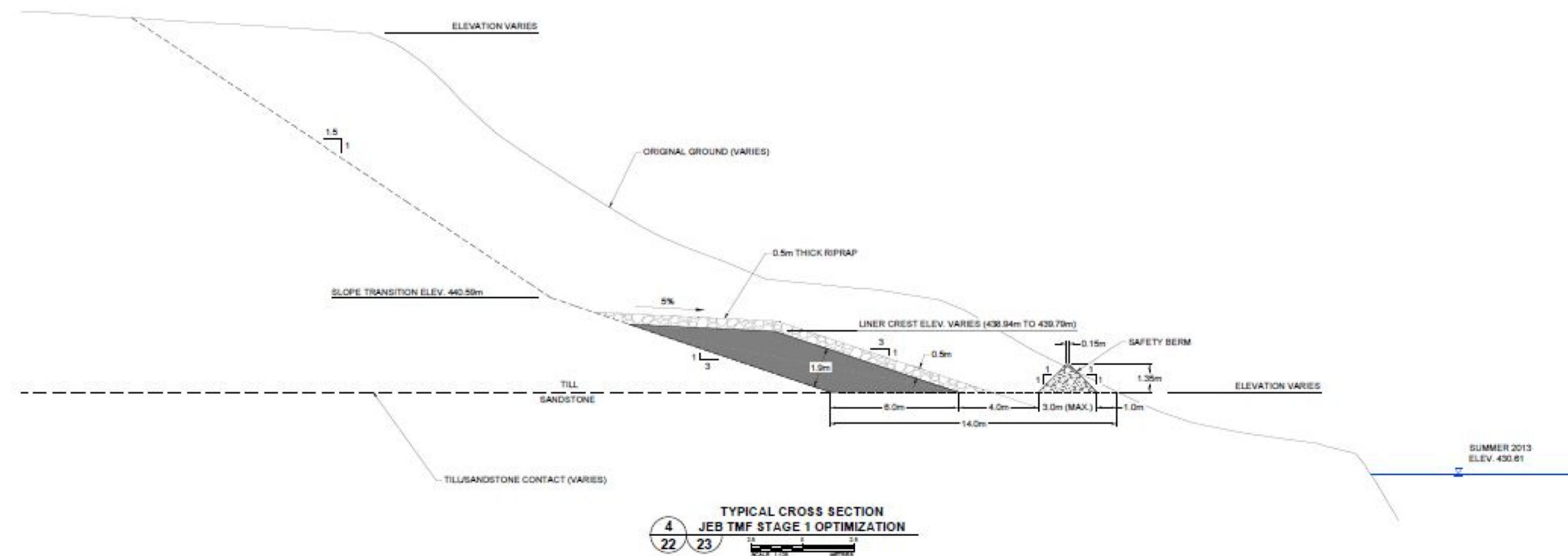
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 Data Sources: ORANO, GOLDER ASSOCIATES

McCLEAN LAKE OPERATION

FIGURE 2.4-1
 JEB TMF OPTIMIZATION STAGE 1 - EXCAVATION PLAN

TAILINGS MANAGEMENT TID





- NOTES
1. ELEVATIONS AND COORDINATES ARE REFERENCED TO LOCAL MINE COORDINATE SYSTEM.
 2. AS-BUILT SURFACES SHOWN WERE OBTAINED FROM AS-BUILT SURVEYS COMPLETED BY GOLDER ASSOCIATES IN 2013 (VARIOUS DATES).

THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (E.G. 1:1000 AND) ARE BASED ON 24"X36" FORMAT DRAWINGS.



Association of Professional Engineers & Geoscientists of Saskatchewan
CERTIFICATE OF AUTHORIZATION
Golder Associates Ltd.
 Number C0230
 Permission to Consult held by:
 Discipline: Sk. Reg. No. Signature: *[Signature]*



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 Date:
 Data Sources: ORANO, GOLDER ASSOCIATES

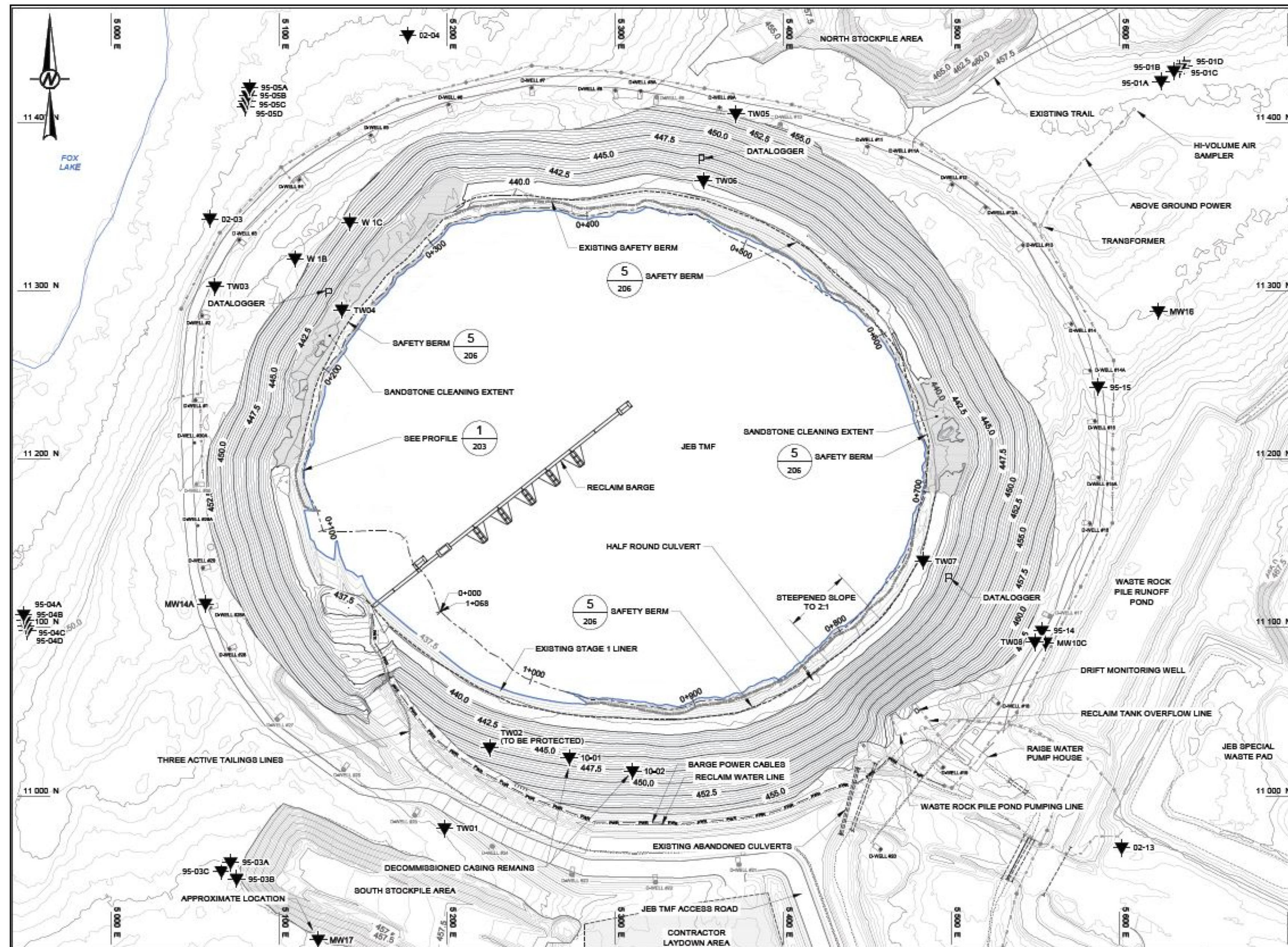
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McCLEAN LAKE OPERATION

FIGURE 2.4-3
 JEB TMF OPTIMIZATION STAGE 1 - TYPICAL CROSS SECTION

TAILINGS MANAGEMENT TID





- NOTES**
1. TOPOGRAPHIC SURFACE GENERATED FROM LIDAR SURVEY, 2009, GOLDER SURVEY OF 2013 PIT EXCAVATION AND LINER PLACEMENT, 2017 TAILINGS LINE BENCH AND 2018 PIT EXCAVATION AND LINER PLACEMENT.
 2. CONTOURS SHOWN AT 1m INTERVAL.
 3. ELEVATIONS AND COORDINATES ARE REFERENCED TO LOCAL MINE COORDINATE SYSTEM.
 4. UNITS ARE METRES UNLESS OTHERWISE NOTED.
 5. GREY DEWATERING WELLS ARE DECOMMISSIONED.
 6. DECOMMISSIONED CASING REMAINS FOR W18 AND W1C.

RECORD DRAWINGS



Projection:
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Date:
Data Sources: ORANO, GOLDER ASSOCIATES

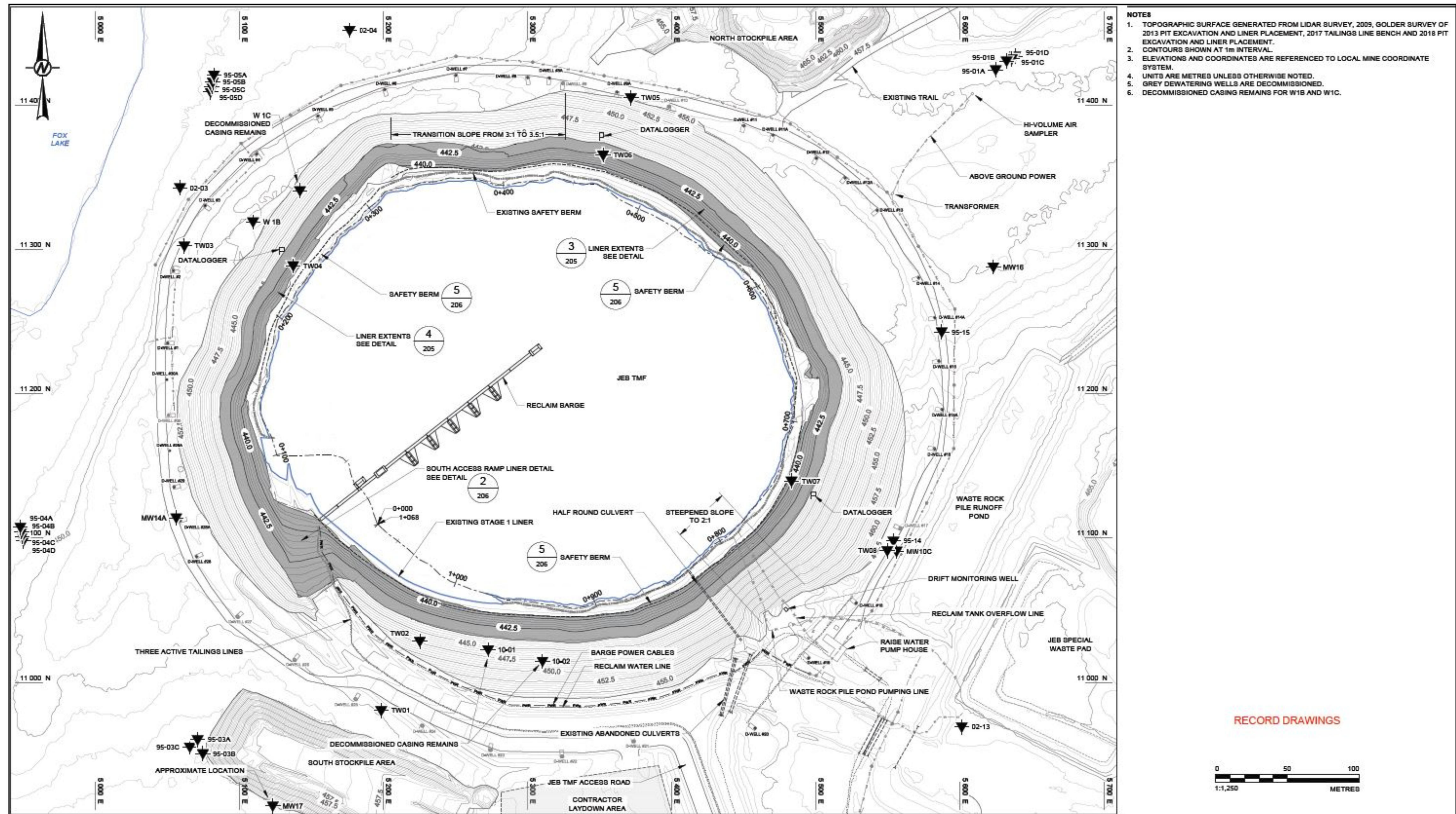
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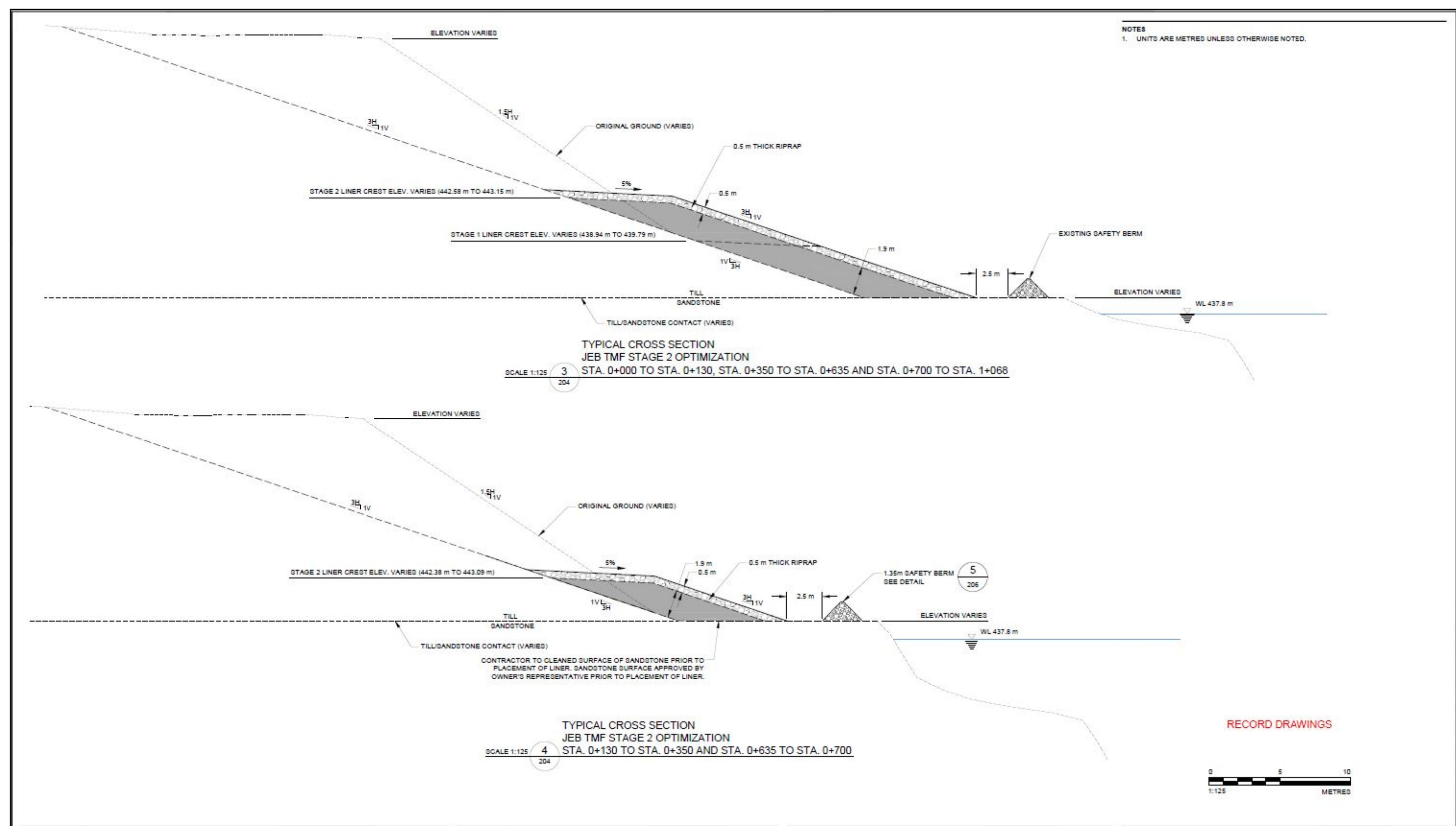
MCCLEAN LAKE OPERATION

FIGURE 2.4-4
JEB TMF OPTIMIZATION STAGE 2 - EXCAVATION PLAN

TAILINGS MANAGEMENT TID







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Date:
Data Sources: ORANO, GOLDER ASSOCIATES

Drawn:
Scale:

McCLEAN LAKE OPERATION

FIGURE 2.4-6
JEB TMF OPTIMIZATION STAGE 2 - TYPICAL CROSS SECTIONS

TAILINGS MANAGEMENT TID



2.4.1.3 Tailings Consolidation Settlement

At the time of the JEB TMF Optimization Project, the assessed and accepted top of consolidated tailings was to an elevation of 434 mASL following the placement of a cover during decommissioning. The original assessment of consolidation settlement of the tailings was undertaken to provide input to the design of the JEB TMF, and to the application for approval to construct the JEB TMF. The consolidation analysis was updated and documented in the Tailings Management Technical Information Document, McClean Lake Operation, February 2004 Version 01/Revision 01 (COGEMA 2004b). Both of these consolidation analyses considered uniform tailings characteristics throughout the JEB TMF. To estimate the amount of tailings consolidation settlement after the placement of the cover, considering the segregated nature of the tailings, an assessment was undertaken by Golder Associates Ltd. (Golder 2010). The analysis estimated a conservative consolidation settlement value of 5 m. This is less than the 14 m of settlement predicted in the 2004 analysis for uniform consolidated tailings placed to approximately the same elevation (one of the 2004 cases is based on placement to 434 mASL, with settlement predicted to 420 mASL).

2.4.2 JEB TMF Expansion Project

The JEB TMF Expansion Project was proposed as an expansion of the existing TMF providing the ability to place and store tailings above the level of the sandstone/till contact (434 mASL) as was initially contemplated with original JEB TMF design. The Expansion Project proposal included the construction of an embankment around the TMF perimeter and placement of a soil-bentonite liner to contain the pond water above the tailings during the operating period (Appendix B, Section D).

On August 26, 2011, Orano submitted a Project Description and request to amend the McClean Lake Operation operating licence for the vertical expansion of the TMF by the construction of embankment to 468 mASL. In November 2011, the CNSC determined that a federal screening level environmental assessment (EA) under *Canadian Environmental Assessment Act (CEAA 1992)* was required for the Project, with the EA process overseen by the CNSC. In July 2012, the *Canadian Environmental Assessment Act, 2012* (S.C. 2012, c.19, s. 52) came into force, Orano was notified that an EA would no longer be required and that the Project would continue to the licensing process under the *Nuclear Safety and Control Act (NSCA)*.

In 2014, Orano revised its mine plan (removing resources that were no longer included in the forecast), resulting in a reduction in the forecasted tailings production. The reduction was significant enough that Orano determined it was necessary to revisit the alternatives assessment for the management of tailings. The subsequent alternatives assessment confirmed that expanding the TMF remained the preferred option, although with a reduced scope in design (still requiring an embankment to be constructed, however to a lower elevation). The project description was revised and re-submitted to the CNSC in 2016 and accepted in 2017. In 2018, an application to construct was submitted to SMOE Environmental Protection Branch (EPB) requesting to approve a TMF embankment raise to 457.5 mASL. This project was approved by SMOE in 2019 (No. PC19-053 dated April 17, 2019) and progressed in two campaigns over 2021 and 2023. In 2021, Orano constructed an embankment to an elevation of 457.5 mASL and in 2023 placed the liner to increase the soil bentonite liner crest elevation from 448.0 mASL to 452.5 mASL.

As processing of ore from the Cigar Lake mine has progressed, the tailings produced from milling Cigar Lake ore used significantly more capacity (per tonne of ore processed) of the TMF than initially expected. In 2019, Orano submitted an updated project description to CNSC for the expansion of the JEB TMF to 468 mASL. In 2020 CNSC staff determined that the project results in a change to the existing licensing basis and therefore requires a Commission decision. The CNSC commission hearing was held on October 4, 2021 with a favorable decision received on January 17, 2022. Orano was authorized to modify the outer perimeter of the JEB TMF for expansion up to 468 mASL and to accommodate disposal of tailings up to a consolidated tailings elevation of 462 mASL.

Over the course of 2028-2035 JEB TMF facility will be further expanded to the CNSC-approved embankment elevation of 468 mASL, allowing for a maximum pond elevation of 466.5 mASL. The remaining expansion project is yet to be reviewed and approval by SMOE.

2.4.2.1 Design Criteria

The design criteria for the JEB TMF Expansion Stage 1 Embankment are summarized below. Detailed information can be found in the "JEB Tailings Management Facility Optimization Stage 2 and Expansion Stage 1 Design Report", October 2018 (Golder 2018). Records of construction to date may be found in Appendix B Section D.

JEB TMF Expansion Stage 1 Embankment

This stage involved constructing an embankment around the TMF perimeter and installing a soil-bentonite liner, chosen based on the criteria outlined during the planning and design of the JEB TMF Optimization Project. The upstream slopes of the TMF Expansion Stage 1 Embankment were designed at 3H:1V from 443 to 457.5 mASL, except for a section near the raise water pumphouse, which was designed at 2H:1V to avoid disturbing the raise water pump building. Additionally, a section on the north side of the TMF was designed at 3.5H:1V to smooth the curve of the embankment crest. The downstream slopes of the embankment were designed at 3H:1V to mitigate potential erosion.

A JEB TMF access ramp (Figure 2.4-9), was designed on the upstream slope of the TMF Expansion Embankment at a grade of up to 10% for TMF access and tailings line routing. The ramp was designed to a width of 21 m, including 11 m of driving surface, 4 m of tailings lines, 3 m for the reclaim line and barge power cable, and 3 m of safety berms. Earthen safety berm side slopes were designed at 1H:1V.

The maximum elevation of the TMF Expansion Stage 1 Embankment was 457.5 mASL, allowing for unconsolidated tailings deposition up to 452 mASL, with a 3-meter water cover, a 1.5 m allowance for PMP event storage, and 1 meter for freeboard. The Stage 1 Expansion provided storage capacity for unconsolidated tailings throughout operations from 439 to 452 mASL and offered an additional 1,540,000 m³ of consolidated tailings storage above the JEB TMF Optimization Stage 2 unconsolidated tailings surface. The general arrangement of the expanded TMF is illustrated in Figure 2.4-10.

JEB TMF Expansion Stage 1 Soil Bentonite Liner

A Soil-bentonite liner was constructed on the 3H:1V interior slope of the TMF Expansion Stage 1 Embankment, extending from the crest of Optimization Stage 2 liner (443 mASL) to the crest of the TMF Expansion Stage 1 Embankment (457.5 mASL) as shown in Figure 2.4-11. The liner has a minimum thickness of 1.9 m, compacted to at least 97% of the Standard Proctor Maximum Dry Density (SPMDD) and within -1% to +2% of the optimum moisture content. Approximately 128,150 m³ of soil-bentonite liner material was required for the construction of the JEB TMF Expansion Stage 1 Embankment liner. Additionally, around 33,800 m³ of riprap was placed on the surface of the liner to a minimum thickness of 500 mm, providing erosion protection against runoff from the embankment crest and wave action within the TMF.

Erosion Protection and Sediment Control

The erosion protection and sediment control measures for the TMF Expansion Stage 1 Embankment have been designed in accordance with the Transportation Association of Canada (TAC) National Guide to Erosion and Sediment Control on Roadways (2005). The design included an erosion control swale and berm, as well as sedimentation traps.

The erosion control swale and berm was constructed by excavating a small trench in the vegetation and building a berm on the exterior side of the trench at the toe of the embankment. The swale was designed to be 0.5 m deep with a 6 m wide base and 3H:1V side slopes, graded to direct drainage towards two sedimentation traps. Grubbing was replaced in the swale to encourage vegetation growth. The excavated grubbing was used to construct the control berm, which had a height of 1.3 m, a crest width of 2.5 m, and 1H:1V side slopes.

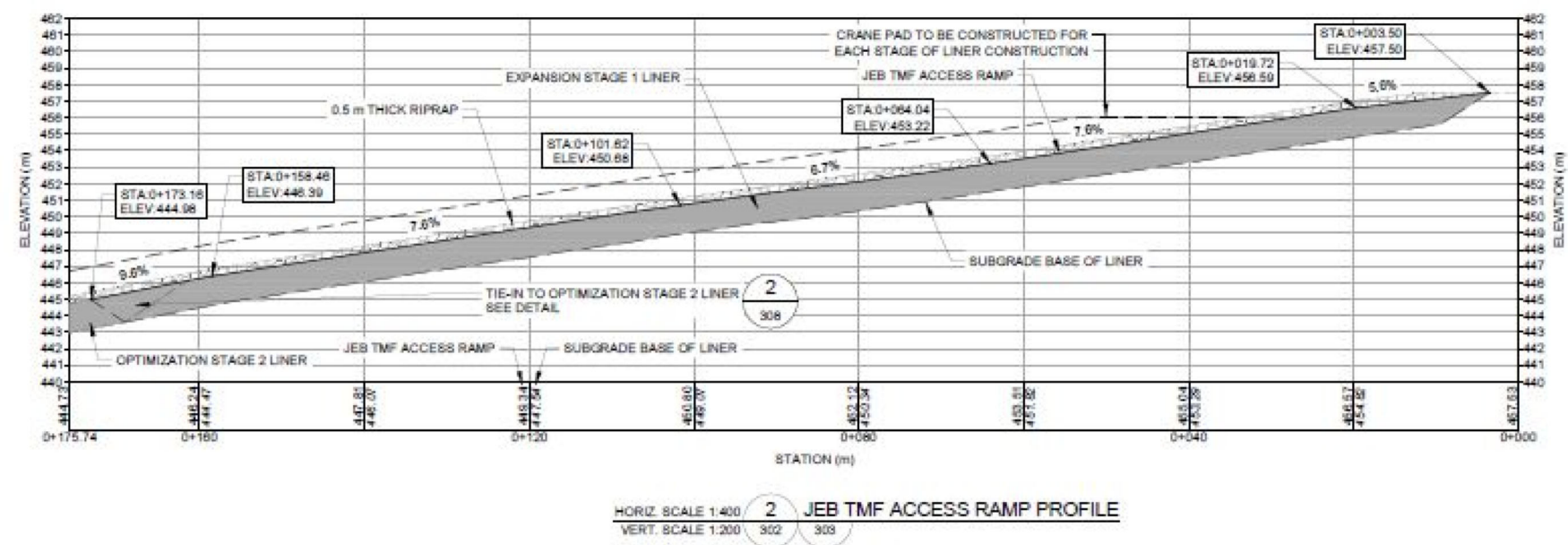
Two sedimentation traps were designed to be naturally low areas: one at the northwest toe and one at the southwest toe of the embankment. These traps were designed to capture runoff from the erosion control swale, reduce the velocity of the runoff, and provide a ponding area for sediments to settle before the runoff is released into the environment. The sedimentation traps were constructed by excavating a 0.5 m deep by 8 m wide serpentine channel and building berms to a height of 2 m with a 2 m crest width and 1H:1V side slopes. An 11 m wide, 1.6 m high riprap check structure with 1H:1V side slopes was constructed at the outlet of each sedimentation trap to promote ponding and provide erosion protection. The upstream slope of the check structure was designed at 2H:1V, and the downstream slope at 3H:1V. A 0.4 m thick riprap apron was placed at the toe of the downstream slope, extending 8 m from the toe. A non-woven geotextile was placed as a separator below the check structure.

2.4.2.2 Construction

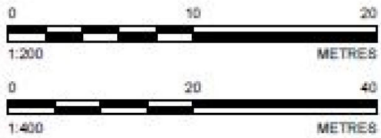
Liner Placement in 2019

The initial phase of the JEB TMF Expansion commenced in 2019 with liner placement to approximately 448 mASL. Liner soil material was produced by blending crushed sandstone and till. An untreated Wyoming sodium bentonite was used to amend the liner soil material in a pugmill at a minimum of 5% by weight, similar to the JEB TMF Optimization liner. Prior to liner construction, a test pad was constructed to confirm that the contractor's construction methodology would produce a soil bentonite liner with the properties specified in the design. A third-party representative provided quality assurance/quality control (QA/QC) testing throughout construction. The work completed was constructed under the Saskatchewan Ministry of Environment Approval to Construct No. PC19-053 and the Canadian Nuclear Safety Commission letter (File No. 2.04 ML-A) dated September 30, 2010.

- NOTES
- 1. TOPOGRAPHIC SURFACE GENERATED FROM LIDAR SURVEY, 2009.
 - 2. ELEVATIONS AND COORDINATES ARE REFERENCED TO LOCAL MINE COORDINATE SYSTEM.
 - 3. UNITS ARE METRES UNLESS OTHERWISE NOTED.



NOT FOR CONSTRUCTION



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Data Sources: ORANO, GOLDER ASSOCIATES

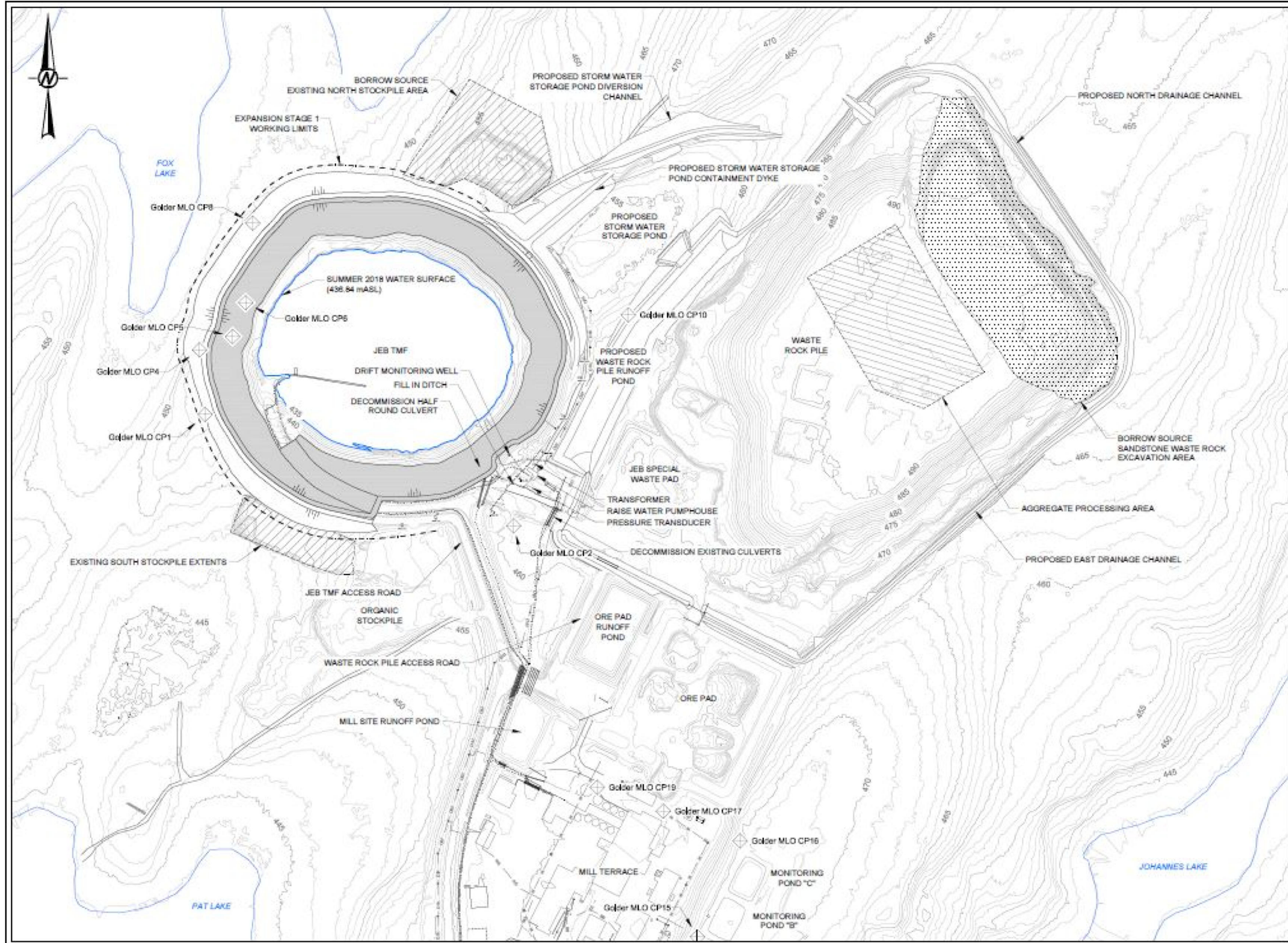
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McCLEAN LAKE OPERATION

FIGURE 2.4-9
JEB TMF ACCESS RAMP PROFILE

TAILINGS MANAGEMENT TID





- NOTES
1. TOPOGRAPHIC SURFACE GENERATED FROM LIDAR SURVEY, 2009.
 2. CONTOURS SHOWN AT 1m INTERVAL.
 3. ELEVATIONS AND COORDINATES ARE REFERENCED TO LOCAL MINE COORDINATE SYSTEM.
 4. UNITS ARE METRES UNLESS OTHERWISE NOTED.
 5. ADDITIONAL CONTROL POINTS TO BE ESTABLISHED BY OWNER PRIOR TO CONSTRUCTION.

CONTROL POINT TABLE			
DESCRIPTION	NORTHING (m)	EASTING (m)	ELEVATION
Golder MLO CP1	11109.63	5040.22	453.183
Golder MLO CP2	10949.17	5485.63	461.420
Golder MLO CP4	11202.78	5032.19	451.656
Golder MLO CP5	11221.79	5079.85	452.798
Golder MLO CP6	11270.63	5098.78	451.451
Golder MLO CP8	11385.20	5108.89	448.702
Golder MLO CP10	11253.05	5650.67	459.211
Golder MLO CP12	10114.42	5502.91	463.704
Golder MLO CP15	10356.90	5750.30	470.339
Golder MLO CP16	10405.32	5811.64	469.775
Golder MLO CP17	10538.13	5701.14	461.070
Golder MLO CP19	10572.35	5605.97	461.833
Golder MLO CP21	10261.84	5459.70	460.164
Golder MLO CP22	10201.97	5372.89	461.021

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Data Sources: ORANO, GOLDER ASSOCIATES

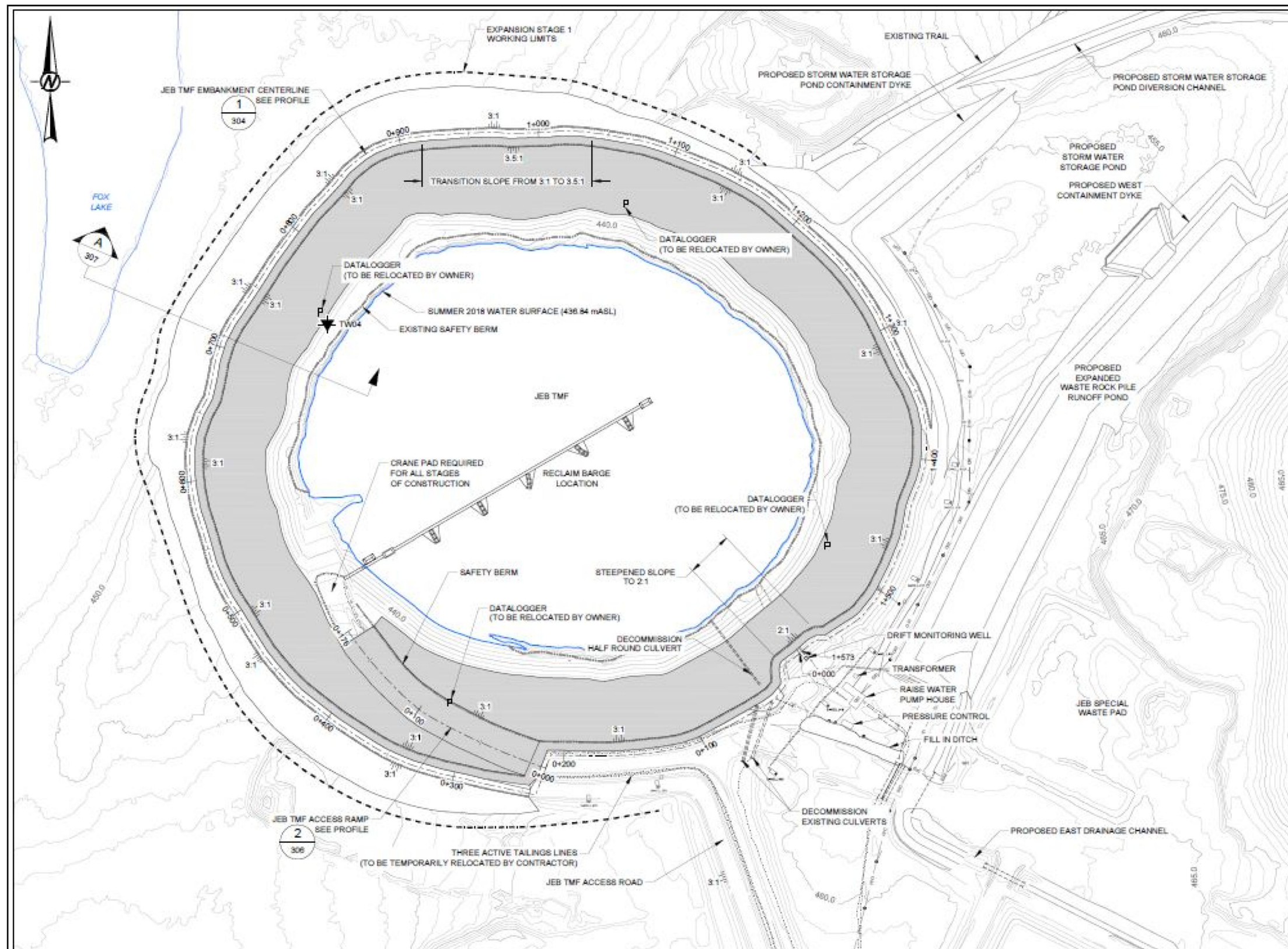
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McCLEAN LAKE OPERATION

FIGURE 2.4-10
JEB TMF EXPANSION STAGE 1 EMBANKMENT GENERAL ARRANGEMENT PLAN

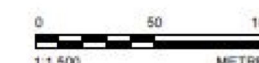
TAILINGS MANAGEMENT TID





- NOTES**
1. TOPOGRAPHIC SURFACE GENERATED FROM LIDAR SURVEY, 2009 AND GOLDER RECORD OF CONSTRUCTION SURVEYS, SEPTEMBER 2017.
 2. CONTOURS SHOWN AT 1m INTERVAL.
 3. ELEVATIONS AND COORDINATES ARE REFERENCED TO LOCAL MINE COORDINATE SYSTEM.
 4. UNITS ARE METRES UNLESS OTHERWISE NOTED.

NOT FOR CONSTRUCTION



Projection:
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Data Sources: ORANO, GOLDER ASSOCIATES

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McCLean Lake Operation

FIGURE 2.4-11
JEB TMF EXPANSION STAGE 1 EMBANKMENT LINER CONSTRUCTION PLAN

TAILINGS MANAGEMENT TID



Soil bentonite liner was constructed within the TMF with a crest width of approximately 6 m that achieved the minimum thickness and compaction specifications. Laboratory hydraulic conductivity tests were completed on 44 samples of liner material and 8 field hydraulic conductivity tests were conducted. The laboratory hydraulic conductivity test results ranged from 1.5×10^{-11} m/s to 9.0×10^{-11} m/s with a mean value of 6.7×10^{-11} m/s. Field hydraulic conductivity results ranged from 3×10^{-10} m/s to 8×10^{-11} m/s with a mean value of 1.8×10^{-10} m/s. Test results show that the constructed liner achieved the specified maximum of 1×10^{-9} m/s. Detailed as-built information is provided in the record of construction submissions (Huffman to Merkowsky and Akhter, February 5, 2020) and Golder 2019b.

Embankment to 457.5 mASL in 2021

Construction of the JEB TMF Expansion Stage 1 Embankment began in April 2021 and was completed in October 2021. Construction areas are detailed in Figure 2.4-13 and summarized below (Golder 2021b):

Site Preparation

Initial tree clearing was completed in winter 2021, extending approximately 5 m beyond the design boundary to ensure adequate space for construction activities. Grubbing was carried out up to the design location of the erosion control berm. In total, approximately 31,276 m² of tree clearing and 24,493 m² of grubbing were completed.

A known layer of buried organics beneath portions of the TMF perimeter road required removal, necessitating excavation of the overlying till before footprint preparation. Excavation began in areas with confirmed buried organics. In areas where presence was uncertain, surficial organics were stripped inward from the embankment perimeter until no further organic material was observed. A total of 47,632 m³ of organic material was excavated.

In the northwest portion of the TMF, excavation of surficial organics created a low-lying area that accumulated water. This area required dewatering before subgrade compaction and embankment construction could proceed.

Density Testing and Subgrade Preparation

Golder Associates conducted density testing on the native till foundation outside the TMF embankment using the nuclear densometer method (ASTM D6938). Tests were performed at depths of 0.3 to 0.6 m below the stripped surface at 15 accessible locations. Dry density values ranged from 1,950 kg/m³ to 2,159 kg/m³. Additional testing on unprepared subgrade at 0.3-meter depth yielded dry densities ranging from 1,950 kg/m³ to 2,174 kg/m³.

Subgrade compaction required a minimum of 95% SPMDD prior to embankment fill placement. Approximately 55,121 m² of embankment subgrade was compacted.

Embankment Construction

The expansion embankment was constructed using Common Fill (native till) and Waste Rock Type 1 (sandstone waste rock). Common Fill was sourced from the south till stockpile and TMF perimeter road excavations, totaling approximately 46,742 m³. Fill thickness ranged from 0 to 3.1 m, with top elevations between 447.5 mASL and 455 mASL.

Waste Rock Type 1, sourced from the JEB Clean Waste Rock Stockpile, was placed using methods developed during test pad construction. Approximately 214,951 m³ of waste rock was used, with thickness ranging from 0 to 10 m. The embankment was constructed with a 7 m wide crest and an interior crest elevation of 457.5 mASL.

Erosion and Sediment Control Construction

Figure 2.4-14 displays the locations of the constructed swale, berm, and sediment traps. A swale and berm system was constructed along the exterior toe of the TMF 457.5 mASL expansion to manage surface water and sediment control.

To establish proper drainage toward the sediment traps, fill was placed in low-lying areas, and approximately 6,200 m³ of grubbing material was used. The swale base measured approximately 5 m in width. A berm, constructed along the forest edge for the entire length of the swale, was formed using grubbing material. This berm stands approximately 1.8 m high with a 1.5-meter wide crest.

Sediment traps were constructed using berms made of grubbing material, each approximately 2 m in height, with a 6 m wide base and a 2 m wide crest. The total length of the sediment traps is approximately 1,106 m, with serpentine bases measuring about 8 m in width.

Trap outlets were constructed with approximately 218 m² of riprap underlain by 325 m² of non-woven geotextile. The outlets included a riprap check structure measuring 8 m wide by 1.6 m high, with 3H:1V side slopes oriented perpendicular to the flow direction. Additionally, a riprap apron measuring 8 m by 11 m with a 0.4-meter thickness was installed.

Design Modifications

During construction, design modifications were required. These are presented in Figure 2.4-14 and summarized below:

- **Fill Placement Outside Embankment Toe:** Fill was placed outside the embankment toe between Station 0+950 and Station 1+123 to manage surface water.

- **Excavation of Organics Beneath Soil-Bentonite Liner:** Organic material was excavated from beneath the soil-bentonite liner between Station 0+650 and Station 0+700. A portion of the liner was removed and subsequently replaced.
- **Excavation of Organics Beneath TMF Access Road:** A continuation of buried organics was encountered beneath a section of the TMF access road, necessitating excavation and reconstruction of that portion of the road.
- **Exclusion of Granular Filter Layer:** Following test pad construction and preliminary analysis, it was determined that a granular filter layer was not required between the compacted waste rock fill and the soil-bentonite liner. The compacted fill was constructed to the design lines and grades of the liner base, replacing the designed 0.5-meter granular filter. A further assessment will be conducted to confirm whether a filter layer is needed prior to constructing the clay liner for the 457.5 mASL expansion.
- **Trail Construction Between South Stockpile and Embankment:** Due to the presence of buried organics beneath the south till stockpile, the trail between the stockpile and the embankment was constructed using fill to avoid further excavation near the sediment traps.
- **Fill in Erosion in Swale:** Fill was placed in the base of the erosion control swale to improve drainage toward the sedimentation traps.
- **Sediment Trap Modification at Station 0+200:** The orientation of berms at the sediment trap near Station 0+200 was adjusted to allow vehicle access to the 95-03 series monitoring wells.

Detailed embankment as-built information can be found in the "JEB Tailings Management Facility 457.5 m ASL Embankment, 293ML Record of Construction – Document Number 239ML-400-RP-Z-141", December 2021 (Golder 2021).

Liner Placement in 2023

Construction of the 452.5 mASL soil-bentonite liner construction began in April 2023 and was completed in October 2023. Construction areas are displayed in the site arrangement plan Figure 2.4-15 and details are summarized below:

Site Excavation

To tie in the existing south access ramp to the 452.5 mASL elevation, approximately 4,875 m³ of native till was excavated from the top of the 448 liner (Figure 2.4-16). During this process, organic waste material was encountered at the base of the ramp and had to be removed to ensure a stable foundation for the 452.5 mASL liner. Around 2,738 m³ of organic waste was excavated and transported to the organics stockpile.

Additionally, accumulated sediment on top of the 448 liner was removed to prevent contamination of the rip rap material. The rip rap along the entire alignment of the 448 liner was excavated. Approximately 6,881 m³ of excavated rip rap was placed along the edge to the TMF as temporary safety berm or stockpiled for later use.

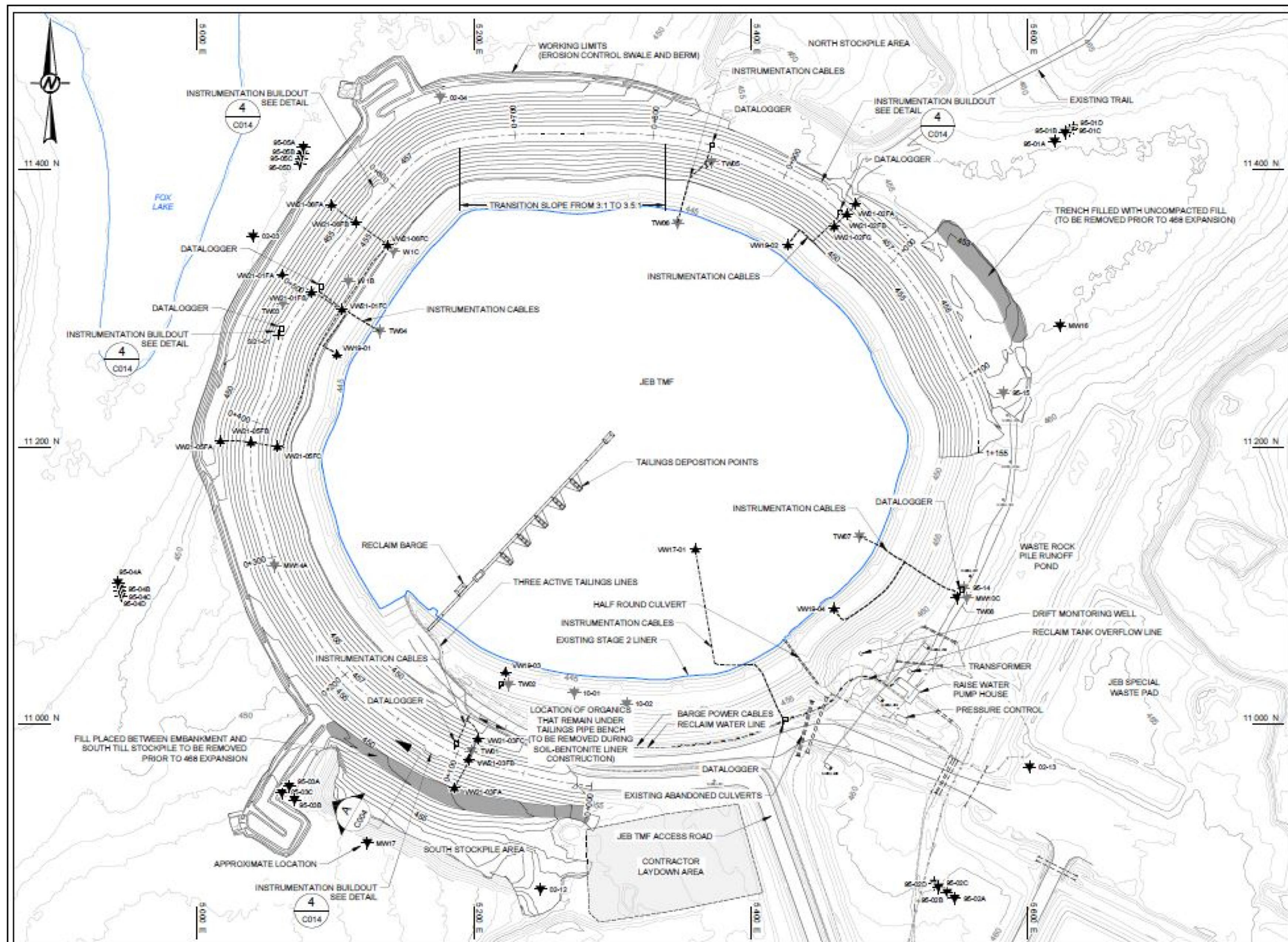


FIGURE 2.4-13
JEB TMF 457.5 mASL EMBANKMENT CONSTRUCTION PLAN 2021

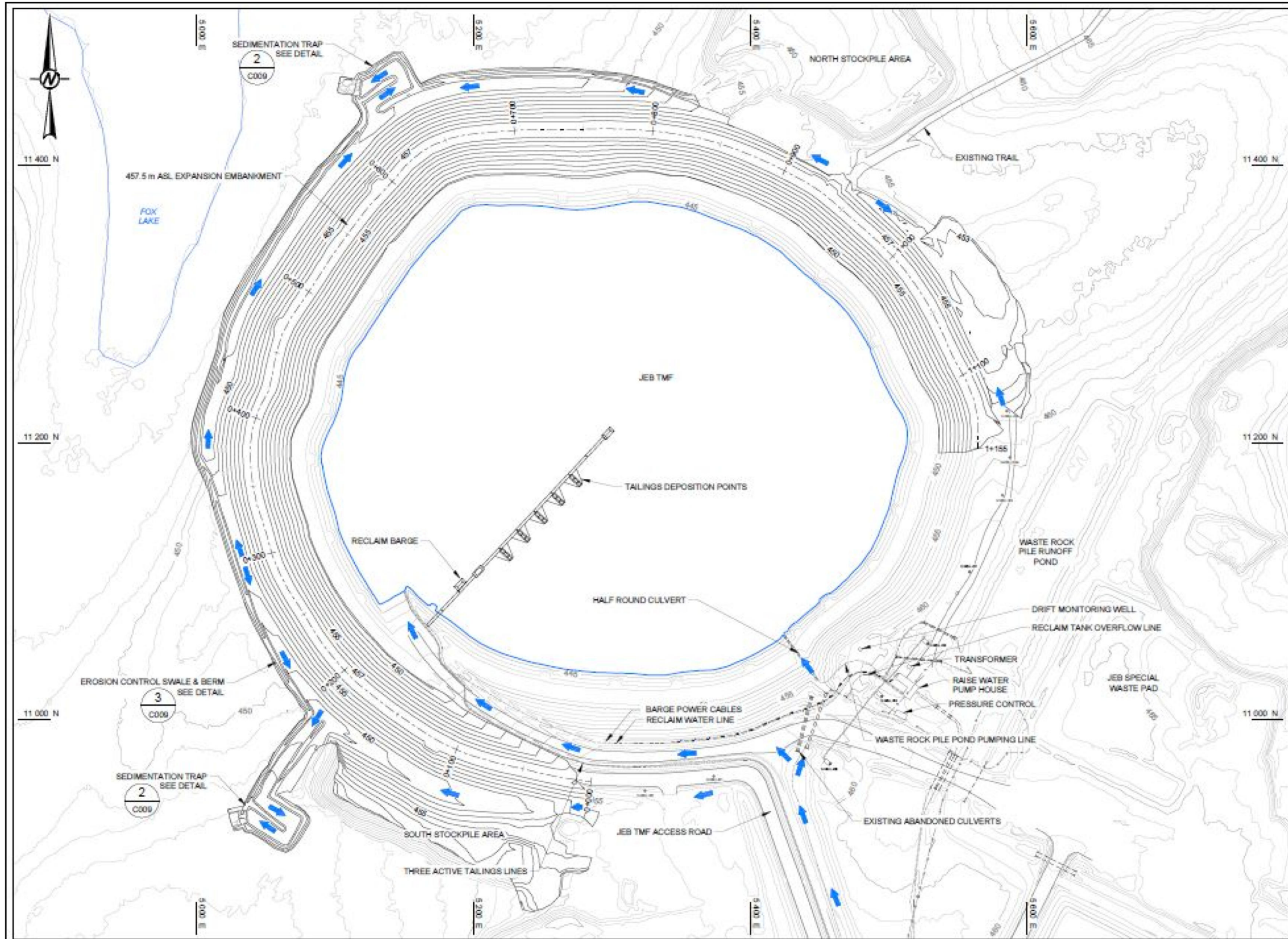
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Date:
Data Sources: ORANO, GOLDER ASSOCIATES

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Date:

McCLEAN LAKE OPERATION

TAILINGS MANAGEMENT TID





- NOTES
1. TOPOGRAPHIC SURFACE GENERATED FROM LIDAR SURVEY, 2009 AND GOLDER SURVEYS OF 2018 CONSTRUCTION AND 2019 LINER CONSTRUCTION.
 2. CONTOURS SHOWN AT 1m INTERVAL.
 3. ELEVATIONS AND COORDINATES ARE REFERENCED TO LOCAL MINE COORDINATE SYSTEM.
 4. UNITS ARE METRES UNLESS OTHERWISE NOTED.
 5. GREY DEWATERING AND MONITORING WELLS ARE DECOMMISSIONED.

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Data Sources: ORANO, GOLDER ASSOCIATES

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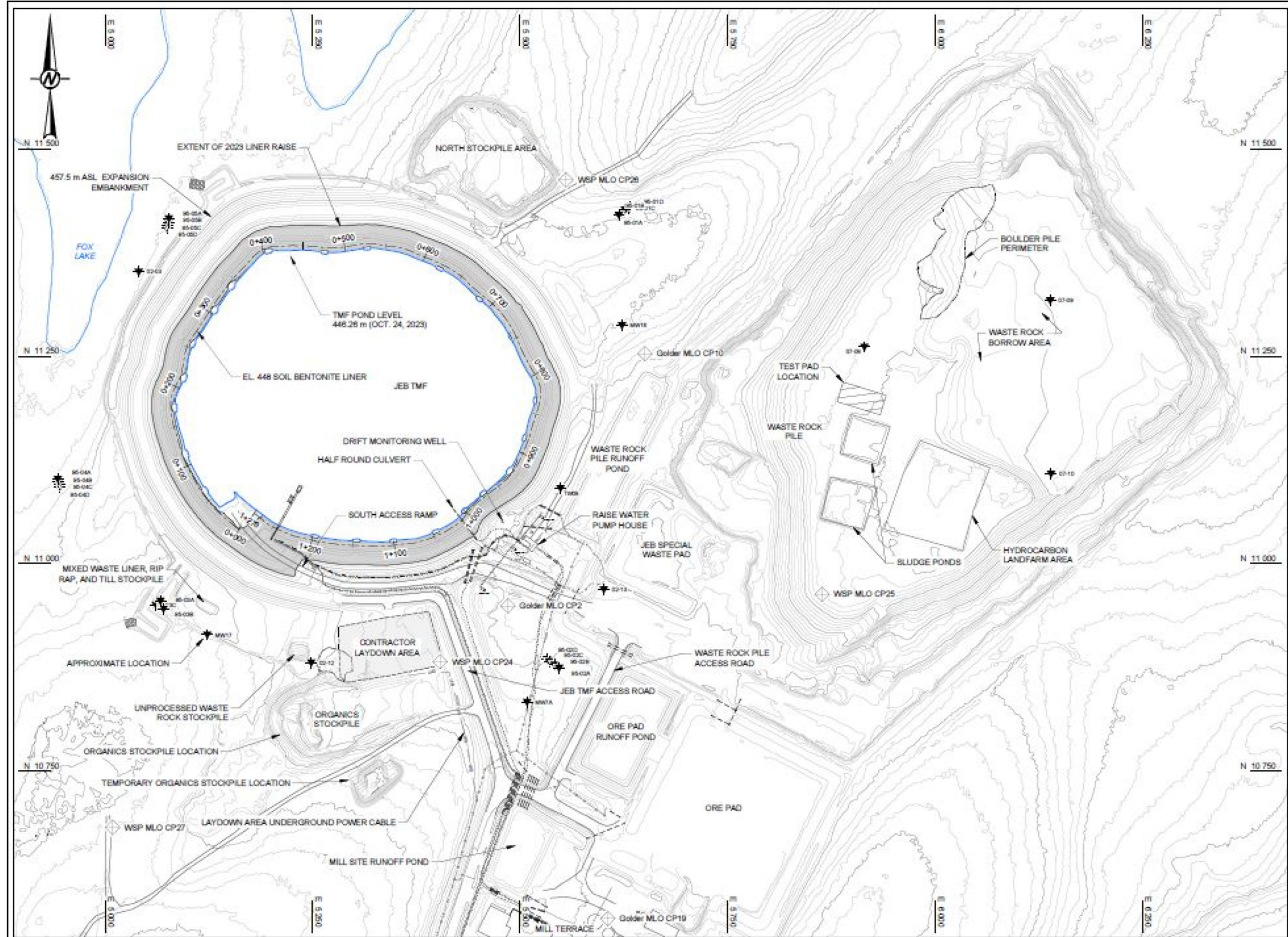
McCLEAN LAKE OPERATION

FIGURE 2.4-14
JEB TMF 457.5 mASL EMBANKMENT EROSION AND SEDIMENT CONTROL PLAN - 2021

TAILINGS MANAGEMENT TID



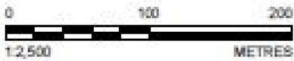
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- NOTES
1. TOPOGRAPHIC SURFACE GENERATED FROM LIDAR SURVEY, 2009 AND GOLDER SURVEYS FROM 2018, 2019, 2021 AND 2023 PIT EXCAVATION, LINER PLACEMENT AND EMBANKMENT CONSTRUCTION.
 2. CONTOURS SHOWN AT 1m INTERVAL.
 3. ELEVATIONS AND COORDINATES ARE REFERENCED TO LOCAL MINE COORDINATE SYSTEM.
 4. UNITS ARE METRES UNLESS OTHERWISE NOTED.
 5. ADDITIONAL CONTROL POINTS TO BE ESTABLISHED BY OWNER PRIOR TO CONSTRUCTION.

CONTROL POINT TABLE			
ID	NORTHING (m)	EASTING (m)	ELEVATION (mASL)
Goldier MLO CP2	10,940.17	5,485.63	461.420
Goldier MLO CP10	11,253.05	5,650.67	459.211
Goldier MLO CP12	10,114.42	5,502.91	463.704
Goldier MLO CP15	10,556.90	5,750.30	470.339
Goldier MLO CP16	10,495.32	5,811.84	469.775
Goldier MLO CP17	10,536.13	5,701.14	461.070
Goldier MLO CP19	10,572.35	5,605.97	461.633
Goldier MLO CP21	10,281.84	5,459.70	460.164
Goldier MLO CP22	10,201.97	5,372.89	461.021
Goldier MLO CP23	10,496.44	4,952.62	448.125
WSP MLO CP24	10,881.96	5,404.11	458.125
WSP MLO CP25	10,963.05	5,963.86	467.401
WSP MLO CP26	11,462.65	5,555.62	457.950
WSP MLO CP27	10,682.15	5,009.02	448.400

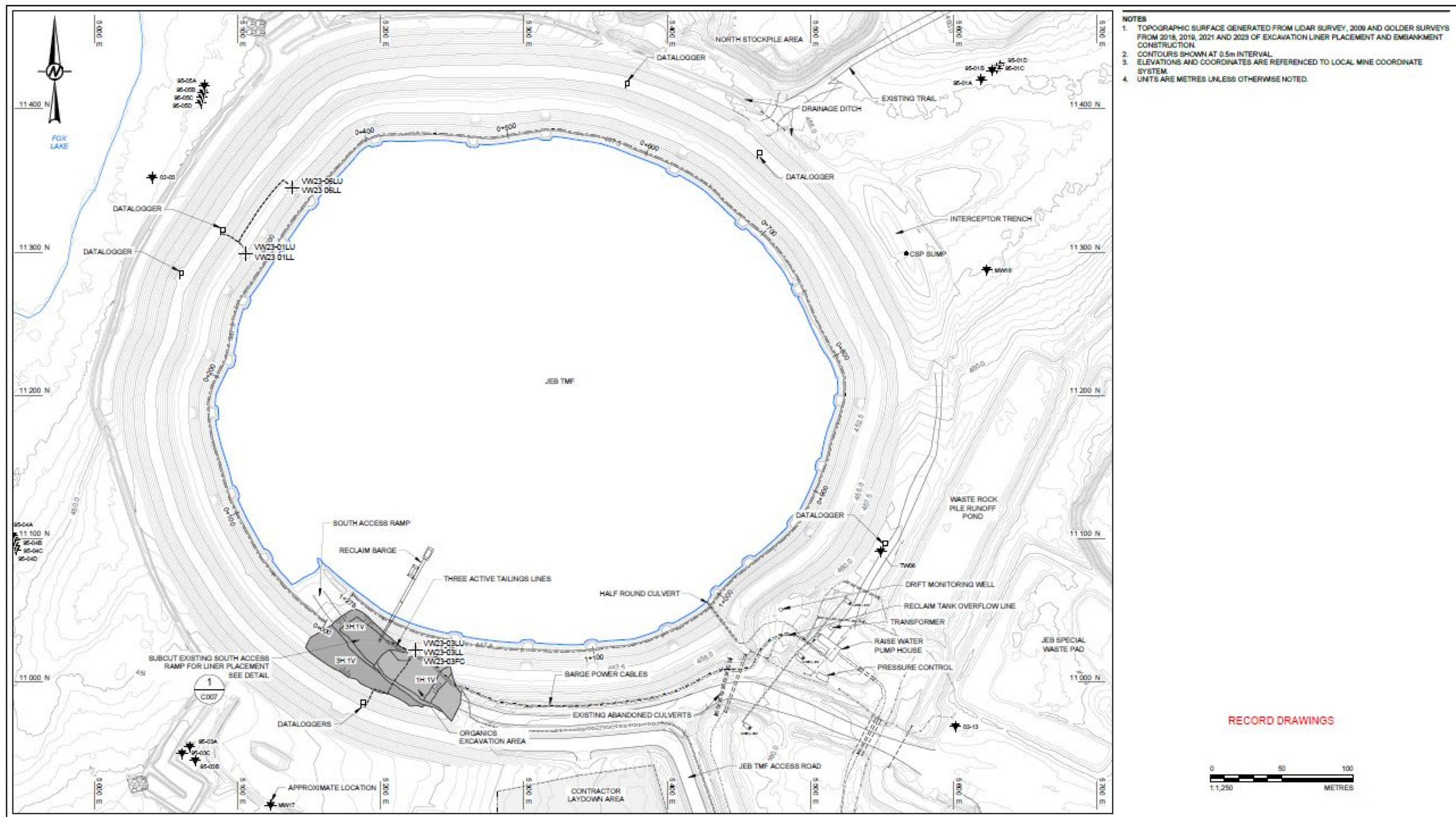
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Date:
Data Sources: WSP 2023.

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FIGURE 2.4-15
JEB TMF 452.5 SOIL BENTONITE LINER SITE GENERAL ARRANGEMENT PLAN - 2023



Projection:
Compiled:
Date:
Data Sources: WSP 2023.

Drawn:
Scale:

FIGURE 2.4-16
JEB TMF 452.5 SOIL BENTONITE LINER EXCAVATION PLAN - 2023

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The excavated slopes were trimmed to an even surface with the specified tolerance of the design slope using a GPS equipped CAT D6T and Komatsu 71Pxi dozers. The excavated area along the south ramp was compacted with a smooth drum roller prior to liner placement.

Material and Site Preparation

Approximately 60,351 m³ of soil material was produced on top of the JEB Clean Waste Rock Pile. This was blended material sourced from sandstone excavated from the waste rock pile and till from the south stockpile. A total of 123 grain size analyses (ASTM6913) were conducted by WSP, meeting the minimum testing frequency requirement of one test per 500 m³, with an actual rate of one test per 490 m³ of liner soil.

Approximately 12,270 m³ of rip rap was produced by crushing sandstone rock sourced from the waste rock pile. A total of 25 visual assessments were conducted by WSP, meeting the minimum testing frequency requirement of one test per 500 m³ presented in the QA/QC plan, with an actual rate of one test per 490 m³ of rip rap material.

Prior to liner placement, the TMF slope was prepared to repair erosion and ensure alignment with the 452.5 design geometry. The preparation process included filling erosion rills with common fill, excavating and backfilling erosion gullies, followed by compaction with common fill. Drainage ditches were constructed between the 448 liner and TMF slope in areas affected by groundwater seepage to direct water away from the working area.

Soil-Bentonite Liner Construction

The soil-bentonite liner was constructed by blending liner soil material with bentonite and water using a pugmill. The mixture included a minimum of 5% bentonite content (by dry weight of liner soil material). The bentonite used was Puregold Gel, an untreated Wyoming sodium bentonite produced by the American Colloid Company Co. This product meets the requirements of API 13A Section 10, as required by technical specifications.

A total of 44,800 m³ of soil-bentonite liner material was placed on the 452.5 mASL liner, connecting to the crest of the 448 mASL liner (Figure 2.4-17). Following the completion of the soil-bentonite liner, rip rap was placed on the slope and crest to a thickness of approximately 500 mm. A total of 21,387 m³ of rip rap was used to cover the 452.5 mASL liner.

QA/QC testing was conducted in accordance with the frequencies outlined in the QA/QC Plan. Detailed results are documented in "JEB Tailings Management Facility 452.5 mASL Soil-Bentonite Liner, (22-177-ML) Record of Construction - Appendix G," December 2023 (WSP 2023). A summary of the completed tests is provided below:

Grain Size Analysis (ASTM D6913)

- 25 tests completed (1 per 1,625 m³)
- Meeting minimum requirement of 1 test per 2,000 m³

Standard Proctor Maximum Dry Density (SPMDD) (ASTM D698)

- 26 tests completed (1 per 1,575 m³)
- Meeting minimum requirement of 1 test per 2,000 m³

Nuclear Density and Water Content Testing (ASTM D6938) – 452.5 Liner

- 412 tests completed (1 per 100 m³)
- Meets minimum requirement of 1 per 100 m³
- Required compaction: Minimum 98% SPMDD within -1% to +2% of optimum moisture content
- Average dry density achieved: 99.8% SPMDD

Nuclear Density and Water Content Testing (ASTM D6938) – Saturated Slope Repair Liner

- 37 tests completed (1 per 25 m³)
- Meeting minimum requirement of 1 per 100 m³
- Required compaction: Minimum 95% SPMDD
- Average dry density achieved: 98.5% SPMDD

Oven Moisture Content Testing

- 47 tests completed (1 per 9 nuclear gauge tests)
- Meets minimum requirement of 1 per 10 nuclear gauge tests

Hydraulic Conductivity Testing: Specification: Maximum hydraulic conductivity of 1×10^{-9} m/s

Field Testing (ASTM D5126) Following Compaction:

- 9 tests completed (1 per 4,957 m³)
- Meets minimum requirement of 1 per 5,000 m³
- Average field conductivity: 2.4×10^{-10} m/s

Laboratory Testing (ASTM D5084) Prior to Compaction:

- 45 tests completed (1 per 1,000 m³)
- Meets minimum requirement of 1 per 1000 m³
- Average lab conductivity: 3.2E-11m/s

Direct Shear Testing (ASTM D3080)

- 7 tests completed (1 per 6,400 m³)
- Meeting minimum requirement of 1 per 8,000 m³

South Ramp Access

Embankment construction was required to build the south access ramp landing and driving surface in the south ramp area. A total of 4,424 m³ of common fill was used to construct the landing and to backfill an organics excavation area near the TMF barge walkway entrance. The landing was constructed to an approximate width of 20 m. Additionally, 270 m³ of compacted common fill was used to construct a 16.5 m wide driving surface.

Eroded portions of the TMF slope were excavated and backfilled with common fill, ensuring the embankment matched the design geometry of the 452.5 mASL liner base. Approximately 950 m³ of rip rap material was used to construct 14 barge anchor platforms on the 452.5 mASL liner riprap slope around the TMF. These platforms were built with an approximate crest width of 4 m and side slopes of 2H:1V.

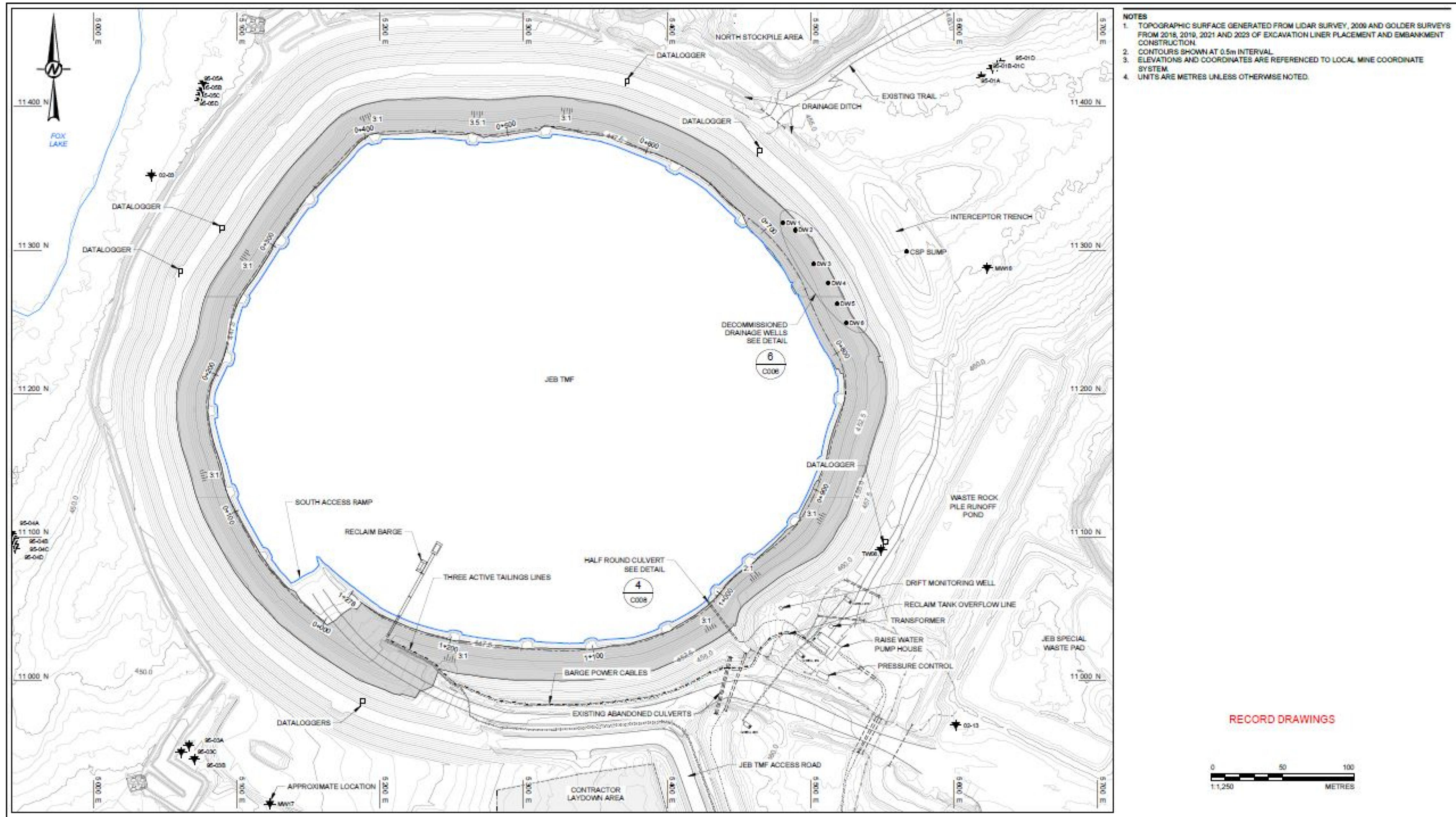
After completion of the embankment, the slopes were trimmed to create an even surface. The pond side slope of the south access ramp landing was lined with riprap to a nominal thickness of 500 mm to mitigate erosion caused by pond water. Berms were constructed along the pond side edge on either side of the barge power cables, tailings and reclaim pipelines.

Design Modifications

During construction, design modifications were implemented. These are summarized below:

- Barge Anchor Platforms: The total number of barge anchor platforms was revised to 14.
- Organic Waste Excavation: A significantly greater volume of organic and unexpected waste material was encountered in the south area, requiring additional excavation.
- Test Pits: Due to the unforeseen organic and waste materials in the south ramp area, the number of test pits was increased to 12.
- Interceptor Trench: Due to changed groundwater conditions at the site, a groundwater interceptor trench was constructed between the TMF and the topographic low area northeast of the TMF to reduce groundwater flow toward the working area.
- Drainage Ditch: Due to changed groundwater conditions at the site, construction of an upstream dewatering system comprising a toe ditch and drainage wells was required to reduce hydraulic pressure at the 452.5 liner base.
- Southwest Sediment Trap: Grading was required to direct surface water toward the southwest sediment trap, preventing flow along the trail leading to the 95-03 monitoring wells.

A full record of all as-built 452.5 liner construction information can be found in the "JEB Tailings Management Facility 452.5 m ASL Soil-Bentonite Liner, (22-177-ML) Record of Construction", December 2023 (WSP 2023).



Projection:
Compiled:
Date:
Data Sources: WSP 2023.

Drawn:
Scale:

FIGURE 2.4-17
JEB TMF 452.5 SOIL BENTONITE LINER CONSTRUCTION PLAN - 2023

McCLEAN LAKE OPERATION

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2.4.3 Changes to Existing JEB TMF Infrastructure

The Optimization and Expansion Projects described in Sections 2.4.1 and 2.4.2 also involved some changes to the supporting JEB TMF Infrastructure. These modifications are summarized below.

2.4.3.1 Changes to TMF Monitoring Wells

The purpose of the inner trend monitoring wells was to provide an early detection of loss of hydraulic containment within the JEB TMF. The outer ring of trend wells were used to monitor the groundwater levels necessary for the hydraulic containment strategy. The installation of the trend monitoring wells was described in the JEB TMF Construction Licence Additional Information, Appendix 5 (COGEMA 1998).

The inner (TW02, TW04, TW06, and TW07) and outer (TW01, TW03, TW05 and TW08) trend monitoring wells were within the footprint of the JEB TMF Optimization Project and the majority could not be maintained in their original configurations. TW08 was outside of the construction footprint and will be maintained until future facility expansion warrants decommissioning. Trend well TW03 was damaged during removal of the submersible pump and was fully decommissioned. Vibrating wire piezometers were installed in all remaining trend monitoring wells to preserve the primary function of monitoring head. Collection of water samples from the trend wells (a secondary purpose) was discontinued.

Major changes to existing infrastructure in the vicinity of the JEB TMF are shown in Figure 2.4-7 and Figure 2.4-8.

2.4.3.2 Base Drain Pumping and Decommissioning of Dewatering Wells

Following completion of Stage 1 of the JEB TMF Optimization Project the pond level of the TMF was raised above the sandstone/till contact. A corresponding rise in the level of the dewatering wells meant that they were above the normal water table and no longer useful. Certain dewatering wells and associated infrastructure were also within the footprint of the JEB TMF Optimization Project necessitating decommissioning. Prior to Stage 2 of the JEB TMF Optimization Project select dewatering wells were decommissioned and hydraulic containment was maintained through water removal from the raise water system. A model of these changes was completed based on initial proposals for the JEB TMF Expansion Project, which confirmed that base drain pumping would be adequate to maintain containment during operations (Appendix D Section E). Three dewatering wells remain to be fully decommissioned as part of future TMF expansions. The maintenance of hydraulic containment is discussed in Section 2.2.2

2.4.3.3 Other Modifications to JEB TMF Infrastructure

In preparation for completion of the JEB TMF Optimization Stage 2 till resloping work, and to allow for the expansion of the JEB TMF (i.e. embankment construction), various infrastructure were modified in 2017. In

addition to the decommissioning of dewatering well infrastructure at the JEB TMF discussed in above, the following projects were conducted:

- Relocation of the temporary contaminated materials landfill from the brow of the JEB TMF to a permanent facility constructed in the Sue C pit (Golder 2017a)
- Realignment of the tailings pipeline bench and JEB TMF access road and ramp, and construction of a waste rock pile access road (Golder 2017b)

In addition to the TMF 457.5 mASL embankment construction as discussed in Section 2.4.2.2, the following projects were conducted in 2021:

- Removal of the reclaim water tank in the JEB TMF pumphouse and successful bypass installation.
- Decommissioning of monitoring wells 95-15 and 02-04 was required because these wells were located within construction extents.
- Installation of a slope inclinometer (1) and vibrating wire piezometers (VWPs) at five monitoring sections in sets of three (15 total VWPs) within the embankment foundation and relocation of existing VWPs installed in 2019. The VWPs were installed according to methodology provided in “JEB TMF 2021 Construction Implementation Requirements and Recommendation”, dated April 23, 2021 (Golder 2021).

In addition to the 452.5 m ASL soil-bentonite liner construction as discussed in Section 2.4.2.2, the following projects were conducted in 2023:

- Removal of the tremie barge and the flexible walkway associated with subaqueous deposition from the TMF. Additionally, a portion of the walkway connecting the header barge to the former tremie barge was dismantled as discussed in section 2.7.
- Installation of additional vibrating wire piezometers (7 Total VWPs) at 3 existing monitoring sections (Monitoring Section 1, 3 and 6)