



Wolverine Project

TAILINGS AND INFRASTRUCTURE DESIGN AND CONSTRUCTION PLAN

VERSION 2009-02

DRAFT (WITHOUT APPENDICES)

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EXECUTIVE SUMMARY

This *Tailings and Infrastructure Design and Construction Plan* (Version 2009-02) presents the detailed design of the tailings storage facility (TSF) for the Wolverine underground zinc-silver mine located in south eastern Yukon Territory. The Wolverine Project has received *Quartz Mining License QML-0006* (QML-0006) and *Type A Water Licence QZ04-065* (QZ04-065) and is proceeding with detailed engineering design for all components. The bulk of construction activities are scheduled for spring 2009, and full operation of the tailings facility is scheduled for June 2010 with mill startup. For additional Wolverine Project information, refer to *General Site Plan* (Version 2008-04), which includes updated information on the overall project layout, project development schedule, site and underground mine development overview, and construction details for the permanent camp, and site roads.

This Plan has been prepared to satisfy *QML-0006* Condition 13.3. This report consolidates changes made to the TSF since the *Feasibility Study* and *Optimized Feasibility Study* were issued in 2006 and 2007, respectively, and submission of the *Revised Documentation in Support of A-Licence Application QZ04-065* in January 2007.

Site Conditions

The project is located in gently rolling hills and mountains with elevations up to 1800 m. The TSF area is covered with small shrubs and grasses near elevation 1300 m. The TSF is formed by a 700 m long L-shaped dam, up to 23.5 m high, located in a small drainage northeast of Go Creek. The foundation soils consist of medium dense to dense ablation tills up to 15 m deep that overlie bedrock. Local shallow peat deposits occur within the basin. The area is of moderate seismicity.

The mean annual precipitation and evaporation are 570 mm and 400 mm, respectively. Average snowpack is 175 mm of snow water equivalent. Mean monthly temperatures are below zero from October to April. The hydrogeologic regime consists of a shallow aquifer in the soils immediately above the bedrock and the estimated groundwater flow beneath the tailings basin is approximately 15 L/s.

A site investigation program was carried out that consisted of 5 drill holes and 20 test pits within the TSF area, and additional drilling, testpits and geophysical surveys were completed in the general area. Laboratory testing consisted of index testing, shear strength determination and consolidation tests on the tailings. The dam foundation soils are not susceptible to liquefaction. Dam construction fills, to be borrowed from the interior of the impoundment, consist of competent glacial silty sands and gravels.

Tailings Storage Facility Design

The milling process will produce tailings, which will either be deposited in the underground mine as paste backfill, or deposited in the tailings facility. The tailings have high sulphide content and have the potential to become acid generating if allowed to oxidize. Therefore, tailings will be stored in the saturated containment system described herein.

The design of the facility is based on field and laboratory investigations of the foundation conditions and considerations of geochemical characteristics of the tailings and supernatant water. The design incorporates the availability of local dam borrow materials, storage capacity requirements, site water balance, dam failure consequence rating, and earthquake and flood potential.

The impoundment is designed to safely route the 1:10,000 year return period flood through spillways (Starter Spillway and Ultimate Spillway) located in the west flank of the dam. During operations the TSF will also store the 1:200 year return-period flood event, without the release of water. The design earthquake is a 1:10,000 return period, with a peak ground acceleration of 0.22 g. The minimum geotechnical factors of safety during operations are 1.5 for static stability and 1.1 for pseudo-static stability. Analysis of the impoundment liner leakage rate indicates an actual seepage predicted rate of 10^{-5} L/s. The negligibly low seepage rate provides a safety margin against the potential for long-term degradation of portions of the liner.

The tailings facility includes a L-shaped tailings dam, a tailings pond, a seepage recovery dam and pond, two upland diversion ditches, and spillways (see Drawing D-3004). The impoundment covers an area approximately 600 m long and 300 m wide. The catchment area for the TSF will be reduced with the construction of two main diversion ditches (Ditches A and B). The

maximum dam height is 16.5 m and 23.5 m high at project start up and after Year 2 of mining operations, respectively.

The tailings dam is a compacted homogeneous earthfill dam with an impervious geosynthetic liner. The liner will cover the base of the tailings impoundment and the upstream face of the dam up to the Ultimate Dam crest. A seepage collection pond will be constructed downstream of the main dam as a contingency to allow return of contaminated water.

Construction and Operations

Dam construction is scheduled to start in spring 2009, with drainage and surface preparation works having commenced in fall 2008. A QA/QC program will be carried out during construction, and as-built records will be prepared. Construction of the TSF will use best practices for control of erosion and sediment, as outlined in *General Site Plan (2008-04)*.

The TSF will be constructed in two stages, a 16.5 m high Starter Dam, which will then be raised to a 23.5 m high Ultimate Dam in 2011. The starter dam will be a homogeneous earthfill dam with a 6 m wide crest and a 2H:1V downstream slope and a 2H:1V upstream slope. The dam raise will be by the downstream method. The impoundment will be lined with a 40 mil linear low-density polyethylene (LLDPE) geomembrane liner placed on a foundation prepared by compaction with a smooth drum roller. Fine material will be placed as required to produce a suitable base.

Tailings will be spigotted from the dam crest and from the upstream edge of the impoundment. A reclaim pond will initially form near the south side of the dam and in approximately Year 5 tailings will be spigotted from the dam at the south end of the impoundment and the reclaim pond will be reformed towards the north end to facilitate closure. In approximately Year 6, the reclaim barge will be moved to the north end.

Water Management and Treatment

Water within the TSF will be reclaimed to the mill. The water balance results in a net annual water surplus of approximately 4.1 m³/h to 7.6 m³/h, which will be treated prior to discharge. A pilot water treatment plant will be constructed in the first year of operations to develop the final

plant design based on the actual supernatant solutions. Storage capacity is provided in the TSF for the first few years of operations to allow for pilot plant testing with actual process water to design and construct the water treatment plant.

Closure Plan

Reclamation and closure plans for closure of the tailings facility are documented in the approved *Wolverine Project Reclamation and Closure Plan (2008-02)*. A revised Reclamation and Closure Plan is required by QML-0006 to be submitted in December 2009, and updated plans for closure of the tailings facility will be based on as-built drawings. In general, the dam and the closure spillway are designed as “robust” structures which will be resistant to long-term erosion forces. As per QML-0006 Condition 16.5, a minimum of 1.0 m of coarse grained material, demonstrated to not have ARD/ML potential, will be placed over the stored tailings.

Additional QML-0006 Requirements

An *Operation, Maintenance and Surveillance (OM&S) Manual* will be prepared to document best practices for TSF operations, and will be submitted in 2009 to Yukon Energy, Mines and Resources for review and approval. The preliminary *Emergency Response and Preparedness Plan*, provided in Appendix IV, will be updated and integrated into the *OM&S Manual*.

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1. INTRODUCTION

This report presents the detailed design and construction plan for the tailings facility and related infrastructures for the Yukon Zinc Corporation (YZC) Wolverine Project. The project is an underground zinc-silver, massive sulphide mine located in south-eastern Yukon Territory. Yukon Zinc Corporation was issued *Quartz Mining License QML-0006* by Yukon Energy, Mines and Resources (EMR) in December 2006 and *Type A Water Licence QZ04-065 (A-Licence)* by the Yukon Water Board in October 2007. This report consolidates and updates previous reports or report sections related to the Wolverine Project tailings storage facility (TSF) prepared by Klohn Crippen Berger Ltd. for YZC, including:

- Environmental Assessment Report, (YZC and AXYS 2005).
- Environmental Assessment - Response Document (YZC 2006a).
- Tailings and Infrastructure Design and Construction Plan, Version 2006-01 (KCBL 2006).
- Tailings and Related Infrastructures – Feasibility Design Update Report (KCBL June 2007).
- Revised Documentation in Support of Water Use Application QZ04-065, Sections 35, 37, 38 and 40 (YZC 2007).

This Tailings and Infrastructure Design and Construction Plan has been prepared to satisfy *QML-0006* Condition 13.3, which requires the submission to EMR of a document for review and approval that contains the following information:

- a) final designs and specifications of all structures forming part of the tailings facility including the seepage collection dams, diversion ditches, locations of piezometers and other monitoring instruments;
- b) quality assurance and quality control for construction of all structures forming part of the tailings facility, including dams and liners;
- c) an operations and maintenance manual for the tailings facility including details of how tailings, waste rock and dense media separation float material will be deposited within the lined impoundment and an operating manual consistent with the CDA Dam Safety Guidelines and the Guide to the Management of Tailings Facilities;

- d) descriptions of measures to be in place to respond to any emergencies including descriptions of location and quantities of stockpiled construction materials and equipment always to be available on site;
- e) provisions for managing seepage from the tailings facilities;
- f) for high density sludge, carbon column and bio-reactor proposals; and
- g) adaptive management measures to respond and adapt to unexpected changes.

Based on an optimization study conducted in late 2007 and the completion of preliminary detailed engineering design work completed in fall 2008 for the various project components, several minor modifications have been made to the tailings facility including:

- The dense media separation (DMS) circuit has been removed from the plant process, thereby negating the requirement for a DMS stockpile and a DMS haul road to the tailings facility;
- The tailings facility water treatment plant and retention pond will be located within the industrial complex area;
- The tailings facility diversions ditches (Ditches A and B) have been re-designed to reduce overall length and minimize disturbance while diverting the same catchment areas around the facility, thereby minimizing water treatment requirements;
- The access road adjacent to the tailings facility has been designed to run along the south and southwest side of the tailings facility. The current site road joining to the access road on the northeast side of the tailings facility will be used for construction of Ditch B and the water reclaim line.;
- The starter and ultimate dam heights have increased from 16.0 m to 16.5 m, and 21 m to 23.5 m, respectively;
- The timing of the process plant start-up has been changed to June 2010, which provides time to capture and store the spring runoff in the TSF for the water required for mill start-up. Consequently, the Go Creek diversion and pipeline is no longer required;
- The dam classification rating presented in the new Canadian Dam Association Dam Safety Guidelines (2007), has a change in terminology and the previously

classified “High” category is now equivalent to a “Very High” dam rating; there are no changes to the design criteria;

- The seepage collection ditches have been “downsized” to collection channels at the toe of the dam;
- The tailings pipeline has been realigned along the new access road; and
- The spillways have been relocated to the northwest abutment of the Starter Dam and Ultimate Dam. The new locations result in shorter spillway lengths and lower total hydraulic head drop. These modifications also reduce the potential risk of spillway erosion leading to dam failure because they are located in sections with lower dam heights.

1.1 Tailings Facility Summary

The tailings impoundment site is located in a natural, northwest-southeast trending elongated depression located on the northeast valley slope of Go Creek (See Drawing D-3001). The depression is flanked on the downhill side by a natural ridge that drops in height gently towards the upstream end of the tailings facility. The design of the facility is based on field and laboratory investigations of the foundation conditions and considerations of geochemical characteristics of the tailings and supernatant water. The design incorporates the availability of local dam borrow materials, storage capacity requirements, site water balance, dam failure consequence rating, and earthquake and flood potential.

The tailings dam is a compacted homogeneous earthfill dam with an upstream impervious geosynthetic liner. The liner will cover the base of the tailings impoundment and the upstream face of the dam up to the Ultimate Dam crest. A seepage collection pond will be constructed downstream of the main dam as a contingency to allow return of contaminated water.

The dam will be constructed in two stages: the 16.5 m high Starter Dam will be constructed to elevation 1306.5 m in 2009, in preparation for mill start-up in June 2010; in 2011 the dam will be raised 7 m using the downstream construction method to the final elevation at 1313.5 m. During operations there will be storage for mine tailings plus an operating settling pond and flood storage.

Associated water management facilities include: Ditch A and Ditch B, which will direct clean surface runoff around the impoundment; and a Starter Dam emergency spillway and an Ultimate Dam closure spillway.

During the operation of the Wolverine Mine, approximately 4 Mt of tailings will be generated. Approximately 50% will be stored as paste tailings within the underground stope voids, and the remainder (approximately 2.03 Mt) will be stored in the tailings impoundment. Geochemical testing of the tailings indicates that they have the potential for developing acid rock drainage. Therefore, the tailings will be stored in a saturated impoundment with a water cover on closure.

1.2 Report Disclaimer

This report is an instrument of service of Klohn Crippen Berger Ltd. The report has been prepared for the exclusive use of Yukon Zinc Corporation for the specific application to the Wolverine Project. The report's contents may not be relied upon by any other party without the express written permission of Klohn Crippen Berger. In this report, Klohn Crippen Berger has endeavoured to comply with generally accepted geotechnical practice common to the local area. Klohn Crippen Berger makes no warranty, express or implied.

The data were obtained by Klohn Crippen Berger Ltd. for a specific purpose and specific project using the standard of care prevailing at the time the work was done. The data are not to be used for any purpose or project other than that for which the data were obtained. The data are provided for information only. Use of the data is at the *third party's* own risk and does not relieve the *third party* of sole responsibility for all liability associated with the *third party's* use of the data.

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2. SITE CONDITIONS

The topography of the general area consists of gently rolling hills and mountains, with an elevation range of 1200 m to 1800 m. The tailings impoundment area is covered with small shrubs and grasslands and is located near elevation 1300 m.

Photo 2.1 presents a photograph of the tailings facility area looking northwest, with the tailings impoundment outlined in yellow and the main dam located at the left end of the yellow outline.



Photo 2.1 Tailings Facility General Area, looking northwest.

2.1 Geology and Seismicity

The geology characterization and seismicity assessment are included in Appendix I and summarized in the following sections.

2.1.1 Geology

The Wolverine Lake area lies within the limits of the McConnell Glaciation (youngest of the four glaciations in Yukon Territory) and most of the geomorphic features in the area are related

to this glaciation. McConnell glacial ice covered this area between 14,000 and 35,000 years ago. As the McConnell ice retreated and down-wasted, a complex network of ice tongues developed in valley bottoms. Morainal deposits are found at lower to mid-elevation and valley floors, and may contain a more complex assemblage of glacio-fluvial, colluvial and fluvial sediments (Mougeot 1996). The main glacial soils in the vicinity of the tailings impoundment consist of up to 20 m of silty sand and gravel, with cobbles overlying bedrock.

The area is underlain by bedrock strata generally paralleling the valley trend, i.e., striking in the direction of the valley. The bedrock consists of an interlayered sequence of volcanoclastic (rhyolite and quartz feldspar) and carbonaceous/argillic sediments, overlain with basalt. The iron formation, which hosts the ore zone, trends northwest-southeast throughout the project area.

2.1.2 Seismicity

The most seismically active region near the Wolverine Project area is along the plate boundaries in the coastal and offshore area. The most significant inland seismicity occurs along segments of the Denali fault zone system, where the seismicity rate is an order of magnitude lower than that in the coastal region. The region between the Denali and Tintina systems is relatively aseismic, with relatively few and small earthquakes.

Data on recent earthquakes that occurred within about 600 km from the project site (61.41°N and 130.09°W) from September 1899 to December 2005 was extracted from the Canadian EPB/GSC/PGC database and are shown on Figure 2.1. No earthquakes with magnitude greater than 5 have occurred within 200 km from the site. However, a magnitude 5 event did occur about 28 km northwest of the project site with a focal depth of 5 km on May 12, 1999.

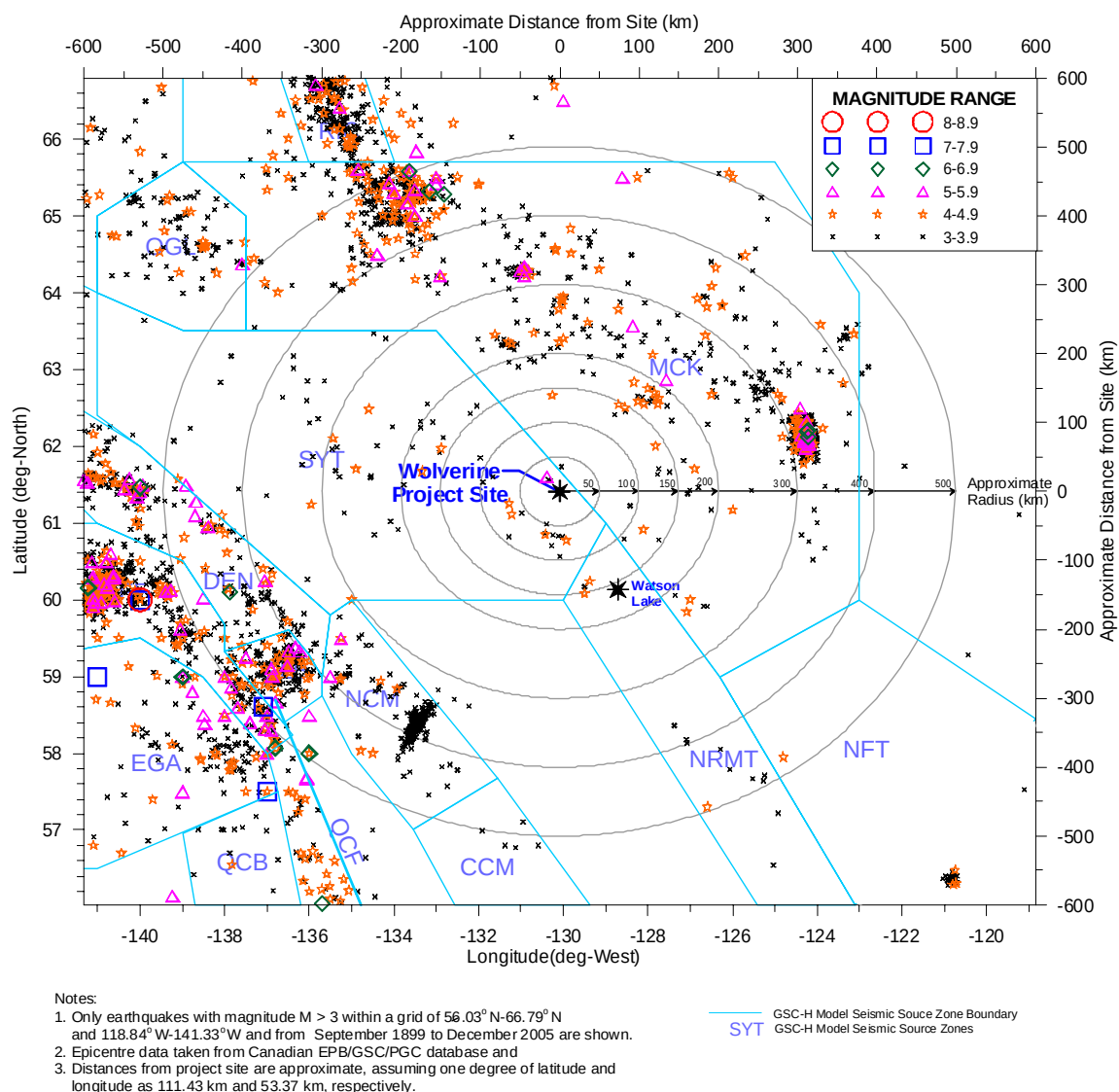
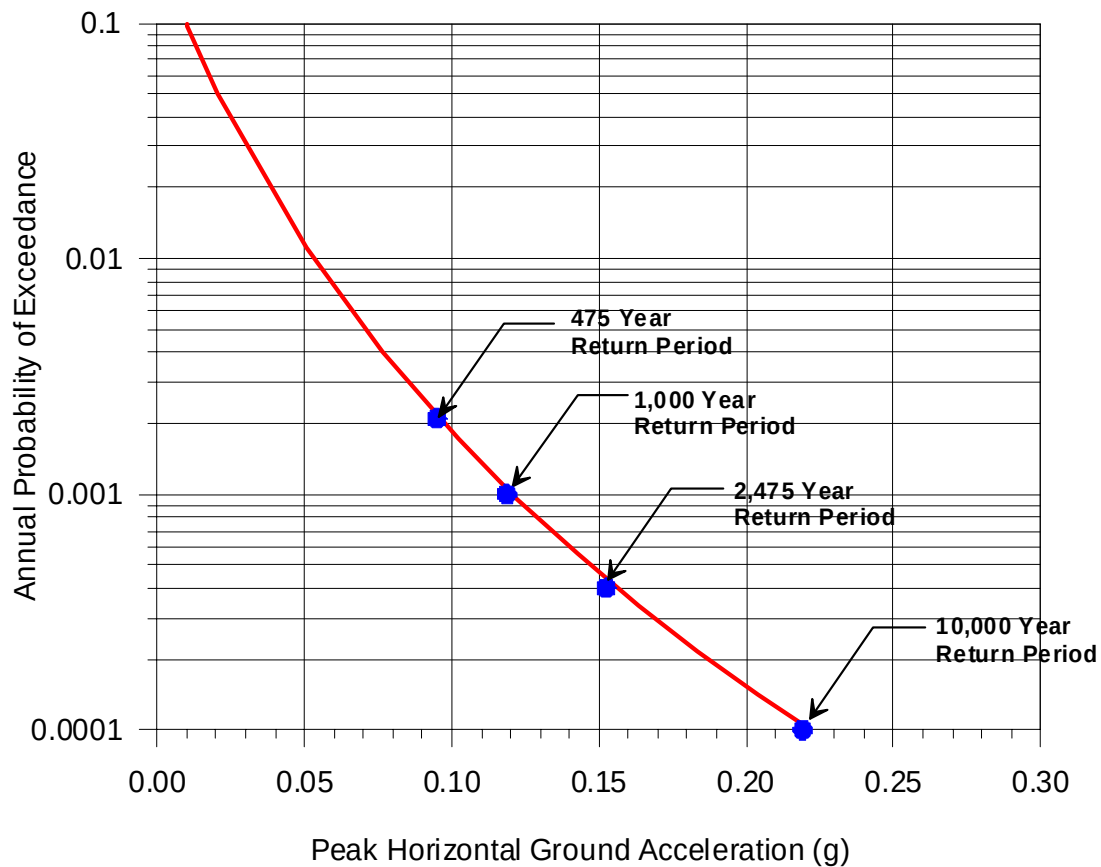


Figure 2.1 Location Map of Recent Regional Epicentres

The probabilistic seismic hazard assessment has been determined using both the GSC-H and GSC-R seismic source zonal models developed by the Geological Survey of Canada for the new National Building Code of Canada 2005 (Adams and Halchuk 2003). The model incorporated the work conducted by Atkinson (2004) for a site-specific seismic hazard analysis for Faro, Yukon (62.2°N and 133.2°W). In that analysis, an apparent linear alignment of seismicity in the region along the Tintina Trench fault system was grouped into a Tintina seismic source zone. This Tintina source zone was incorporated in the model for computing site peak horizontal acceleration as shown in Figure 2.2 and Table 2.1.

Table 2.1 Probabilistic Evaluation of Peak Horizontal Ground Acceleration at Project Site

ANNUAL PROBABILITY OF EXCEEDANCE	RETURN PERIOD (years)	PEAK GROUND ACCELERATION PGA (g)	
		GSC-H 2005 MODEL	GSC-H 2005 MODEL WITH TINTINA SOURCE ZONE
0.0021	475	0.08	0.097
0.001	1,000	0.10	0.12
0.00040	2,475	0.14	0.15
0.0001	10,000	0.20	0.22

**Figure 2.2 Peak Horizontal Ground Acceleration at Various Probability of Annual Exceedance**

Two earthquake scenarios were considered for the deterministic evaluation for the site peak horizontal ground acceleration as shown in Table 2.2: a local earthquake at the site with magnitude $M=6$; and an earthquake at the Tintina Fault with magnitude $M=7.2$. The deterministic assessment was used to assess the potential for liquefaction of the foundation soils, as discussed in Section 7.2 of this report.

Table 2.2 Deterministic Evaluation of Peak Horizontal Ground Acceleration at Project Site

EARTHQUAKE SCENARIO	MAGNITUDE	EPICENTRAL DISTANCE (km)	FOCAL DEPTH (km)	PEAK GROUND ACCELERATION PGA (g)
Local	6	0	2.9	0.34
Tintina Fault	7.2	53	2.9	0.11

2.2 Hydrology and Groundwater

The estimated mean annual precipitation for the Wolverine Minesite is 570 mm, and the estimated mean annual evaporation rate is 400 mm. Average snowpack for the minesite is estimated to be 175 mm snow-water equivalent.

Table 2.3 presents the ratios of dry and wet year annual precipitations and mean monthly runoff flows, to the average mean annual precipitation and mean monthly flows, respectively (Madrone 2006). Additional hydrology data is provided in Appendix III Part I.

Table 2.3 Ratios of Dry and Wet Year Annual Precipitations and Mean Monthly Runoff Flows

EVENT	RATIO							
	200 yr dry	100 yr dry	10 yr dry	AVERAGE	10 yr wet	100 yr wet	200 yr wet	1,000 yr wet
Annual Precipitation	0.586	0.622	0.762	1	1.159	1.388	1.441	1.561
Mean Monthly Runoff flow	0.611	0.641	0.779		1.248	1.524	1.60	1.773

Table 2.4 presents the monthly precipitation distribution and the monthly runoff distribution. A summary of monthly flows for various site locations are shown in Table 2.5.

Table 2.4 Monthly Precipitation and Runoff Distribution

MONTH	% PRECIPITATION	% FLOW
January	7	0
February	6	0
March	5	0
April	4	1
May	7	19
June	11	35
July	14	17
August	11	9
September	10	9
October	9	6
November	8	3
December	8	1

Table 2.5 Expected Mean Monthly and Annual Flows (m³/s) for Selected Locations

STATION	W31	W16	W12	W44	W14
MONTH	GO CREEK AT AIRSTrip (4.7 km ²)	GO CREEK AT HAWKOWL CREEK (10.2 km ²)	GO CREEK AT MONEY CREEK (36.5 km ²)	TAILINGS DAM CATCHMENT (1.05 km ²)	MONEY CR. DOWNSTREAM OF GO (238 km ²)
Jan	0.007	0.017	0.065	0.0015	0.479
Feb	0.007	0.016	0.061	0.0015	0.435
Mar	0.007	0.015	0.055	0.0014	0.392
Apr	0.010	0.021	0.079	0.0021	0.537
May	0.048	0.108	0.410	0.0099	2.938
Jun	0.045	0.111	0.490	0.0079	4.324
Jul	0.034	0.083	0.352	0.0062	2.970
Aug	0.021	0.050	0.212	0.0038	1.772
Sep	0.020	0.047	0.198	0.0036	1.642
Oct	0.018	0.044	0.180	0.0035	1.450
Nov	0.013	0.030	0.119	0.0025	0.906
Dec	0.009	0.021	0.083	0.0018	0.631
Year	0.022	0.051	0.207	0.0041	1.643

In the vicinity of tailings impoundment area, the groundwater table is generally sloping southwest following the trend of the topography. Near the downstream end of the impoundment basin at TH05-8 and MW05-7 (refer to Drawing D-3002), the piezometric pressure in the bedrock is slightly artesian (few meters above ground) and the water table rises, with the topography, towards the dam abutments. In general, the groundwater table in the overburden is slightly lower than that in the bedrock except at TH05-9. The groundwater table exhibits seasonal variation, reaching highest elevation after spring runoff season.

Table 2.6 summarizes piezometric elevations monitored during September 7-9, 2005 at test hole locations and monitoring wells installed in the general tailings impoundment area.

Table 2.6 Summary of Piezometric Elevations in Tailings Impoundment Area

MONITORING WELL OR TEST HOLE	GROUND EL. (m)	TOP OF RISER PIPE ABOVE GROUND (m)	DEPTH TO WATER FROM TOP OF RISER PIPE (m)	PIEZOMETRIC EL. (m)	PRESSURE GAUGE ABOVE GROUND (m)	ARTESIAN PRESSURE (ABOVE PRESSURE Gauge el.)
MW05-6A (Bedrock)	1348	0	6.93	1341.07		
MW05-6B (Overburden)	1348	0.12	7.32	1340.8		
MW05-7A (Bedrock)	1286	0.46	0.17	1286.29	0.53	-
MW05-7B (Overburden)	1286	0.37	0.5	1285.87		
TH05-7A (Bedrock)	1305	0.53	10.26	1295.27		
TH05-8A (Bedrock)	1290	0.18	-	>1290.25	0.25	<1 psi
TH05-8B (Overburden)	1290	0.15	0.46	1289.79	0.22	-
TH05-9A (Bedrock)	1303	0.25	10.71	1292.54		
TH05-9B (Overburden)	1303	0.3	3.82	1299.48		
TH05-10A (Bedrock)	1308	0.25	1.35	1306.9		
TH05-10B (Overburden)	1308	0.25	3.37	1304.88		

Baseline groundwater flow rates for the region have been estimated on the basis of a 10% infiltration rate, over the hydrologic catchment area, and an annual precipitation of 570 mm, and are summarized in Table 2.7.

Table 2.7 Summary of Baseline Groundwater Flow for Selected Locations

LOCATION	CATCHMENT AREA (km ²)	GROUNDWATER FLOW (m ³ /s)	PREDICTED WINTER BASEFLOW (m ³ /s)
Go Creek, Near Dam	10	0.015	0.01
W – 12 (Go Creek)	36.5	0.060	0.083
W – 14 (Money Creek)	238	0.420	0.54

The main groundwater aquifer is the 10 m to 20 m thick overburden overlying bedrock within the Go Creek Valley. Downstream of Go Creek valley, which appears to be a hanging valley, the morphology changes to a broader terraced valley where much thicker deposits of post glacial outwash soils provide a larger groundwater flow regime.

2.3 Water Quality

Surface and groundwater quality data is included in Appendix III and the main observations are summarized below.

Surface Water Quality in the Tailings Impoundment Area

Baseline surface water quality samples (n=13) were collected from October 2005 to August 2007 from Station W44, which is located on a small stream that drains through the tailings impoundment area. The data indicate that water quality in this small stream is dominated by meteoric waters of low hardness, low alkalinity and circum-neutral pH. The water is low in sulphate, nutrients and metal content is generally low, with slightly higher concentrations observed during peak snow melt periods when TSS levels are elevated. Data is provided in Appendix III Part 3.

Groundwater

Baseline groundwater quality data was collected from 2005 to 2008 at the tailings impoundment area monitoring wells: MW05-2A, MW05-2B, MW05-6A, MW05-6B, and MW05-7B (refer to Drawing D-3002) and data is included in Appendix III Part 3. Two new monitoring wells (MW08-13 and MW08-14), were installed in late October 2008 and water quality data from MW08-13 is provided in Appendix III. Sampling was not conducted at MW08-14 as it was frozen. The results indicate that the groundwater has a neutral to slightly alkaline pH and low conductivity values. The groundwater is generally calcium-bicarbonate (Ca-HCO₃) type water, which is associated with glacio-fluvial sediments and ground moraine.

3. DESIGN CRITERIA

The Wolverine Project tailings dam is designed to national standards, using the Canadian Dam Association – Dam Safety Guidelines (CDA, 2007). The main design criteria are summarized in Table 3.1 and discussed in the following sections.

Table 3.1 Summary of Tailings Dam Design Criteria

ITEM	CRITERIA
Storage Capacity: Tailings	2.03 Mt @ 1.6 t/m ³ = 1.267 Mm ³
Flood Management during Operation: Diversion of upland catchment Flood storage in impoundment Flood discharge	1: 100 year peak flow 200 year return period (approx. 0.3 m of pond rise) + seasonal storage of water Exceeding 1:200 year peak flow, no dam overtopping during 1:10,000 year
Seismic Return Period During Operation and Closure	10,000 year return period (PGA = 0.22g)
Geotechnical Factors of Safety during operations: Static Pseudo-static, seismic coefficient = 0.125 (a = 0.125 g)	FS = 1.3 (end of construction) and FS = 1.5 (operational) FS = 1.1 (note FS = 1.0 required by CDA 2007)
Environment - Operations Tailings pond Allowable seepage flows out of impoundment	Saturated tailings to prevent acid rock drainage Effluent treated until water quality meets discharge limits Seepage < 0.5 L/s. Contaminated seepage from the TSF, if present, will be collected and pumped to tailings pond
Closure Flood Handling Diversion Ditches Spillway Geotechnical stability Safety Factor Static Pseudo-static, seismic coefficient = 0.125 (a = 0.125 g) Geochemical stability Allowable Seepage	Diversion ditches to be decommissioned 1:10,000 year return period routed peak flow FS = 1.5 FS = 1.15 (Seed, 1979) (note FS = 1.0 required by CDA 2007) 0.5 m minimum water cover to maintain saturation to prevent acid rock drainage. Seepage < 0.5 L/s . Effluent treated until water quality meets discharge limits

3.1 Dam Classification Assessment

The recent Canadian Dam Association Dam Safety Guidelines (CDA 2007) were adopted to confirm the classification of the tailings facility for seismic and flood protection criteria. The dam classification is primarily based on the consequence of failure and the guideline is summarized in Table 3.2. To assess the potential consequence of failure, the industry practice is to conduct a “dam break” assessment, which assumes that the dam could fail and determines what the potential run-out of tailings and water could be.

The selected dam classification, based on the dam break analysis presented in Section 3.1.1, is “High” to “Very High”, and the criteria for Very High has been selected for design. The use of the Very High rating provides additional security for the long term performance of the tailings facility after closure.

Table 3.2 Dam Classification Guideline (CDA 2007)

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

Note 1. Definitions for population at risk:

None - There is no identifiable population at risk, so there is no possibility of loss of life other than through unforeseeable misadventure.

Temporary - people are only temporarily in the dam-breach inundation zone (e.g., seasonal cottage use, passing through on transportation routes, participating in recreational activities).

Permanent - The population at risk is ordinarily located in the dam-breach inundation zone (e.g., as permanent residents); three consequence classes (high, very high, extreme) are proposed to allow for more detailed estimates of potential loss of life (to assist in decision-making if the appropriate analysis is carried out).

Note 2. Implications for loss of life:

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

3.1.1 Dam Break Assessment

The tailings facility is located in a remote area of Yukon and, except for a campsite on Frances Lake, there are no major population centres or commercial and industrial activities downstream of the impoundment. In the event of an incident at the tailings impoundment, the discharge from the facility would enter Go Creek and then Money Creek. Money Creek discharges into Frances Lake, which is located east of the mine about 40 km downstream of the tailings impoundment. The most significant infrastructure crossing along this flow path is the Robert Campbell Highway over Money Creek, just before the creek enters Frances Lake.

The expected peak flood outflow from the tailings pond occurring as a result of a dam breach was estimated using charts compiled by MacDonald and Monopolis (1984), and by Wahl (1998), based on dam failure case studies. It should be noted that these charts are based on failures of water storage dams. Tailings stored in the tailings ponds have higher viscosity than water and, in the event of a tailings dam failure, usually not all the tailings are released from the pond. Furthermore, tailings tend not travel as far downstream as water. The estimated total storage volume of approximately 1.45 million m³ (Mm³) at closure in the tailings pond will contain approximately 1.27 Mm³ of tailings.

For estimating the peak discharge resulting due to a breach at the Wolverine tailings dam, the following simplifying assumptions were made:

- The total mobilized volume was taken as 100% of the free water in the pond (0.15 Mm³) plus 30% of the stored tailings (0.40 Mm³); and
- The tailings were assumed to behave the same as water, i.e., the entire volume of water plus the 30% of tailings is released from the pond and all of it travels downstream as if it was water.

The analysis of data presented by United States Congress of Large Dams (USCOLD) on tailings dam failures (USCOLD 1995) indicates that, on average, only 30% of the tailings are released from the impoundment as a result of a dam failure. Since the charts being used are based on failures of water storage dams where the entire storage volume above the dam foundation would be released, only 30% of the total tailings are assumed to be part of the storage volume for the dam break analysis of the tailings dam.

The estimated peak outflow released from the dam is 1,850 m³/s, which is expected to attenuate as the flood wave travels downstream. The downstream flows were estimated using the attenuation charts prepared by Petrascheck and Sydler (1984), and the results are summarized in Table 3.3.

Table 3.3 Estimated Dam Breach Flood Peaks Downstream of Tailings Dam

LOCATION	DISTANCE FROM DAM (km)	ESTIMATED PEAK FLOW (m ³ /s)
At Wolverine Tailings Dam	0	1850
Confluence of Go Creek and Money Creek	5	1700
Robert Campbell Highway and Frances Lake	40	1100

The assumptions made and the charts used herein provide approximate estimates of expected dam breach discharge and downstream attenuation.

As Table 3.3 indicates, little attenuation of the flow is expected by the time the flood peak reaches Money Creek, but it is expected to decrease to about 60% of the original flow by the time the flood peak reaches Robert Campbell Highway and Frances Lake. A comparison of the estimated flood peak resulting from a breach at the tailings dam with the natural stream flows indicates that the dam breach flood peak will be about 150 times the naturally expected 200-year peak flow in Go Creek above Money Creek, and it will be about 10 times the naturally expected 200-year peak flow in Money Creek at the Robert Campbell Highway. The expected attenuation of the flood peak presented in Table 3.3 is based on the assumption that the tailings released from the dam migrate downstream the same as water. In reality, the tailings will not be as mobile and a substantial portion of the tailings are expected to be deposited close to the dam.

The potential consequences of the dam failure, that support the dam rating of “Very High”, are summarized below for the key indicators included in Table 3.2.

Populations at Risk and Loss of Life

There are no permanent populations that would be at risk and loss of life would be limited to temporary personnel in the vicinity. Therefore, The “Population at Risk” classification is “Significant”.

Environmental and Cultural Effects

The flood flow would damage and have a negative impact on the aquatic habitat in the flow path. The tailings released from the pond as well as those left in the pond are expected to become acid generating, if left exposed to atmosphere for many years, and would remain acid generating indefinitely until the oxidation process is complete. The potential effect could be significant loss or deterioration of *important* fish or wildlife habitat. Restoration or compensation would be highly possible. Therefore the dam classification is “High”

Infrastructure and Economics

There is limited infrastructure and no industrial facilities downstream of the dam. The potential effect of a dam break would be limited to damage to the Robert Campbell Highway and Money Creek bridge. The potential infrastructure and environmental damage could be substantial and could require recovery of all of the tailings and construction of a new containment facility. Given the potential for large socio-economic and environmental damage, as well as substantial clean-up costs, the tailings impoundment is classified as a “Very High” consequence facility.

3.2 Earthquake, Flood and Seepage Criteria

Recommended design criteria (CDA 2007) for various dam classifications are summarized in Table 3.4 and the selected criteria are discussed in the following sections.

Table 3.4 Inflow Design Flood and Suggested Design Earthquake Levels for Consequence Classes (CDA 2007)

DAM CLASS [NOTE 1]	AEP	
	IDF [NOTE 2]	EDGM [NOTE 3]
Low	1/100	1/500
Significant	Between 1/100 and 1/1000 [note 4]	1/1,000
High	1/3 between 1/1000 and PMF [note 5]	1/2,500
Very High	2/3 between 1/1000 and PMF [note 5]	1/5,000 [note 6]
Extreme	PMF [note 5]	1/10,000 [note 6]
Acronyms: AEP, annual exceedance probability; EDGM, earthquake design ground motion; IDF, inflow design flood; PMF, probable maximum flood. Note 1. As defined in Table 2-2, Dam Classification Note 2. Extrapolation of flood statistics beyond 1/1000 year flood (10^{-3} AEP) is discouraged. Note 3. AEP levels for EDGM are to be used for mean rather than median estimates of the hazard. Note 4. Selected on the basis of incremental flood analysis, exposure, and consequences of failure. Note 5. PMF has no associated AEP. The flood defined as “1/3 between 1/1000 year and PMF” or “2/3 between 1/1000 year and PMF” has no defined AEP. Note 6. The EDGM value must be justified to demonstrate conformance to societal norms of acceptable risk. Justification can be provided with the help of failure modes analysis focused on the particular modes that can contribute to failure initiated by seismic event. If the justification cannot be provided, the EDGM should be 1/10,000.		

Design Earthquakes

The tailings facility is classified as “Very High” consequence and the CDA recommendation seismic guideline is for an earthquake return period of 1:5000 years. As per *QML-0006 Condition 16.2*, the tailings facility must withstand a minimum of a 10,000 year return design earthquake, and has been designed to this standard. For the seepage collection dam, the recommended return period is 475 years to reflect the low consequence of failure and the short service life.

Design Floods

The design flood criteria selected for various components of the water management facilities associated with the tailings impoundment are summarized in Table 3.5. The corresponding dam safety criteria for a “Very High” consequence dam is “2/3 between 1/1,000 and PMF” and a criterion of 10,000 year return period has been used, as per requirements of *QML-0006 Condition 16.2*.

The expected operating life of the mine was also taken into account in the selection of the design floods for temporary facilities, such as the surface runoff diversion ditches, the starter dam emergency spillway and the seepage collection system. During operations all facilities related to

the tailings impoundment will be monitored, and personnel, equipment and materials will be readily available in the event that remedial measures are required. Therefore, lower design criteria for temporary facilities have been selected.

Table 3.5 Selected Flood Design Criteria for Water Management Facilities

FACILITY	MIN. DESIGN FLOOD RETURN PERIOD (YEARS)	FLOOD STORAGE & FREEBOARD ALLOWANCE	COMMENTS
Surface water diversion ditches	100	-	-
Starter Dam Emergency Spillway	10,000	Storage for 200 year flood	Assume that upland surface water diversion ditches have failed. Spillway also must be able to pass the 10,000-year flood without overtopping the dam.
Tailings Dam Closure Spillway	10,000	-	Assume that upland surface water diversion ditches have been decommissioned.
Seepage Collection Pond Spillway	100	-	Assume that upland surface water diversion ditch is functioning.
Tailings Pond flood storage allowance below spillway level during mine operation	-	0.3 m	For routing of design flood through the tailings pond after closure, the initial water level is assumed to be at the spillway level, i.e., flood storage allowance is assumed to be zero.
Tailings Dam Spillways	-	1.5 m	Minimum freeboard is defined as the difference in elevation between the top of the dam without camber and the maximum pond level that would result from routing the IDF through the reservoir. This is approximately 2.0 m above spillway invert.

Note: IDF = Inflow Design Flood

Design “Allowable” Seepage Assessment

This section presents the design basis for determining the “allowable” seepage rate from the impoundment. The assessment is based on determining the fate and transport of potential contaminants from the impoundment to the receiving environment. During operations, seepage through the dam will be collected with a seepage collection ditch and pond for return to the impoundment, as required. In addition, a portion of seepage from the impoundment (potentially 25% of total seepage) may bypass the seepage collection system and mix with the regional groundwater flow. The groundwater flow system downstream of the seepage collection dam can be characterized as follows:

- In the immediate vicinity of Go Creek and the tailings impoundment, the groundwater flow system within the glaciofluvial soils overlying bedrock could have an estimated groundwater flow of 15 L/s.
- The area near W12, upstream of the confluence of Money Creek and Go Creek appears to have a similar overburden cover as near the dam and the estimated groundwater flow is 60 L/s.
- In the vicinity of W14, downstream of the confluence of Money Creek and Go Creek, the geomorphology changes to a terrace glacial outwash regime with a thicker overburden aquifer, which could have an estimated groundwater flow of 420 L/s.

A portion of the groundwater will report to the deeper groundwater system and flow towards Go Creek and to the groundwater regime in the vicinity of W14.

The criteria for allowable seepage was estimated on the basis of a simple dilution model, using predicted concentrations of cadmium, selenium and zinc in the impoundment and the potential seepage flows from the impoundment. In addition, a factor of 10% has been applied to account for attenuation and adsorption, which will occur along the flow path. Table 3.6 summarizes the concentrations of cadmium, selenium and zinc in the tailings/DMS float pore water, baseline values at W14 and “tolerable” seepage based on the groundwater “dilution” flow and a 10% factor for adsorption. The pore water chemistry is primarily controlled by the process water chemistry during operations (see Section 5.3). Supporting data includes shake flask extraction tests and aging tests of the tailings supernatant.

Table 3.6 Summary of Concentrations of Parameters of Potential Concern and “Tolerable” Seepage Rates

PARAMETER OF POTENTIAL CONCERN	CCME LIMIT (mg/L)	BASELINE CONCENTRATION (mg/L)	IMPOUNDMENT PORE WATER - RANGE (mg/L)	“TOLERABLE” SEEPAGE (L/s)* W-14	“TOLERABLE” SEEPAGE (L/s)* W-12
Cadmium	0.000 017	0.000 05	0.01	20	3
Selenium	0.001	<0.001	1	40	6
Zinc	0.03	<0.005	1 to 5	50	7

Notes:* “Tolerable” seepage based on groundwater dilution flow at W-12 and W-14, with 10% adsorption factor.

Based on the above, a “tolerable” seepage criterion could be approximately 5 L/s, however if adsorption is discounted, the “tolerable” seepage could be 0.5 L/s and, accordingly, a conservative design criteria of <0.5 L/s has been adopted. However, a geosynthetic liner will be used to significantly reduce potential seepage flow to orders of magnitude lower than required. As described in Section 6.3, the seepage analysis indicates that the leakage rate out of the impoundment should be on the order of 0.00001 L/s, which is negligible.

4. GEOTECHNICAL CHARACTERIZATION

4.1 Site Investigations

Geotechnical site investigations for the tailings facility were carried out from July to September 2005. The investigations included 6 drill holes, 2 groundwater monitoring wells and 23 test pits. Testing results, and drill hole and test pit logs are included in Appendix I.

4.2 Laboratory Testing of Construction Materials

Geotechnical laboratory testing included visual classification, moisture content, and gradation tests for overburden samples retrieved from field investigations. Additional standard Proctor compaction tests, triaxial permeability and shear strength tests were carried on the potential borrow materials for the dam fill and on the tailings. These results are summarized in Table 4.1, and test results are included in Appendix I.

Table 4.1 Summary of Engineering Properties Determined from Laboratory Tests on Dam Fill and Tailings

TYPE OF MATERIAL	UNIT WEIGHT γ_{dry} (kN/m ³)	EFFECTIVE SHEAR STRENGTH		HYDRAULIC PERMEABILITY k (m/s)
		Cohesion c' (kPa)	Friction Angle ϕ' (degree)	
Dam Fill	~2.1	0	37	3 E-8
Tailings	~1.85	0	34	7 E-8

Test results for dam fill and tailings were obtained by consolidated-undrained triaxial shear tests with permeability measurement after consolidation and pore pressure measurement during shear. The consolidation stresses used in the laboratory were selected to simulate the field condition.

The tailings testing carried out in 2006 was on a 50:50 mixture of F11 and F12 (Zn, Rougher Scavenger Tail) and F23 and F32 (Zn 1st Cleaner Scavenger Tail). Additional tests were carried out in 2008 on a mixture of 80% rougher tailings and 20% cleaner tailings and the test results are summarized in Table 4.2.

Table 4.2 Summary of Tailings Laboratory Test Results

TEST	TEST RESULTS
Specific gravity	S.G = 3.7 and 3.9
Gradation	% finer than 75 micron = 83% to 92%
5 day jar settling test	Settled density of 71%, equivalent to 1.45 t/m ³
Consolidation	Density at final stress state (75 kPa average) = 80% solid by weight, equivalent to 1.8 t/m ³ Permeability $k < 10^{-8}$ m/s Coefficient of consolidation: $C_v = 10^{-2}$ cm ² /s

Based on the settling and consolidation tests, an average in situ density of 1.6 t/m³ has been used for storage volume calculations.

5. GEOCHEMICAL CHARACTERIZATION

Geochemical assessments were conducted on tailings, dam construction material, and tailings supernatant water. A summary is provided below and the databases included in Appendix II. In addition, an update on the humidity cell testing overseen by Marsland Environmental Associates to September 2008 is included in Appendix II.

5.1 Tailings Geochemistry

To assess the geochemical characteristics of the tailings, four ore composite types were prepared and examined. The four samples were prepared with lock cycle tests (LCT) carried out to simulate the milling process, which produces three tailings sub-streams: ~2% pre-float concentrate (PFC), 88% rougher tails (Ro), and 10% cleaner scavenger tails (CS). The composite ore samples include the following:

- Combined overall diluted ore composite (Comb OD Comp) tailings: Combines the three tailings streams generated by using ore and dilution rock from both Wolverine and Lynx ore zones (LCT3).
- Combined overall ore composite (Comb Overall Ore Comp) tailings: Combines the tailings generated from using only ore from the Wolverine and Lynx ore zones, and does not include any dilution rock. The sample is a composite of two lock cycle tests (LCT1 & LCT2).
- Combined Wolverine composite ore with dilution rock (Comb Wolv D Comp) tailings: Combines all three tailings streams generated from ore with dilution rock from the Wolverine ore zone (LCT4).
- Combined Lynx ore with dilution rock composite (Comb Lynx D Comp) tailings: Combines all three tailings streams generated from ore with dilution rock from the Lynx ore zone (LCT5).

Mineralogy

Mineral assemblage percentages for the four composite tailings samples were assessed using optical microscopy on the four samples and the results are summarized in Table 5.1.

In addition, quantitative phase analysis using x-ray diffraction (XRD) with Rietveld refinement was carried out, to identify the carbonate and sulphide species. The results suggest the onset of acidic conditions may have the potential to release metal (loids) from mineral phases, likely from the sulphide phases confirmed by mineralogical characterization. Furthermore, elements that are mobile under neutral pH conditions (e.g., Se, Zn, etc.) may have the potential to be released.

Table 5.1 Mineral Assemblages and Modal Abundances by Optical Microscopy (wt. %)

MINERAL	COMB OD COMP	COMB OVERALL ORE COMP	COMB WOLV D COMP	COMB LYNX D COMP
Pyrite	53.1	60.1	38.3	60.3
Quartz	20.9	17.1	26.7	16.7
Carbonate	10.5	10.6	14.2	11.6
Muscovite	11.9	5.2	14.3	8.9
Chlorite	1.0	1.1	0.9	0.0
Sphalerite	1.1	1.6	1.3	1.8
Pyrrhotite	0.5	1.6	2.1	0
Amphibole	0	0.6	0.5	0
Arsenopyrite	0.3	0.8	0	0.3
Pyroxene	0.2	0.3	1.5	0.0
Chalcopyrite	0.5	0.4	0.2	0.0
Galena	0.0	0.4	0	0.8
Biotite	0	0.2	0	0
Magnetite	0	0.1	0	0
Total	100	100	100	100

Acid Base Accounting

The results of the ABA tests carried out on all of the tailings sub-streams are summarized in Table 5.2. All samples have high sulphide content and a low Neutralization Potential Ratio (NPR) of less than one, and are classified as having a high potential for producing acid rock drainage. However, the samples have enough NP (carbonate neutralization potential of 20 kg to 100 kg CaCO₃/t) to remain at a near-neutral pH, when initially exposed to oxygen. This is confirmed with the relatively high paste pH values of 6.9 to 7.85. In addition, most samples indicate the presence of non-carbonate neutralization potential, possibly from the muscovite, clinocllore and kaolinite, indicated by the mineralogical analysis.

Shake Flask Tests

The results of the shake flask extraction tests from the four combined tailings samples are included in Appendix II. The shake flask extraction tests show that the final pH was near neutral to slightly alkaline and ranged from pH 7.3 to pH 8.4. The initial exposure of tailings to atmospheric conditions should result in minimal trace metal(loid) releases, except for the Combined Overall Ore Composite tailings, which shows Cd (0.134 mg/L), Se (0.20 mg/L), Tl (0.022 mg/L) and Zn (6.87 mg/L) releases. The major ions Ca^{2+} , Na^{+} , Mg^{2+} , Mn^{2+} , Cl^{-} , SO_4^{2-} and thiosalts also show releases, most likely due to the dissolution of gypsum (CaSO_4) and other salts and sulfosalts present at low abundances.

Table 5.2 Tailings Acid Base Accounting Results for Tailings Sub-Streams

PARAMETER	UNITS	OVERALL COMP LCT2 RO	OVERALL COMP LCT2 CL SC	OVERALL COMP LCT2 COMB	OD RO	OD CL SC	OD COMB	WOLV RO	WOLV CL SC	WOLV COMB	LYNX RO	LYNX CL SC	LYNX COMB
Paste pH	-	7.79	7.26	7.42	7.85	6.69	7.27	7.68	6.91	7.35	7.67	6.45	7.36
Fizz Rate	-	3	3	3	3	2	2	3	2	2	3	2	2
Total S	%S	22.3	39.5	29.2	17.5	43.0	26.6	12.3	39.4	19.7	23.7	48.4	31.2
Acid Leachable SO ₄ ²⁻	%S	1.07	6.98	2.51	0.02	1.18	2.04	0.45	1.63	1.74	0.92	6.45	0.74
Sulphide S	%S	20.2	28.5	25.0	15.7	39.0	22.9	10.1	34.1	15.7	20.4	39.4	27.8
Insoluble SO ₄ ²⁻	%S	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Organic S	%S	1.10	4.00	1.73	1.72	2.83	1.67	1.79	3.64	2.34	2.35	2.61	2.68
AP	kg CaCO ₃ /t	631	891	781	491	1220	715	315	1070	489	638	1230	869
Sobek NP	kg CaCO ₃ /t	103	41.8	72.8	114	21.9	82.5	119	32.1	94.6	111	20.9	49.4
Net NP	kg CaCO ₃ /t	-528	-849	-708	-377	-1198	-632	-196	-1038	-395	-526	-1209	-820
Sobek NP/AP	-	0.16	0.05	0.09	0.23	0.02	0.12	0.38	0.03	0.19	0.17	0.02	0.06
Carb NP	kg CaCO ₃ /t	72.6	23.4	59.4	91.4	20.5	98.3	105	24.6	106	94.4	22.1	52.3
Carb NP/AP	-	0.11	0.56	0.08	0.19	0.02	0.14	0.33	0.02	0.22	0.15	0.02	0.06
TOC	%C	na	na	na	0.54	0.43	0.62	0.69	0.75	0.98	0.49	0.25	0.48
TIC	%C	na	na	na	1.32	0.11	0.94	1.39	0.14	1.2	1.30	0.21	0.79
C(t)	%C	1.72	0.87	1.48	1.86	0.54	1.56	2.07	0.88	2.14	1.79	0.46	1.27

na= not analyzed

Humidity Cell Testing

Four humidity cells were initiated in mid 2005 and results are included in Appendix II. Two humidity cells containing Overall Ore Composite (OC) and Overall Ore Diluted (OD) samples are operational and an updated report to September 2008 is included in Appendix II. A summary illustrating the changes to water quality during the test period (using week 15 and week 160 as indicator weeks) is presented in Table 5.3 and the main observations of the testing to date include:

- The pH has remained circum-neutral over other the period except for a few anomalous spikes, which appear to be due to variability in reaction rates within the samples;
- The sulphate production rates have shown a slight decline over the testing period and both samples have similar sulphate loading rates (approximately 100 mg/kg/wk);
- A conservative interpretation of potential time to sulphide depletion in the laboratory is 3 years to 10 years for the OD and OC samples respectively, which could equate to >25 years in natural conditions; and
- The elemental loading rates for soluble selenium and zinc appear relatively constant, although the zinc loading rate for the OC samples had a zinc loading rate that declined, then increased slightly from week 90 to week 150. Average loading rates are approximately 2 mg/kg/wk for zinc and 0.08 mg/kg/wk for selenium. Typical Se concentrations in the leachate for week 160 were in the order of 0.05 mg/L to 0.1 mg/L.

The testing indicates that the lag time for acid generation will be many years and that elemental loading of zinc and selenium, via leachates, could continue for a number of years.

Table 5.3 Typical Humidity Cell Leachate Concentrations for Combined OC Composite and Combined OD Tailings

PARAMETER	UNITS	OC TAILINGS		OD TAILINGS	
		Leachate concentrations (selected Weeks)			
		Week 15	Week 160	Week 15	Week 160
Leachate Volume	ml	401	498	431	424
pH	units	6.87	6.67	6.97	6.72
Alkalinity	mg CaCO ₃ /L	7	7	11	5
Acidity	mg CaCO ₃ /L	163	3	434	1
Conductivity	μS/cm	551	564	1540	651
SO ₄ ²⁻	mg/L	250	270	890	270
Cl	mg/L	0.1		0.1	
F	mg/L	0.08		0.14	
NO ₃ ⁻	mg N /L	0.025		0.025	
NH ₃ + NH ₄ ⁺	mg N /L	0.5		0.2	
Thiosalts	mg S ₂ O ₃ /L	156	5	384	5
CN _(T)	mg/L	0.005		0.001	
CNO	mg/L	0.05		0.5	
CNS	mg/L				
Hg	μg/l	0.05		0.05	
Ag	mg/L	0.0025	0.000005	0.0025	0.000005
Al	mg/L	0.005	0.005	0.005	0.0027
As	mg/L	0.006	0.003	0.017	0.0037
Cd	mg/L	0.0935	0.197	0.0677	0.0456
Cu	mg/L	0.0025	0.0051	0.0031	0.0050
Pb	mg/L	0.019	0.0171	0.0026	0.00188
Sb	mg/L	0.025	0.00291	0.025	0.00124
Se	mg/L	0.285	0.112	1.18	0.147
Tl	mg/L	0.0075	0.0035	0.014	0.00232
Zn	mg/L	4.04	8.19	3.01	2.29

Note: All metals are dissolved concentrations

5.2 Borrow for Dam Construction Materials

Borrow materials from within and adjacent to the impoundment will be used for constructing the earthfill tailings dam. Geochemical tests, including shake flask tests and acid base accounting (ABA) tests, were carried out for samples collected from the test pits located in the impoundment and from the project borrow area located northwest of the tailings facility (see Drawing D-3002), and results are included in Appendix II. These tests indicate that the borrow materials have a low leaching potential, and are not potentially acid generating.

5.3 Supernatant Water Chemistry

The tailings supernatant water quality acquired from the lock cycle test work is summarized in Table 5.4. During operations, variations outside of this range may occur with fluctuations or alterations in reagent dosage during ore processing. Certain dissolved parameters (e.g., Na, K, Cl and SO₄) may tend to re-circulate through the mill in the reclaim water. Eventually these parameters will reach a re-circulating equilibrium concentration, that may in part be controlled by the solubility limit of the parameter of interest (e.g., sulphate can be expected to eventually be limited by gypsum solubility in the presence of calcium addition as lime in the mill circuit). The tailings supernatant chemistry will be typical of the pore water quality in the tailings. The main parameter of potential concern is selenium, which had a typical concentration of approximately 9.5 mg/L.

Table 5.4 Tailings Supernatant Geochemistry

Parameter	Concentration
	(mg/L)
pH	7.4 - 7.9
Ammonia-N	0.1 - 0.35
Nitrate	0.30
CN-total	0.02 - 3.5
Thiosalts	400 - 600
SO₄	500 - 1500
Al	0.02 - 0.14
Sb	0.02 - 0.065
As	0.002 - 0.1
Cd	0.001 - 0.005
Cu	0.012 - 0.11
Fe	<0.03
Pb	0.003 - 0.135
Hg	0.0001
Ni	0.002 - 0.008
Se	9.1 to 9.7
Ag	0.003 - 0.004
Zn	0.01 to 0.13

The supernatant water in the tailings pond will undergo “aging” when tailings deposition stops, which could occur during periods of temporary shutdown or on closure. Aging tests were carried out to assess the behaviour of the supernatant water overlying the tailings. In addition, sub-aqueous column leach tests were carried out to assess the change in void water quality as the tailings are leached with fresh surface water.

Tailings Aging Tests

The four composite tailing samples were “aged” in the laboratory for up to 120 days, to assess the water chemistry changes in the tailings pond over time. During aging, the supernatant was exposed to atmospheric oxygen and carbon dioxide, as would be the case in the tailings impoundment during temporary suspension of milling activities (e.g., maintenance shutdowns)

or post-closure. At closure, or during sustained shutdown, there will be a short lag time (up to 9 months) until the remaining thiosalts are oxidized and water quality stabilizes. During this period there is a slight depression in pH, which then rises after the thiosalts are oxidized. Selenium, cadmium and zinc for some of the samples show elevated concentrations at 120 days (Table 5.5). Concentrations of some parameters had not reached equilibrium after 120 days. Additional testing will be conducted during the operations period to refine the estimates of post-closure tailings pond water quality behaviour.

Table 5.5 Summary of Tailings Aging Tests at 120 Days

PARAMETER	COMB OVERALL ORE COMP	COMB OD COMP	COMB WOLVERINE D COMP	COMB LYNX D COMP
pH	7.39	7.16	7.11	7.63
Hardness	860	560	544	813
Sulphate	1200	920	890	1200
Thiosalts	<10	133	243	<10
Total Cyanide	0.01	<0.01	<0.01	<0.01
Ammonia	0.2	1.2	1.1	0.9
Ag	<0.0001	0.0003	0.0039	<0.0001
As	0.021	0.006	0.016	0.0050
Cd	0.0169	0.0257	0.0040	0.0027
Cu	0.0024	0.0038	0.0048	0.0050
Pb	0.0266	0.0053	0.0031	0.0047
Hg	<0.0001	<0.0001	0.0002	<0.0001
Sb	0.0142	0.0094	0.0297	0.0072
Se	0.994	0.388	1.26	0.12
Tl	0.0089	0.0029	0.0034	0.0020
Zn	5.57	1.68	0.514	0.54

Note: All metals are dissolved concentrations.

Sub-aqueous Column Leach Tests

Sub-aqueous column leach tests were conducted on the two combined ore composite samples (OC and OD) to simulate the leaching effects from material stored under water cover, and the results are summarized in Table 5.6. The columns have similar construction to the humidity cells, however a water cover was maintained on the sample, and leachate was collected weekly. The leachate volume of each weekly sample was approximately 7 times the pore volume of the

sample. The leachate of the sub-aqueous columns was collected and analyzed for pH, conductivity, acidity, alkalinity, thiosalts, anions (F^- , Cl^- , SO_4^{2-} and NO_3^-), cyanide (CN), thiocyanate (CNS), cyanate (CNO), ammonia + ammonium ($NH_3 + NH_4^+$) and a suite of dissolved metal(loid)s via ICP-MS (including mercury) by SGS Lakefield.

Table 5.6 Summary of Subaqueous Column Results after 8 Weeks

PARAMETER	COMB OVERALL ORE COMP (OC)	COMB OD COMP (OD)
pH	7.86	7.65
Sulphate	52	38
Thiosalts	5	5
Total Cyanide	<i>0.005</i>	<i>0.005</i>
Ammonia	0.1	0.7
Ag	<i>0.00005</i>	<i>0.00005</i>
As	<i>0.0025</i>	<i>0.002</i>
Cd	0.00005	<i>0.000015</i>
Cu	<i>0.004</i>	<i>0.0005</i>
Pb	0.0005	0.0003
Hg	<i>0.00005</i>	0.0014
Sb	0.0092	0.0228
Se	0.008	0.010
Tl	<i>0.0001</i>	0.0021
Zn	0.005	0.009

Note: All metals are dissolved concentrations (mg/L). Italicized values indicate measured values less than detection limit, and listed as one half of the detection limit; Bold values indicated measured values in excess of 10x CCME guideline.

The water quality of the leachate stabilized after 4 weeks to typical values shown in Table 5.6. The test indicates that the water quality improves with time, as the process water is “flushed” out. For example, the number of pore water volumes in the four weeks was approximately 30 times indicating that a leaching water volume of approximately 2 L/kg is required to “flush” residual contaminants.

6. TAILINGS IMPOUNDMENT

The tailings facility includes a tailings impoundment, L-shaped tailings dam, a seepage recovery dam and pond, two upland diversion ditches, and a spillway (see Drawing D-3004). The tailings impoundment site is located in a natural, northwest-southeast trending elongated ephemeral drainage basin perched on the northeast valley slope of Go Creek (see Drawing D-3001). The basin is flanked on the downhill side by a natural ridge trending in the same direction that drops in elevation gently towards the upstream end of the tailings facility, and ends rather abruptly at the elbow point of the L-shaped tailings dam at the downstream end. The impoundment covers an area approximately 600 m long and 300 m wide.

Site investigations indicate that the tailings basin is mantled by glacio-morainal deposits, which may have been altered by the stream flowing along the thalweg. Along the ridge, the depth to bedrock ranges from 30 m to 40 m, while between the ridge and the northeast valley slope the depth is shallower, ranging from 20 m to 25 m.

6.1 Storage Capacity

The annual storage requirements are summarized in Table 6.1 and the capacities of the impoundment with Stage 1 and Stage 2 dams is shown on Figure 6.1. In addition to storage of tailings solids, the tailings facility will provide for the following:

- minimum operational water volume of 40,000 m³ for settling of solids and operation of pumps ;
- seasonal storage for average conditions of 60,000 m³;
- 200 year flood storage consisting of 200 yr wet month precipitation with snowmelt of 37,500 m³; and
- 2 m of freeboard, which provides for routing of the 10,000 year return period flood event through the spillway (0.5 m) and 1.5 m of freeboard.

Table 6.1 Tailings Production Rate (t/y) and Volume

CALENDAR YEAR	OPERATION YEAR	TOTAL TAILINGS PRODUCTION (TONNES)	TAILINGS TO IMPOUNDMENT (TONNES)
2010 ¹	1	305,586	159,486
2011	2	484,319	257,910
2012	3	485,645	272,219
2013	4	484,319	231,690
2014	5	484,319	229,410
2015	6	484,319	229,410
2016	7	485,645	230,039
2017	8	484,319	229,410
2018	9	371,805	187,385
Total Tonnage		4,070,275	2,026,960
Total Volumes² (m³)		na	1,267,000

1: Based on 184 days of production

2: Based on an *in situ* density of 1.6 t/m³

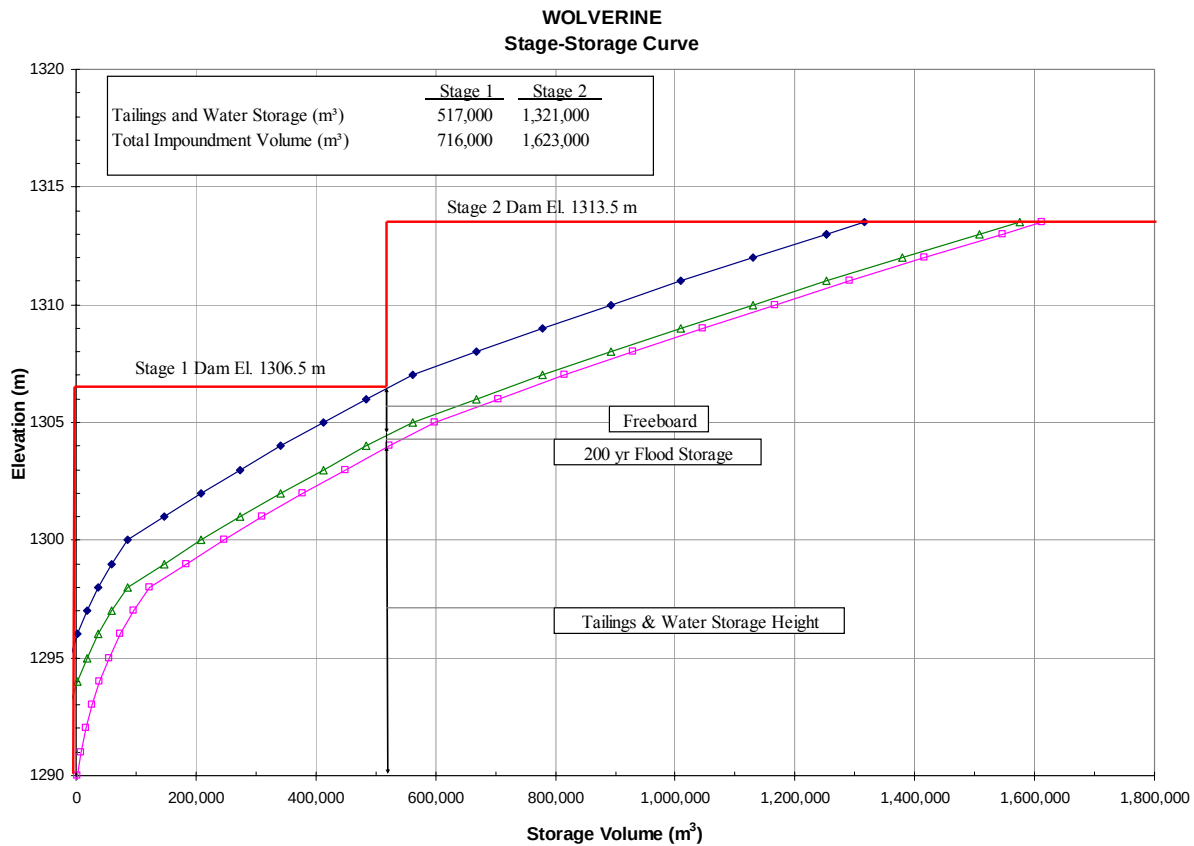


Figure 6.1 Stage Storage Curve – Tailings Impoundment

6.2 Deposition Strategy and Staged Development

The tailings will be deposited via one or two spigot discharges. In approximately the first five years of operations, tailings will be spigotted from two locations: a) from the west flank of the dam (as shown on Drawing D-3004), and b) from the north end of the impoundment. The tailings beach will slope towards the southeast where the water reclaim barge will initially be located near the east side of the dam. The tailings will form a beach, which will slope at approximately 1% towards the water pond. In approximately Year 6 the reclaim barge will be relocated to the north end of the impoundment near the Ultimate Spillway (see Drawing D-3001). Tailings would then be spigotted from the Ultimate Dam to form a beach against the dam.

A Surpac spatial model of the impoundment was run to illustrate the deposition of tailings over the life of the mine. Typical model outputs for tailings deposition are shown on Figure 6.2 to 6.5 for Year 1, Year 2, Year 6, and closure, respectively (water pond is coloured blue and the tailings

are brown). Typical sections are shown schematically on Drawing D-3010 and Drawing D-3011 for various stages of operations.

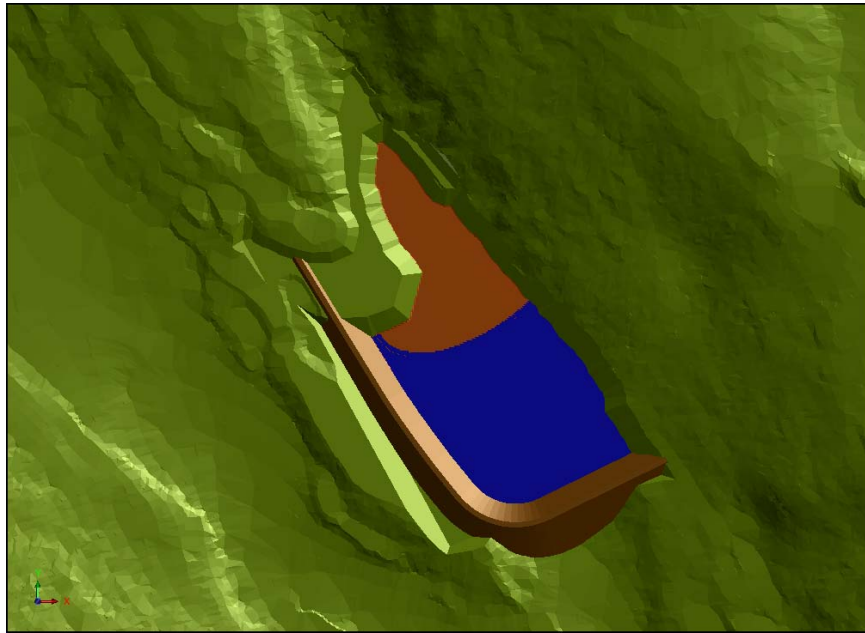


Figure 6.2 Deposition Plan - Year 1

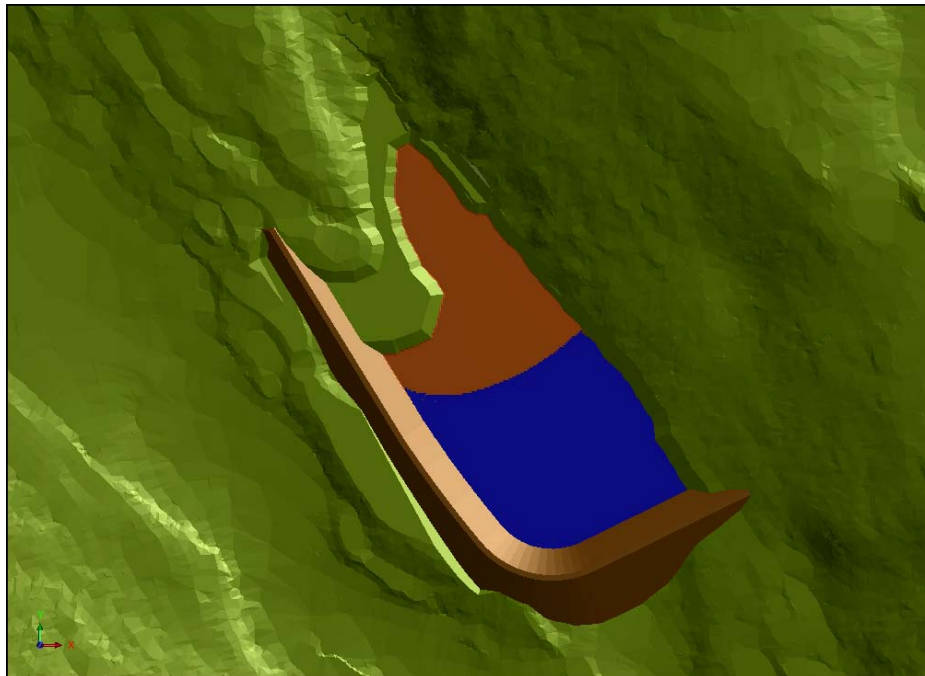


Figure 6.3 Deposition Plan - Year 2

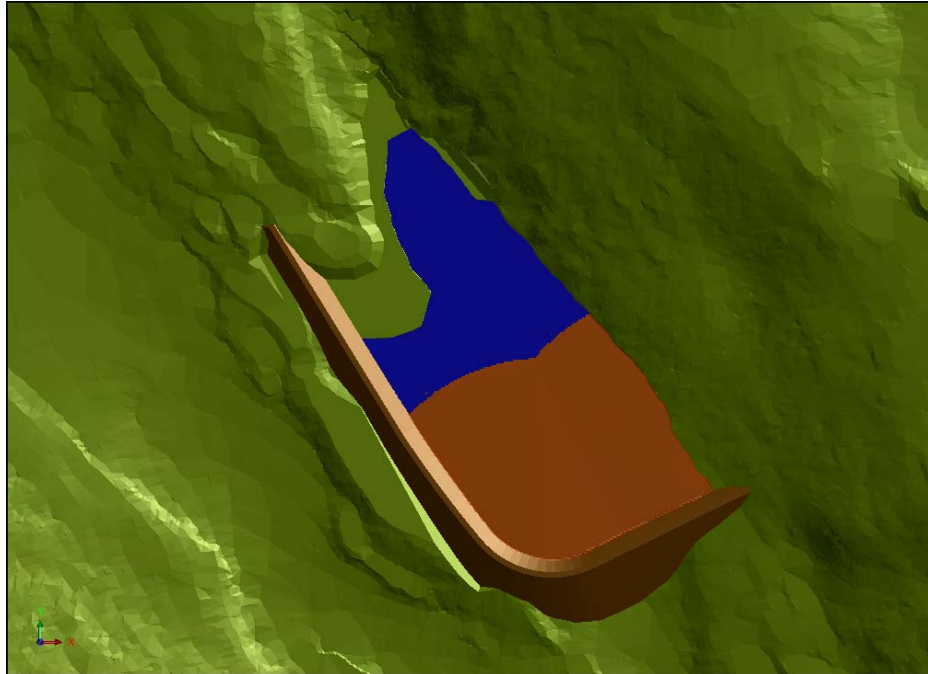


Figure 6.4 Deposition Plan - Year 6

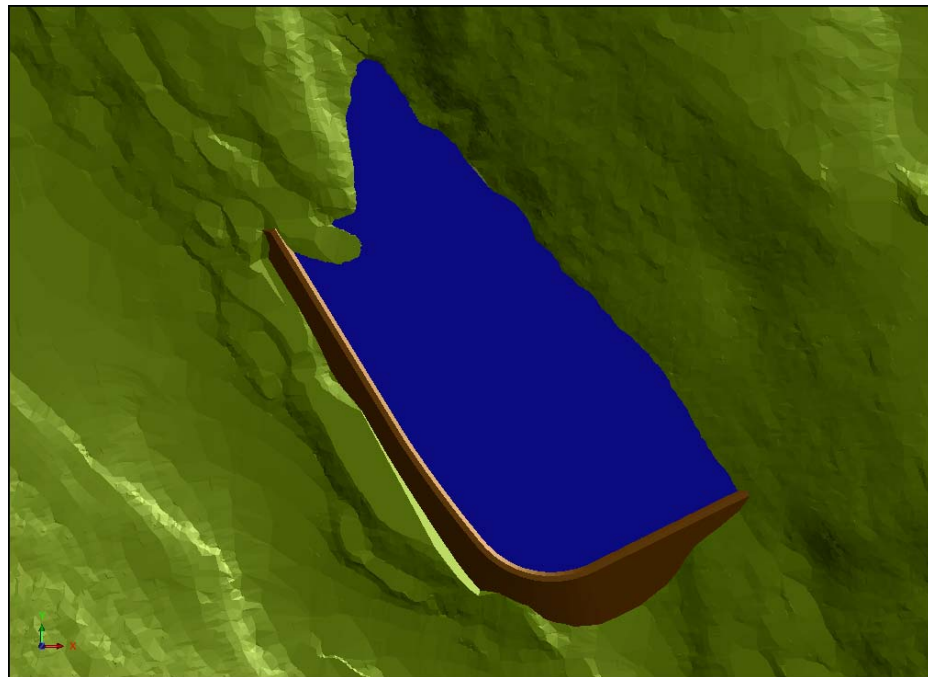


Figure 6.5 Deposition Plan - Closure

6.3 Liner Design

The tailings facility is designed to retain water and minimize seepage from the impoundment and dam. In order to achieve this, A 40 mil LLDPE geosynthetic liner will line the impoundment and along interior face of the dam. Overburden material in the impoundment will be excavated and used as general fill for the dam. Typical excavation and fill sections for the impoundment are shown in Drawings D-3007 and D-3009.

Prior to preparing the foundation base for the liner, a short underdrain will be installed to prevent uplift pressures from developing beneath the liner in the low area of the impoundment, near the upstream toe of the dam (See Drawings D-3006 and D-3007). The drain will become redundant after the liner is covered with water and/or tailings. Following installation of the underdrain, the foundation base of impoundment will be prepared by heavy compaction of the natural soils. Local placement of finer material will be required in areas of very coarse gravel or boulders.

The lining system will be constructed in two stages as shown on Drawings D-3006 and D-3008. Specifications for liner materials and placement are summarized in Section 6.3. The liner will be anchored in a trench around the perimeter of the impoundment (at the edge of the Stage 1 road for the Starter Dam and Stage 2 Road for the Ultimate Dam).

An assessment of the potential leakage for various scenarios (i.e., base case, partially degraded liner and no liner) is summarized in Table 6.2 and included in Appendix I. The seepage analyses indicate that the leakage rate out of the impoundment should be on the order of 0.00001 L/s, which is negligible.

Table 6.2 Summary of Leakage Sensitivity Analysis

ANALYSIS CONDITION	BASIN/LINER PERMEABILITY (m/s)	TOTAL SEEPAGE (L/sec)
Base Case – Liner with good QA/QC	Defect Analysis	0.00001
Partially “Degraded” Liner	10^{-10}	0.13
Unlined facility	10^{-6}	6.8

The sensitivity analysis also indicates that the worst-case condition, considering complete degradation of the liner would result in a seepage rate on the order of 6.8 L/s. Because liner degradation is often a result of UV effects, complete degradation of the impoundment liner, which will be covered by tailings, is considered to be highly improbable. As such a more realistic “worst case” evaluation, considering only partial degradation, suggests that seepage under this condition would be less than 0.13 L/s.

6.4 Tailings Facility Water Balance

A water balance for the tailings facility over the 9 year mine life has been carried out and the complete set of tables is included in Appendix III. The water balances for four scenarios are summarized in this section, including:

- The first year of tailings facility operation (Year 2);
- The final year of tailings facility operation (Year 8);
- After mine closure, with diversions; and
- After mine closure, without diversions.

The cases were run for the average year, 100 year wet, and 100 year dry. Inflows to the tailings pond include:

- Surface water runoff and snowmelt from the tailings facility catchment, and direct precipitation on the tailings facility;
- Milling transport water, which includes: tailings transport water, sewage treatment plant effluent, underground mine water and collected runoff from the industrial complex area; and
- Water transferred from the seepage recovery pond to the tailings pond.

Outflows from the tailings facility include:

- Evaporation from the pond;
- Reclaim water recycled to the mill during mining operation;
- Water lost to tailing voids as porewater;
- Water pumped to the water treatment plant for treatment and subsequent discharge; and

- Seepage losses from the tailings pond.

The groundwater table is near surface and after placement of tailings, the groundwater gradients will be downward. Therefore, the contribution of groundwater into the impoundment is considered negligible.

The tailings pond has a total natural catchment area of about 105 ha. With the upland diversion ditches in place, the reduced tailings facility catchment is about 16 ha.

Table 6.3 presents the results of the average annual water balance for the four scenarios. As the table indicates, there will be surplus water of approximately 5 m³/hr in the tailings pond during mine operation for the average year. The surplus will increase to approximately 9 m³/hr for the 1:100 year wet year, and a water neutral condition is expected to occur during the 1:100 year dry year. The average annual water balance for the complete mine life and the average monthly water balances for the life of the project are included in Appendix III.

The water balances for the closure scenarios indicate that there will be surplus water during the average year and the 1:100 year wet and dry years, with and without the upland diversion ditches in place. The upland diversion ditches will be decommissioned after mine closure to ensure that water cover on the deposited tailings is maintained.

Table 6.3 Tailings Pond Annual Water Balances for Four Scenarios

CONDITION	NET AVERAGE WATER SURPLUS (m ³ /hr)		
	AVERAGE	100 YR DRY	100 YR WET
Year 2 operations with diversions	4.6	-0.5	8.5
Year 8 operations with diversions	5.8	0.2	10.2
Closure with diversions	7.6	2.0	12.0
Closure without diversions	16.6	6.3	24.6

6.5 Water Quality Management

The water balance shows that during operations, over 90% of the water entering the impoundment is tailings slurry water. During operations, the impoundment will have a net water surplus, as indicated in the water balance presented in Section 6.5. Discharge from the impoundment will be managed to maintain receiving water quality, which will comprise two main components:

- Excess water will be stored in the tailings impoundment during the low flow months of November to April, and treated and discharged during the high flow months of May to October.
- Discharge concentrations and flows will be managed to meet A Licence QZ04-065 requirements.

The Starter Impoundment has sufficient capacity to store excess water in the first few years of operations. This will allow for pilot testing and detailed design of the water treatment plant during the initial years of operations without the requirement for discharge.

7. TAILINGS DAM

The tailings dam is “L-shaped” in plan (see Drawing D-3004), with the short leg of the “L” alignment extending across a side valley from the east to the west for a length of approximately 250 m. The dam alignment then bends around and follows the trend of a flanking ridge for another 450 m towards the northwest. The maximum dam height is 16.5 m and 23.5 m high at project start up and after Year 2 of mining operations, respectively. The dam section has a crest width of 6 m and a 2H:1V downstream slope and a 2H:1V upstream slope (see Drawing D-3007).

The tailings dam is a compacted, homogeneous earthfill embankment dam with an upstream impervious geosynthetic liner. The liner will cover the base of the tailings impoundment and upstream face of the dam up to the ultimate dam crest level (see Drawing D-3005).

The dam will be constructed in two stages. The Starter Dam will be constructed to elevation 1306.5 m in 2009, one year prior to mill start-up. The dam will be raised 7 m using the downstream construction method to the final elevation at 1313.5 m in Year 2 of mine operation (2011). During operations there will be storage for tailings plus operations water, and capacity for the 200 year flood. Starter and Ultimate Dam spillways will be constructed to pass larger flood events (see Drawing D-3004).

On closure, a 1.0 m thick layer of granular soil/rockfill will be placed over the tailings to reduce the potential for fine solids to become re-suspended. In addition, a 0.5 m minimum depth of water over the stored tailings will provide an oxygen barrier to prevent acid generation and metal leaching of the solids. An ultimate spillway will modified as necessary to function as the closure spillway. There will be 1.5 m of freeboard (2 m over spillway invert) above the normal pond water level to provide long term security against wave run-up, crest erosion and temporary spillway blockage.

7.1 Geotechnical Parameters

The dam foundation consists of up to 20 m thick competent till-like overburden overlying bedrock. A layer of about 0.3 m thick topsoil overlies most of the tailings impoundment area.

Test pits excavated in the vicinity of the tailings basin indicate that most of the borrow materials are available from within the footprint of the impoundment.

Table 7.1 summarizes the geotechnical properties of materials used in the seepage and limit equilibrium slope stability analyses. These properties are based on field and laboratory test data acquired for the project and supplemented by general properties available in literature.

Table 7.1 Geotechnical Properties Used in the Slope Stability Analyses

MATERIAL	UNIT WEIGHT ¹ γ bulk (kN/m ³)	EFFECTIVE SHEAR STRENGTH	
		Cohesion c' (kPa)	Friction ϕ' (deg)
Foundation soils	22	0	34
Foundation bedrock	27	0	40
Dam Fill	22	0	36
Glacial Till	22	0	36
Tailings	22	0	25
Geomembrane liner	-	-	-

¹Bulk unit weight is the in situ wet density.

7.2 Slope Stability Analyses

Static and pseudo-static stability analyses were carried out using the computer program SLOPE-W (Geo-Slope 2004) and the Morgenstern-Price method to determine the factor of safety and the results are presented in Figure 7.1, and summarized in Table 7.2,

Pseudo-static slope stability analyses were carried out using a seismic coefficient (k_h) of 0.125, corresponding to a design earthquake magnitude of 7.2, based on interpolation from Seed (1979). In the analyses, no seismic-induced excess pore pressure was assumed in either the dam or foundation material.

Table 7.2 Summary of Safety Factors for Tailings Dam

a)

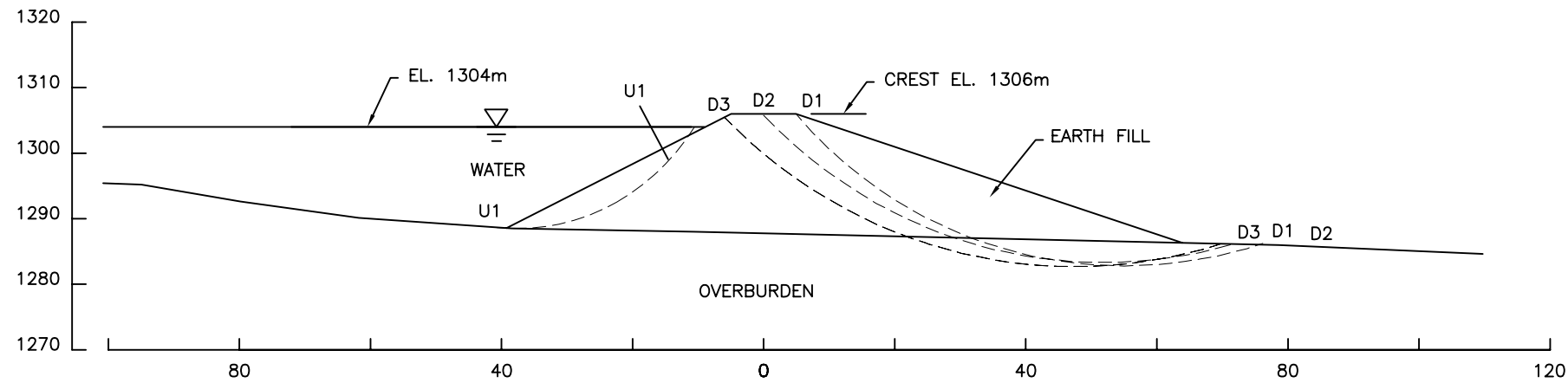
FAILURE SURFACE	STARTER DAM ² -FACTORS OF SAFETY	
	STATIC	PSEUDO-STATIC ¹
D1	1.6	1.3
D2	1.6	1.3
D3	1.6	1.3
U1	2.2	1.9

b)

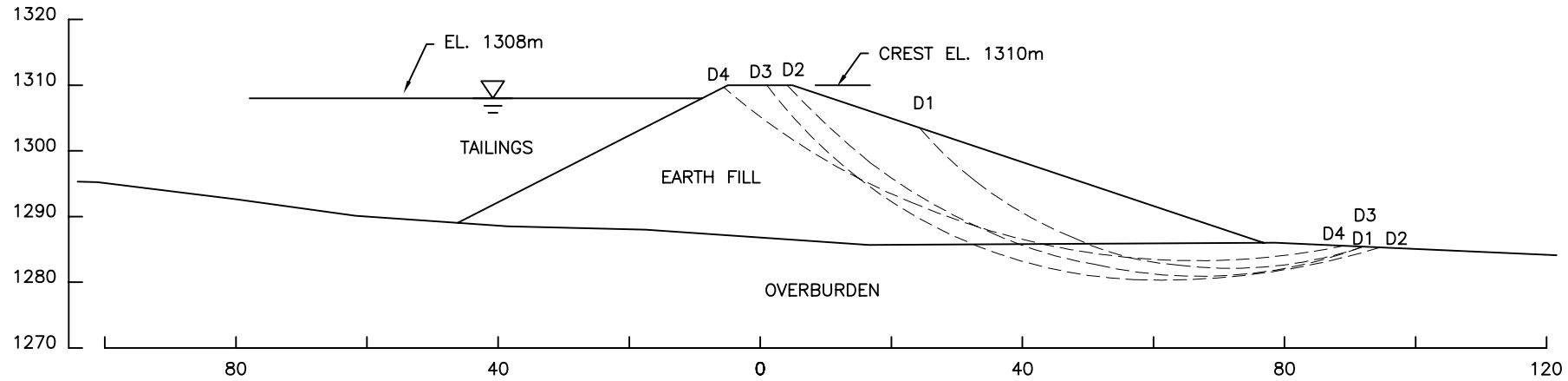
FAILURE SURFACE	ULTIMATE DAM ² -FACTORS OF SAFETY	
	STATIC	PSEUDO-STATIC ¹
D1	1.6	1.3
D2	1.6	1.2
D3	1.5	1.2
D4	1.6	1.2

¹Pseudo-static analysis used a seismic coefficient = 0.125 g.

² Starter Dam elevation analysed was 1306.5 m and Ultimate Dam elevation analysed was 1313 m.



STARTER DAM



ULTIMATE DAM

SUMMARY OF MATERIAL PROPERTIES

MATERIAL	UNIT WEIGHT, γ_{bulk} (kN/m ³)	EFFECTIVE SHEAR STRENGTH	
		FRICTION, ϕ' (deg)	COHESION, c' (kPa)
EARTHFILL	21.8	36	0
OVERBURDEN	21.8	34	0
TAILINGS	23.2	25	0

SUMMARY OF FACTOR OF SAFETY FOR STARTER DAM

FAILURE SURFACE	STATIC FACTOR OF SAFETY (MORGENSTERN-PRICE)	PSEUDO-STATIC FACTOR OF SAFETY (MORGENSTERN-PRICE) ⁽¹⁾
D1	2.2	1.6
D2	2.3	1.7
D3	2.4	1.7
U1	2.2	1.9

SUMMARY OF FACTOR OF SAFETY FOR ULTIMATE DAM

FAILURE SURFACE	STATIC FACTOR OF SAFETY (MORGENSTERN-PRICE)	PSEUDO-STATIC FACTOR OF SAFETY (MORGENSTERN-PRICE) ⁽¹⁾
D1	2.2	1.6
D2	2.2	1.6
D3	2.2	1.6
D4	2.3	1.7

NOTE

1. HORIZONTAL SEISMIC COEFFICIENT OF 0.125 WAS USED IN THE PSEUDO-STATIC ANALYSES

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Dam Foundation Liquefaction Assessment

The liquefaction assessment was carried out in general accordance with the Seed simplified approach as described in Youd et al. (2001). The earthquake induced Cyclic Stress Ratios (CSR) were computed using the Seed's simplified relationship for level ground conditions. The Cyclic Resistance Ratios (CRR) were estimated based on Standard Penetration Test (SPT) $(N_1)_{60cs}$ values derived from the measured SPT and Large Penetration Test (LPT) blow count data. The factor of safety against liquefaction (FOS_{Liq}), which is defined as the ratio of CRR to CSR was determined to evaluate the liquefaction potential of granular soils at the site. Table 7.3 shows the liquefaction assessment based on the LPT data at test holes TH05-07 and TH05-08 and SPT data at test holes, TH05-09 and TH05-10.

Based on the seismic hazard analyses, the following two deterministically based design earthquake scenarios were considered in the liquefaction assessment:

- **Scenario 1 (Probabilistic):** Earthquake with magnitude M7 and Peak Horizontal Ground Acceleration (PHGA) of 0.22 g.
- **Scenario 2 (Deterministic):** Earthquake with magnitude M6 and PHGA of 0.34 g.

The PHGAs listed above are representative for the “firm ground” conditions and they were amplified at the surface. The conventional method was used to determine the LPT/SPT blow counts N_{LPT}/N_{SPT} . If refusal was reached after 150 mm of penetration during the LPT or SPT testing, the LPT/SPT blow counts were estimated based on the data up to the point of refusal.

As can be seen from Table 7.3, the measured SPT and LPT data at these test hole locations indicate that liquefaction will not occur under either design earthquake scenario.

Table 7.3 Dam Foundation Liquefaction Assessment Based on LPT/SPT Data

TEST HOLE	DEPTH (m)	SPT/ LPT	SPT or LPT BLOWCOUNT NLPT or NSPT	SPT (N_1) _{60CS}	EARTHQUAKE SCENARIO 1 (M=7, PGA=0.22g)			EARTHQUAKE SCENARIO 2 (M=6, PGA=0.34g)		
					CRR	CSR	FOS _{Liq}	CRR	CSR	FOS _{Li}
TH-07-7	1.52	LPT	101	112	>0.6	0.38	>1.5	>0.8	0.45	>1.8
	3.05	LPT	81	89	>0.6	0.37	>1.5	>0.8	0.44	>1.9
	4.57	LPT	58*	52	>0.6	0.37	>1.5	>0.8	0.44	>1.9
	6.10	LPT	60*	46	>0.6	0.37	>1.5	>0.8	0.43	>1.9
	9.14	LPT	70*	44	>0.5	0.36	>1.5	>0.8	0.42	>1.9
	12.19	LPT	Refusal	-	-	0.33	-	-	0.39	-
	15.24	LPT	Refusal	-	-	0.29	-	-	0.35	-
	18.29	LPT	Refusal	-	-	0.26	-	-	0.31	-
	21.34	LPT	Refusal	-	-	0.23	-	-	0.27	-
	24.38	LPT	Refusal	-	-	0.21	-	-	0.25	-
TH05-8	1.52	LPT	40*	44	>0.6	0.38	>1.5	>0.8	0.45	>1.8
	3.05	LPT	47*	51	>0.6	0.37	>1.5	>0.8	0.44	>1.9
	4.57	LPT	48*	43	>0.6	0.37	>1.5	>0.8	0.44	>1.9
	6.10	LPT	42*	32	>0.6	0.37	>1.5	>0.8	0.43	>1.9
	9.14	LPT	50*	31.5		0.36	>1.5	>0.8	0.42	>1.9
	12.19	LPT	60*	33.5		0.33	>1.5	>0.7	0.39	>1.9
	15.24	LPT	120*	59.4		0.29	>1.5	>0.7	0.35	>1.9
	18.29	LPT	Refusal	-	-	0.26	-	-	0.31	-
TH05-9	1.52	SPT	57	97	>0.6	0.38	>1.5	>0.8	0.45	>1.8
	3.05	SPT	51	86	>0.6	0.37	>1.5	>0.8	0.44	>1.9
	4.57	SPT	125	172	>0.6	0.37	>1.5	>0.8	0.44	>1.9
	6.10	SPT	40*	48	>0.6	0.37	>1.5	>0.8	0.43	>1.9
	9.14	SPT	52*	51	>0.5	0.36	>1.5	>0.8	0.42	>1.9
	12.19	SPT	Refusal	-	-	0.33	-	-	0.39	-
	15.24	SPT	Refusal	-	-	0.29	-	-	0.35	-
	18.29	SPT	Refusal	-	-	0.26	-	-	0.31	-
	21.34	SPT	Refusal	-	-	0.23	-	-	0.27	-
	24.38	SPT	Refusal	-	-	0.21	-	-	0.25	-
	27.43	SPT		-	-	0.20	-	-	0.24	-
	30.48	SPT	Refusal	-	-	0.19	-	-	0.23	-
TH05-10	1.52	SPT	40*	68	>0.6	0.38	>1.5	0.8	0.45	>1.8
	3.05	SPT	40*	67	>0.6	0.37	>1.5	0.8	0.44	>1.9

Notes: * Refusal reached between 150mm and 450 mm penetration and N_{LPT}/N_{SPT} estimated based on blow counts up to the point of refusal; LPT = Large Penetration Test ; SPT = Standard Penetration Test

8. WATER MANAGEMENT INFRASTRUCTURE

The water management infrastructure associated with the tailings impoundment and dam includes the following (refer to Drawing D-3001):

- Operational diversions: Diversion Ditches A and B to direct clean surface water runoff around the tailings storage facility;
- Seepage collection dam and pond to collect runoff from the downstream dam face, and as a contingency measure to collect impoundment/dam seepage;
- Starter Dam spillway; and
- Ultimate Dam spillway.
- Tailings and reclaim pipelines and reclaim pump barge
- Water treatment plant (located at the Industrial Complex)

8.1 Surface Water Diversion Ditches

Two diversion ditches associated with the tailings facility are Ditch A and Ditch B as shown in Drawings D-3032 and D-3033, respectively. The ditches consist of open channel excavations with corrugated steel pipe (CSP) culverts in areas where the gradients are steeper than 2%. The ditch side slopes are typically 2H:1V. Approximate lengths and gradients of the ditches are provided in Table 8.1.

Ditch A:

Runoff from the catchment northwest of the tailings impoundment will be intercepted by the mine access road upstream of the tailings impoundment. This runoff will be picked up by Ditch A and conveyed to Go Creek downstream of the airstrip.

Ditch B:

Ditch B will intercept runoff directly north and northeast of the tailings basin. Ditch B will direct the flow, via a culvert, to Go Creek downstream of the seepage collection pond.

Table 8.1 Length and Gradient of Diversion Ditches

DIVERSION DITCH	APPROX. LENGTH (m)	GRADIENT (%)	
		Minimum	Maximum
Ditch A – open section	220	0.5	0.5
Ditch A – culvert section	270	0.47	8.2
Ditch B – open section	760	1.0	1.96
Ditch B- culvert section	510	1.0	9.74

The catchment area for each diversion ditch and the estimated flows for short and long term duration storms are presented in Table 8.2. These flows were estimated using the Rational Method with an assumed runoff coefficient of 0.6.

Table 8.2 100-year Flood Flows for Ditches A and B based on Rational Method

DIVERSION DITCH	CATCHMENT AREA (ha)	RAINSTORM DURATION			
		25 Minutes*		24 Hour	
		Rainfall (mm)	Peak Flow (m ³ /s)	Rainfall (mm)	Average Flow (m ³ /s)
Ditch A	67	12	3.2	53	0.25
Ditch B	33	12	1.6	53	0.12

*NOTE: The times of concentration for Ditch A and Ditch B is approximately 25 minutes.

Regional analysis of snowmelt indicates a peak annual daily change in snowpack of about 5 cm to 15 cm, with a mean of 8.6 cm. Assuming a snowmelt rate of 15 cm/day, the snow water equivalent is approximated as 15 mm over a 12 hour period. If this snowmelt is added to the peak design flow values presented in Table 8.2, the flows in Ditch A and Ditch B will increase by 0.2 m³/s and 0.1 m³/s, respectively. The mean annual and seasonal flows anticipated in the ditches are summarized in Table 8.3.

Table 8.3 Mean Annual and Seasonal Flow in Diversion Ditches

DIVERSION DITCH	MEAN FLOWS (m ³ /s)		
	Mean Annual	Summer (High)	Winter (Low)
Ditch A	0.007	0.006 – 0.012	≈ 0
Ditch B	0.006	0.005 – 0.009	≈ 0

The diversion ditches are temporary structures and will be decommissioned upon mine closure. Since the expected mine life is only 9 years, and since the likelihood of a 100-year storm event occurring during the 9 years is relatively small, the design of the various components of Ditch A and Ditch B was carried out on the following basis:

- The open channel portion of the ditch is sized to carry the 100-year peak flow corresponding to the time of concentration, plus a 0.3 m freeboard;
- The open channel portion of the ditch has erosion protection up to the 100-year, 24-hour flow. Erosion and repair of the ditch is expected for flows exceeding the 100-year, 24-hour event. The ditches will be seeded with a native grass species.
- The pipe portion of the ditch was sized to carry the 100-year, 24-hour flow (Table 8.2) plus snowmelt (15 mm snow water equivalent over 12 hours). Pipe diameter is 800 mm.

8.2 Tailing Dam Spillways

The spillway design is based on routing the design flood through the impoundment without overtopping the tailings dam. The spillway inlet is a trapezoidal channel with a base width of 3 m and 2H:1V side slopes. The channel invert at the control section near the dam centerline is located 2.0 m below the dam crest level.

Site investigations indicated that the insitu material along the spillway channel will consist primarily of medium dense to dense silty sand and gravel with cobbles.

8.2.1 Hydraulic Design Parameters

Design Flood Selection

The expected 9 year operating life of the mine was taken into account in the selection of the design floods for temporary facilities, such as the Starter Dam spillway and the Seepage Collection Dam spillway. A 200-year design return period was selected for the Starter Dam spillway, with the proviso that the spillway would pass the 10,000-year flood without overtopping the dam. The spillways were sized based on the criteria and assumptions below.

Table 8.4 Flood Design Criteria for Tailings Dam Spillways

STAGE	DESIGN FLOOD RETURN PERIOD (yrs)	COMMENTS
Starter Dam Spillway	200 & 10,000	Assume that upland surface water diversion ditches have failed.
Ultimate Dam Spillway	10,000	Assume that upland surface water diversion ditches are decommissioned.

Inflow Hydrographs

The 1 to 30-day flood inflow hydrographs for the Tailings Pond were developed using the following method:

- The peak runoff for short duration (i.e., 30 min.) rainfall was estimated using the Rational Method with a runoff coefficient of 1.0; and
- The estimated peak runoff plus 2 to 4 times the estimated long duration (i.e., 1 to 30-day) runoff volume were used to develop the inflow hydrograph.

The above method used to develop the inflow hydrographs tends to conservatively over-estimate the rise in pond water level, and pond outflow rates.

Flood Routing

The inflow hydrographs for various scenarios were routed through the Tailings Pond in order to estimate the peak pond water level and the peak spillway discharge. The size of the spillway was determined such that adequate dam freeboard is available under flood conditions with a reasonable spillway size. The results of the flood routing are summarized in Table 8.5.

Table 8.5 Tailings Dam Spillways - Design Flood Flows and Freeboards

DAM	CATCH-MENT AREA (ha)	SURFACE WATER DIVERSION DITCHES	DESIGN STORM	PEAK OUTSFLOW (m ³ /s)	DAM FREEBOARD (m)
Starter	16	Functioning	200-yr, 30-min	0.0	2.2
	105	Not functioning	200-yr, 30-min	0.0	2.1
			10,000-yr, 30-min	0.0	2.0
			10,000-yr, 30-days	8.2	0.8
Ultimate	105	Decommissioned	10,000-yr, 30-min	0.2	1.95

Notes:

1. The peak design flows and freeboard for spillways are based on a 3-m wide trapezoidal channel with 2H:1V side slopes, with channel invert located 2.0 m below dam crest level.
2. For routing of the 200-year flood through the Starter Dam, the 0.3 m flood storage allowance is assumed to be fully available. That is, the initial pond level at the beginning of the storm is assumed to be 0.3 m below the spillway invert.
3. For routing of the 10,000-year flood, the flood storage allowance is assumed to be zero for both the Starter Dam and the Ultimate Dam.
4. Minimum freeboard for spillway channel = 0.6 m.

Starter Dam Condition

The 10,000-year, 30-day storm with the diversion ditches assumed to have failed was found to be more critical in terms of flood discharge rate and dam freeboard. The peak inflow to the pond for the 10,000-year, 30-day storm is estimated to be about $9.5 \text{ m}^3/\text{s}$, which attenuates to about $8.2 \text{ m}^3/\text{s}$ as the flood passes through the pond and the spillway. The pond water level will peak at El. 1305.7 m, thus leaving a freeboard of about 0.8 m between the dam crest and the peak flood level.

Ultimate Dam Condition

The 10,000-year, 30-days flood inflows for the Ultimate Dam will be similar to that for the Starter Dam, but the flow will attenuate to about $7.7 \text{ m}^3/\text{s}$ as the flood passes through the pond, because of the larger pond size.

For the 10,000-year, 30-min. storm, minimal rise in pond water level is expected and about 1.95 m of freeboard between the top of the dam crest and the peak flood level will be available. For the 10,000-year, 30-days storm, the available freeboard will reduce to about 0.95 m, which is considered to be reasonable for such an extreme event.

Effect of Snowmelt

The flood routing presented above is based on rainfall. The effect of combined runoff from rainfall and snowmelt on the Tailings Pond freeboard was also investigated. The maximum snowmelt rate of 15 mm/day water equivalent was added as the base flow of the rainfall inflow hydrograph and the combined runoff was routed through the Tailings Pond.

The flood routing indicates that the pond water level will rise an additional 0.0 m to 0.05 m due to the snowmelt. Therefore, the freeboard between the top of the dam and the peak flood level could be 0.05 m less than that indicated in Table 8.5. The reduced freeboard would still be within the acceptable range of flood freeboard for this type of facility.

8.3 Seepage Collection Infrastructure

8.3.1 Seepage Collection Pond

A Seepage Collection Pond will be constructed downstream of the tailings dam to collect potential seepage and local runoff for subsequent return to the tailings impoundment. Flow into the collection pond will be mainly due to precipitation and runoff from the downstream tailings dam slope and the immediate catchment area of the seepage pond, with little or no seepage contribution from the lined tailings impoundment. The quality of the pond water will be monitored and, if it meets discharge quality criteria, it will be discharged to Go Creek; otherwise it will be pumped into the tailings impoundment.

The seepage collection facility will consist of a 5 m high, 5 m wide dyke forming a collection pond with a capacity of approximately 5,000 m³ and a spillway at the dam's northwest abutment (Drawings D-3004 and D-3005). The dam will be a homogeneous earthfill embankment constructed of silty sand and gravel material by a cut and fill operation to 1284.6 m elevation. The pond will be approximately 170 m long, 40 m wide at the widest part, and 4 m deep near the centre of the pond. The seepage dam and spillway will be used during mine operations, and decommissioned when no longer required at closure.

The maximum pumping rate likely required during operations is 20 L/s. The maximum static head for pumping water from the Seepage Collection Pond to the Tailings Pond is 27 m to the Starter Dam crest and 34 m to the Ultimate Dam crest) At the rate of 20 L/s, it will take about 3 days to pump the 5,000 m³ pond storage capacity. A 20 L/s pumping rate is approximately equal to the average pond inflow rate for a 5-year, 24-hour rainfall event.

8.3.2 Seepage Dam Spillway

The seepage dam spillway is designed to route flood water through the pond without overtopping the seepage dam crest. The spillway will consist of an 850 mm diameter culvert discharging directly into Go Creek (refer to Drawing D-3006). The culvert invert is located 1.6 m below the dam crest (refer to Drawing D-3005). .

The design criterion for the seepage spillway is the 100-year return period (Table 8.6). The design criterion was selected based on the rationale that the dam is very low (5 m), tailings will

not be stored behind the dam, and there is a low probability that contaminated seepage will be collected within the pond.

The estimated peak spillway discharge is 0.7 m³/s, and the estimated dam freeboard to the flood level is 0.5 m (Table 8.6).. This flow can be passed with a 850 mm diameter corrugated steel pipe (CSP), which will extend from the west side of the dam to Go Creek, as shown on Drawing D-3006.

Table 8.6 Seepage Dam Spillway Design Flood Flow and Freeboards for

CATCHMENT AREA (ha)	SURFACE WATER DIVERSION DITCHES	DESIGN STORM	PEAK DESIGN FLOW (m³/s)	DAM FREEBOARD (m)
9	Functioning	100-yr, 10-min	0.7	0.5

The spillway culvert will be inspected a minimum of three times per year, with particular attention to the inspection prior to the spring freshet. This will ensure that the culvert is not blocked. The performance of the spillway will also be monitored in the operating period during high runoff periods, while the mine is in operation. Potential problems, if any, will be identified and remedial actions taken as necessary.

9. CONSTRUCTION

9.1 Construction Plan

The construction of the tailings facility occurs in three stages over the life of the operation and includes Starter Dam and Impoundment construction, Ultimate Dam and Impoundment construction and closure. The main activities occurring in each of the stages is summarized below.

9.1.1 Stage I Starter Dam and Impoundment (Year 2008 to 2010)

In winter 2008/2009 site preparation work will be completed, including:

- Construction of a drainage channel through the thalweg of the valley to expedite dewatering of the area, in preparation for other construction activities and spring runoff.
- Construction of Diversion Ditch A and Diversion Ditch B to reduce the quantity of water to be managed during construction of the facility in 2009.
- Stripping of organic material from within the impoundment and dam footprint to allow an “early” construction start-up in 2009; and

Once the winter period is over, and approval for the tailings facility construction is received, activities scheduled for the spring to fall 2009 period include:

- Construction of liner underdrain;
- Grading and proof rolling of dam impoundment footprint;
- Excavation of borrow from the impoundment interior and construction of the Starter Dam and Seepage Collection Dam. Construction of the Stage 1 perimeter access road at El. 1305 m;
- Construction of the Starter Dam Spillway (excavation of channel and placement of culverts and riprap;
- Installation of dam instrumentation;
- Final grading and proof rolling of impoundment footprint in preparation for placement of the liner. Placement of liner bedding in areas of “rough” foundation

base. Excavation of a liner anchor trench around the perimeter of the impoundment and dam;

- Placement of the liner and backfilling of the liner anchor trench; and
- Placement of material over the liner to form a pad for the water reclaim barge.

Prior to the startup of the mill in June 2010, the following activities will occur to enable full operation of the tailings facility:

- Selective diversion of surface water from Ditch A and/or Ditch B to provide for 40,000 m³ of water for start-up of the mill;
- Placement of tailings delivery pipeline and water reclaim pipeline;
- Installation of water reclaim pump barge and associated electrical works.
- Commencement of mill processing and discharge of tailings, and reclaim of water.

9.1.2 Stage II Ultimate Dam and Impoundment (Year 2011)

During the first full year of operation (2011), construction of the Ultimate Dam will commence in late fall. In order to complete this work, the following activities will take place from the spring to fall:

- Foundation preparation for Ultimate Dam footprint and proof rolling of the foundation;
- Excavation of borrow from within the impoundment area and raising of the dam from the downstream side. If sufficient materials are not available then an alternative borrow area located just north of the impoundment will be used for dam fill (See Drawing D-3001);
- Construction of the Stage 2 perimeter access road at El. 1313.5 m (See Drawing D-3008);
- Excavation of the Ultimate Spillway and placement of riprap bedding and riprap;
- Final grading and proof rolling of Ultimate Impoundment footprint in preparation for placement of the liner. Placement of liner bedding in areas of “rough” foundation base. Excavation of a liner anchor trench around the perimeter of the impoundment and dam;

- Placement of the liner and backfilling of the liner anchor trench;

9.1.3 Closure (Year 2019 to 2022)

Closure of tailings facility will take place over a few years and will be integrated with water quality management. Consequently the timing of the works will vary to suit discharge requirements. The main components of the closure will include:

- Continued operation of the water treatment plant, until discharge objectives are met;
- Placement of granular soil or rockfill layer on top of the ice in the first winter. The soil will settle during the spring thaw and the impoundment will be surveyed to confirm the extent of the soil. If required to achieve 1.0 m of cover, a second soil layer will be placed in the 2nd winter;
- Final adjustment of dam heights and spillway invert elevations, if required, to maintain 0.5 m minimum water cover;
- Placement of a 10 m wide non acid generating rockfill along the upstream side of the dam crest to provide additional security for long term dam safety and to keep the water pond away from the dam;
- Decommissioning of the Seepage Dam when the seepage water quality is suitable for discharge;
- Decommissioning of Ditch A and Ditch B upon cessation of mine operations; and
- Reclamation of the dam slopes with placement of topsoil and planting of suitable vegetation (conducted during operations as part of the progressive reclamation program).

9.2 Construction Materials and Details

The main construction materials and details for the construction of the dams and spillways are summarized below.

General Dam Fill

General fill will be borrowed from within the impoundment area and used to construct the homogeneous dams. The material consists of a well-graded silty sand and gravel, with cobbles.

Finer materials will be placed towards the upstream slope of the dam as well as adjacent to the glacial till zone. Coarser materials will be placed towards the downstream slope of the dam.

Glacial Till Zone

The glacial till zone will be placed in the Stage 2 dam. The till will be placed in a 5 m wide zone on the upstream side of the dam between the elevation of the Starter Dam (1306.5 m) and the Ultimate Dam (1313.5 m), as a “backup” to the geosynthetic liner. The glacial till zone will have a minimum of 20% fines passing the 74 micron sieve size.

Geosynthetic Liner

A 40 mil thick LLDPE geosynthetic liner will be placed over the base of the tailings impoundment and extended up the upstream face of the dam and keyed into the dam crest and the perimeter of the impoundment.

Liner Underdrain

A liner underdrain will be placed in the valley thalweg to provide positive drainage under the geosynthetic liner to prevent liner uplift due to potential artesian groundwater. The underdrain will consist of an excavated ditch filled with drain gravel and a perforated pipe, protected with geotextile and sand. The extension of the drain under the dam will be with a solid pipe, and impervious trench backfill, to allow water transport beneath the dam, should the pipe plug.

Liner Bedding

It is anticipated that some bedding materials for the liner may be required in local areas where grading and proof-rolling of the stripped foundation surface can not achieve a smooth and even surface for liner placement. The bedding material will consist of screened sand and fine gravel with a maximum particle size of 25 mm.

Liner Protection

In local areas where temporary construction access for the pump barge may be required, a 300 mm thick low-permeability protection layer of silty overburden material, with no sharp coarse particles, will be first placed over the liner.

Riprap and Bedding

The riprap material will consist of hard durable rock obtained from rock quarries along the access road. Riprap bedding will be processed from granular materials in Km 19 borrow area.

Culverts

Corrugated steel pipe culverts will be used for the diversion ditches and the Starter Dam and Seepage Dam Spillways.

9.3 Construction Methods

Construction of the facility will use best practices for control of erosion and sediment, as outlined in *General Site Plan* (2008-04). The main work components are as follows:

Foundation Preparation

The dam foundation areas will be drained with perimeter diversion ditches and internal ditches, as required to ensure a drained foundation suitable for placement of fill materials. Surface water flows, if present during construction, will be cut off by an upstream ditch and collected in a sump and pumped to the downstream side of the dam to settle out sediments before discharging into Go Creek. The dam footprint will be stripped of all organic, loose and soft materials and proof-rolled with 5 passes of a 10-tonne vibratory roller compactor.

Liner Underdrain

The extent of the underdrain will be determined by the Engineer in the field with observation of the groundwater conditions. A 1 m deep ditch will be excavated leading to the downstream toe of the dam. The ditch will be filled with a geotextile, drain gravel and a perforated drainage pipe

and covered with a protective sand layer. Under the dam embankment, a solid pipe and impervious trench backfill will be used.

Fill Placement

The general dam fill and glacial till fill will be spread in 300-mm thick horizontal layers and compacted to a density of 95% of the Standard Proctor Maximum Density (SPMD). The water content of the fill will be not more than 2% above or 4% below the optimum SPMD water content. All fills will be placed in the “dry”.

Geosynthetic Liner

The liner system will be constructed in 2 stages, as shown on Drawing D-3006 and Drawing D-3008. Overburden material in the impoundment will be excavated and used as damfill. Typical excavation and fill sections for the impoundment are shown in Drawing D-3007 and Drawing D-3009.

Ground preparation in the area of the geosynthetic liner will consist of stripping and grading, followed by proof-rolling. Cobbles, stones, sticks or any other debris that could potentially puncture the liner will be removed. Irregularities in the surface will be levelled, and finer bedding material will be used to cover localized areas with surficial coarse gravel, cobbles or boulders. The geosynthetic liner will be placed in segments and joined in the field. The liner will be placed over the prepared foundation surface in the tailings impoundment and along the upstream face of the dam. The liner will be anchored into the crest of the dam with a 0.6 m deep trench, backfilled with compacted soil.

Seepage Collection Ditch

A provision for a seepage collection ditch is included in the design, however it is very unlikely that the ditch will be required to collect seepage. Nonetheless, a V-shaped ditch would be constructed with a dozer along the downstream toe of the dam to direct seepage and runoff from the face of the dam to the seepage collection pond.

Spillway Control Section

If the control section of the spillway channel, across the dam crest, is excavated through soil, then it will be lined with riprap. This is not only to provide erosion protection but also to discourage future vegetation growth in the channel. The channel side slopes will be excavated at 2H:1V. However, this design slope will be assessed during construction. The side slopes will be adjusted, if necessary, to provide long-term stable slopes.

If the control section of the spillway channel is located in bedrock, then the channel side slopes will be selected based on rock quality. Depending on the depth of cut and rock quality, benches may be provided to intercept rockfalls. All loose rock will be scaled and removed from the channel during excavation and, if required, during operation and closure phases.

The spillway will be constructed using conventional earthworks equipment in conjunction with drilling and blasting for sections of the spillway excavation through bedrock.

9.4 Bill of Quantities

A Bill of Quantities for the tailings facility is shown in Table 9.1.

Table 9.1 Bill of Quantities for the Tailings Dam and Associated Water Management Structures

ITEM	DESCRIPTION	Total Quantity	UOM	Unit Cost	Staged Quantities		Closure
					1	2	
100 Site Preparation							
101	Clear and grub (grasslands and shrubs)	173,600	m2		101,000	72,600	
102	Strip topsoil embankment footprint (assume 1.4 m)	58,000	m3		28,500	29,500	
103	Strip topsoil impoundment (assume 1.4 m)	185,040	m3		112,900	72,140	
104	Excavate unsuitable soils (allowance)	6,000	m3		6,000		
105	Proof Roll Embankment Footprint	41,400	m2		20,367	21,033	
200 Borrow Area Development							
201	Clear & Grub	20,000	m2		10,000	10,000	
202	Strip topsoil (assume 0.6 m)	12,000	m3		6,000	6,000	
203	Reclamation	2.0	ha				2.0
300 Tailings Dam							
301	General Fill - From impoundment	207,600	m3		131,400	76,200	
302	Glacial Till - From impoundment	14,300	m3		0	14,300	
303	General Fill - From borrow	133,700	m3		54,900	78,800	
304	Glacial Till - From borrow	14,300	m3		0	14,300	
400 Geomembrane Liner - Tailings Area							
401	Liner Bed Preparation - impoundment (grade and compact)	163,500	m2		95,500	68,000	
402	Liner Bedding (assumes 10% of impoundment area)	2,453	m3		1,433	1,020	
403	Geomembrane - Impoundment	180,000	m2		105,000	75,000	
404	Anchoring System (trench and sand bags)	1	LS		0.5	0.5	
405	Liner Underdrain - Trench Excavation	81	m3		81		
406	Liner Underdrain - Perforated HDPE Pipe (200mm diam.)	200	m		200		
407	Liner Underdrain - Corrugated Big 'O' Pipe (200 mm diam.)	100	m		100		
408	Liner Underdrain - Filter Fabric	500	m2		500		
409	Liner Underdrain - Drain Rock Backfill	78	m3		78		
410	Liner Underdrain - Impervious Backfill (50 mm-minus)	27	m3		27		
500 Water Management							
501	Overburden Excavation - Ditch A	11,300	m3		11,300		
502	Overburden Excavation - Ditch B	27,900	m3		27,900		
503	Overburden Excavation - Starter Dam Spillway	2,500	m3		2,500		
504	Overburden Excavation - Ultimate Dam Spillway	16,600	m3			16,600	
505	Overburden Excavation - Seepage Collection Channels (assumes 1mx1m)	800	m3		700	100	
506	Overburden Excavation - Stilling Basins (3 total)	270	m3		270		
507	Filter 1 - Ultimate Dam Spillway	560	m3			560	
508	Filter 2 - Ultimate Dam Spillway	160	m3			160	
509	Riprap A - Ultimate Dam Spillway	550	m3			550	
510	Riprap A - Stilling Basins (3 total)	160	m3		160		
511	Riprap B - Ultimate Dam Spillway	390	m3			390	
512	Riprap F - Ultimate Dam Spillway	800	m3			800	
513	CSP Culvert (800 mm diam.) - Ditch A	260	m		260		
514	CSP Culvert (800 mm diam.) - Ditch B	530	m		530		
515	CSP Culvert (1200 mm diam.) - Starter Dam Spillway	120	m		120		
516	Culvert Bedding/backfill - Ditch A	760	m3		760		
517	Culvert Bedding/backfill - Ditch B	1,540	m3		1,540		
518	Culvert Bedding/backfill - Starter Dam Spillway	325	m3		325		
519	General Fill - Ditch A (culvert backfill)	3,200	m3		3,200		
520	General Fill - Ditch B (culvert backfill)	5,450	m3		5,450		
521	General Fill - Starter Dam Spillway (culvert backfill)	720	m3		720		
522	Grass seeding - Channel Slopes	4.4	ha		4.4		
600 Seepage Control							
601	Seepage Dam - Excavation (0.3 m topsoil)	1,300	m3		1,300		
602	Seepage Dam - General Fill	15,000	m3		15,000		
603	Seepage Dam Spillway - CSP Culvert (850 mm)	100	m		100		
700 Closure							
701	Topsoil Cover (assume 0.5 m over outer dam slope)	12,500	m3				12,500
702	Ditch A						
	A - Remove and dispose culvert	260	m				260
	B - Backfill ditch upstream of Ultimate Dam Spillway	7,000	m3				7,000
	C - Grass seeding and re-vegetation	0.70	ha				0.70
703	Ditch B						
	A - Remove and dispose culvert	530	m				530
	B - Backfill ditch	23,400	m3				23,400
	C - Grass seeding and re-vegetation	2.7	ha				2.7
704	Neutral Rock on Tailings Dam Beach (10 m width)	21,900	m3				21,900
705	Granular Cover on Tailings	71,000	m3				71,000
706	Remove Seepage Dam	15,000	m3				15,000
707	Reclamation - dam slopes	2.5	ha				2.5
708	Reclamation - Seepage Dam & Pond	0.7	ha				0.7

NOTES:

- 1 Stage 1 - Starter dam to El. 1306.5; Liner up to El. 1305.
- 2 Stage 2 - Ultimate dam to El. 1313.5; Liner up to El. 1313.5.

9.5 Quality Assurance/Quality Control

All construction work will be monitored by a qualified engineer. The main quality assurance/quality control (QA/QC) components include the following:

- foundation preparation review and approval;
- density and moisture content testing of constructed fill for each lift or every 500 m³ for till and 1,000 m³ for general fill, whichever is more frequent;
- gradation analysis of fills every 1,000 m³ for till and 2,000 m³ for general fill;
- Liner joint tests, to be carried out by the liner installation contractor;
- survey control of fill placement and instrument locations; and
- construction progress reviews, as required.

Diversion ditch and spillway QA/QC measures include general construction survey monitoring of the channel excavation and placement of riprap bedding and riprap for design compliance. The riprap material will be checked visually for quality and size assessment during placement. In addition, the uniformity, thickness and placement limits of the placed riprap will be monitored. Riprap gradation will also be measured if required.

10. WATER TREATMENT PLANT

The tailings impoundment will be operated as a closed system with surplus water treated prior to release. Water treatment and discharge will occur during the six month, ice-free window of May to October. For the purposes of developing and designing a water treatment strategy, treatment of tailings supernatant at a rate of approximately 30 m³/h (9 L/s) has been assumed. The water treatment plant will be located within the Industrial Complex area. The design of the water treatment plant is being carried out by Lorax Environmental Services Ltd. (Lorax) and will require set up of a full scale pilot plant in 2010 once actual process water is available to properly develop and optimize the plant.

The expected chemistry of Wolverine tailings supernatant is presented in Table 5.4 and illustrates a wide range of parameters requiring treatment prior to discharge including total CN, Al, As, Cd, Cu, Pb, Se and Zn. Thiosalts are also present in tailings supernatant and would be expected to oxidize within the impoundment and generate acidity. Based on the bench scale tests conducted on samples obtained from metallurgical lock-cycle testing, treatment of these waters requires a two-stage process. Testwork has focused on first using a high density sludge (HDS) with iron salt addition followed by a polishing stage utilizing biological reduction. Bioreactor testwork was conducted by Inotec at the University of Utah, and the work was supervised by Lorax.

10.1 High Density Sludge (HDS) Water Treatment

10.1.1 Bench Scale Testing Results of HDS

Due to the low iron concentration and high selenium concentration in the tailings water, it is recommended to add iron salt to provide iron for co-precipitation of other metals and effective adsorption of selenium onto ferrihydrite surface. The addition of iron enhances metals removal to extremely low concentration, and the resulting precipitate has shown to be chemically stable. The addition of iron salts is a common practice in North America and has been used to remove contaminants.

For these tests, the tailings water was neutralized to 4 different pH ranges with high iron to metals ratio. Iron was added as ferric sulphate and at 200:1 iron to selenium ratio. The ratio was based on the molar concentration in solution.

The results are shown in Table 10.1 below. As illustrated in the table, most of the metals can be treated to below discharge limit using HDS process with iron salt addition. However, due to elevated selenium levels, a secondary polishing stage will be needed to meet the discharge limit.

Table 10.1 HDS Effluent Quality Following Treatment (mg/L)

	Test 1	Test 2	Test 3	Test 4
pH	6.51	7.03	7.55	7.82
Al	0.002	0.001	0.001	<0.001
Sb	<0.001	<0.001	<0.001	<0.001
As	0.04	0.04	0.05	0.04
Cu	0.07	0.05	0.05	0.06
Cd	0.0006	0.0003	0.0001	<0.0001
Fe	0.04	0.01	0.01	0.02
Pb	<0.0005	<0.0005	<0.0005	<0.0005
Ni	0.02	0.02	<0.01	<0.01
Mn	0.1	0.05	0.04	0.04
Se	4.12	3.98	4.77	5.14
Ag	0.0003	<0.0001	<0.0001	<0.0001
Zn	<0.005	<0.005	<0.005	<0.005

All metals as dissolved

Due to the presence of cyanide, 35% hydrogen peroxide was added to the solution for cyanide destruction and agitated for 30 minutes. Cyanide was reduced from a feed concentration of approximately 3.03 mg/L to 0.41 mg/L.

As illustrated, all parameters are reduced to low concentrations with the exception of Se, which remains at levels on the order of 3.0 mg/L to 5.0 mg/L. Additional removal of Se is required for environmental discharge.

10.1.2 HDS Treatment Process

The HDS Neutralization plant uses well-proven technology to produce clean treated water and a high density sludge containing precipitated metals and gypsum. The high sludge density is achieved by using recycled sludge mixed with lime slurry as the neutralization agent. A schematic of the HDS water treatment plant and infrastructure is provided in Figure 10.1. A more detailed description of the treatment process is provided below.

Solution entering the plant is directed into Reactor Tank #1 which will overflow (via an upcomer) to Reactor Tank #2. Each Reactor tank will have 30 minutes residence time at design flow and will also receive limed sludge from the sludge/lime mix tank. Iron in the form of ferric sulphate will be added to Reactor #1 to provide sufficient iron to other metals ratio for effective chemical reaction and co-precipitation of other metals. Hydrogen peroxide will be added into Reactor #2. Both Reactor tanks are mechanically agitated and have provision for air sparging to ensure that metals are in their appropriate oxidation state for the desired chemical reaction.

Reactor Tank #2 discharges (via up-comer) into a discharge drop box. Provision will also be made for Reactor #1 to discharge into this box in case Reactor Tank #2 is out of service. From the drop box, the slurry will gravity flow via an open launder to the clarifier center well. Flocculent will be added to the feed launder, with provision for alternative addition points.

The clarifier underflow provides sludge for recycle to the sludge/lime mix tank where the recycled sludge is mixed with lime slurry. This mixture of sludge and lime is used to neutralize the feed solution entering the plant. In addition to the recycle stream, a purge system is also provided and excess sludge is purged for disposal.

The sludge lime mix tank receives sludge from the clarifier continuously. The rate at which sludge is recycled depends on the solution treatment rate, and the solids generation potential of the water to be treated. The sludge/lime mix tank also receives lime slurry from the lime stock tank. The rate of lime addition is controlled by the pH in Reactor Tank #1 (or #2). The

sludge/lime mix tank overflows via a launder into Reactor #1, although provision will also be made so it can overflow into Reactor #2 when Reactor #1 is out of service for maintenance.

Clarifier overflow will be directed to the biological treatment system for final polishing and treatment as described below. Residual sludge will be produced at a rate of approximately 260 tonnes per year (~710 kg/d). This material will be blended with the tailings paste backfill cement and placed in the underground voids.

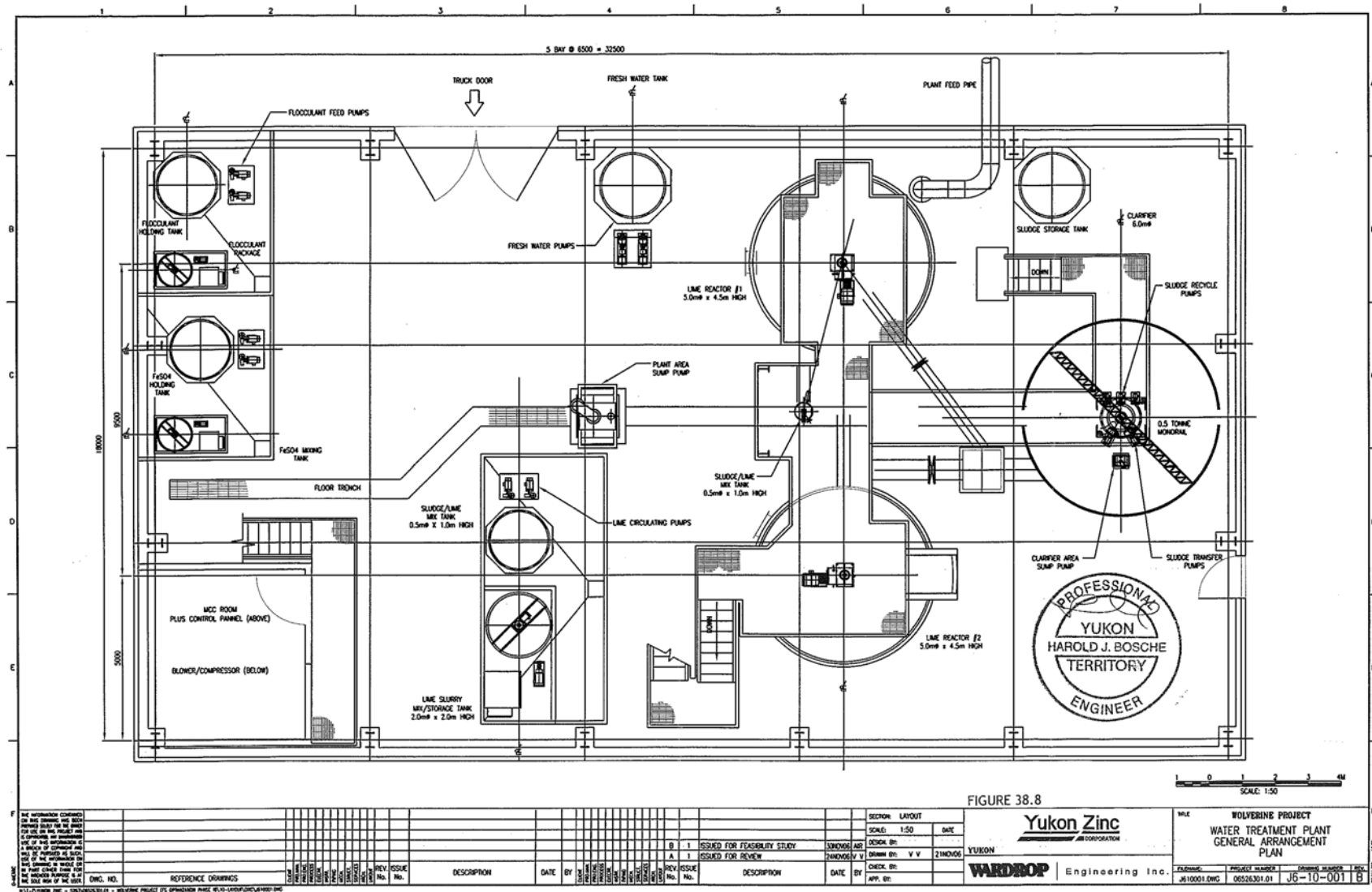


Figure 10.1 Water Treatment Plant General Arrangement Plan

10.2 Bioreactor for Selenium Reduction

Testing of the HDS system indicated good removal of residual cyanide and metal precipitation for essentially all parameters with the exception of selenium. Successful removal of Se to very low levels has been proven using a biological reduction approach. For the Wolverine Project, a bioremediation approach developed and patented by Dr. Jack Adams (University of Utah) has been tested on tailings supernatant water generated from metallurgical testing of Wolverine ore.

The process involves the utilization of naturally occurring bacteria (e.g. *Thauera*, *Pseudomonas spp.*) immobilized in biofilms in a series of reaction chambers (anaerobic solids bed reactors). A nutrient mixture is added to each bioreactor with an organic substrate to foster growth of microbes that utilize selenate in an analogous fashion to those that reduce sulphate. The result is the conversion of dissolved selenium oxyanions in the water to elemental selenium in the solid phase (Oremland et. al., 1989). There is a potential for economic recovery of the elemental Se produced by this process.

Inorganic selenium is most commonly found in four oxidation states (Se^{6+} , Se^{4+} , Se^0 and Se^{2-}). Selenate (SeO_4^{2-}) and selenite (SeO_3^{2-}) are highly water soluble; while elemental selenium (Se^0) is much less soluble in water. Well-aerated surface waters, especially those with alkaline conditions, represent a highly oxidized condition, which contains the majority of selenium as selenate. The relative proportions of selenite and selenate depend on water redox potentials and pH. Selenite is reduced to elemental selenium under mildly reducing conditions while selenate reduction occurs under stronger reducing conditions (Ehrlich, 1990; Hughes and Poole, 1989; Maiers, 1988).

Numerous biological technologies have been tested for selenium removal from water (Case et al., 1990; U.S. Dept. of Int., and Calif. Res. Agency, 1990). Bench scale processes for selenium and general metal removal from mining and other waters using *Pseudomonas stutzeri* and other microorganisms have been demonstrated (Adams et al., 1996a; Adams et al., 1996b; Adams et al. 1993). Mixed cultures of indigenous bacteria demonstrated a 96% percent selenium removal at bench scale (Altringer et al., 1989; Larsen et al., 1989). Pilot

tests using San Joaquin agricultural waters and *Thauera selenatus* removed 98% of the selenium in an anaerobic bioreactor and produced effluent selenium concentrations of less than 5 µg/L (Cantafio et al., 1996). A pilot plant study was conducted in which *E. coli* was used to treat a base metal smelter, weak acid effluent containing 33 mg/L Se. A rotating biological contactor (RBC) was used as the bioreactor. Initial test results indicated that 97% of the selenium was removed from the contaminated solution with a 4-hr retention time. Tests on other mining process waters using a bench scale RBC, *P. stutzeri*, molasses (1.0 g/L), and a 6 hr retention time removed 97% of the selenium (Adams et al., 1993).

Dr. Adams and Lorax Environmental Services Ltd. have developed and tested a staged process that addresses the need for both a chemical process and immobilized enzymes-microbes to reduce selenium to less than 10 µg/L from tailings supernatant concentrations on the order of 5 mg/L to ~10 mg/L. The A Licence discharge limit is 0.02 mg/L. To effectively remove Se to this level, it is necessary to have a staged reaction scheme to address both higher and lower selenium concentrations as well as any TSS and other problematic co-contaminants that might build up in a treatment process. It is important that redox conditions be such that selenium is the primary target; this can be most effectively addressed using a staged reactor system with components and microorganisms selected specifically for selenium binding, sorption, reduction, and sequestration.

The selenium bioreactor process proposed for Yukon Zinc was originally developed in 2004 and was further tested under the US EPA Mine Waste Technology Program in 2007. The process is a newer generation selenium removal technology, and is currently being patented. This biochemical process represents a significant improvement over previous patented selenium removal technology developed by Dr. Adams. For reference, the previous patented technology was evaluated under the EPA's Mine Waste Technology Program – and the original selenium removal patent is held by Weber State University and was tested in conjunction with the EPA and a local water treatment company.

10.2.1 Summary of Test Results Using Biological Reduction

Biological testing of selenium reduction in Wolverine tailings waters has been ongoing since May 2006; a summary of testwork conducted to date is included in Appendix V. Testing has

involved both initial screening analyses for the potential for Se reduction in test waters, followed by collection of sediment samples for isolation and testing of indigenous organisms from Wolverine Creek.

Standard methods were used in all procedural methods and modified or 'special' analysis methods were used for qualitative selenium evaluations. Microbes in site waters were screened for potentially interfering microbes and indigenous selenium reducers using standard culturing and plating procedures.

Screening of stock cultures was completed to select better performing selenium reducing bacterial populations. With screening of 40 selenium reducing cultures, three microbial cultures were found that performed selenium reduction in site waters at high rates at both 4° C and 20° C (Figure 10.2; photos 3a & 3b, respectively). A comparison plate test of one of the microbes on media made with tailings supernatant and purified lab waters is also shown in Figure 10.2 (photos 3c-1 and 3c-2, respectively) cultured at 20° C. As illustrated, microbial growth was not inhibited in the media prepared with tailings supernatant as compared to the purified water media, indicating that growth limitations are not expected to occur due to toxic effects of the tailings supernatant. Selenium bioreduction tests were run for 72 hours at 20° C and 24 hours at 4° C; approximately 3.5 times longer was required for selenium reduction at 4° C than at 20° C.

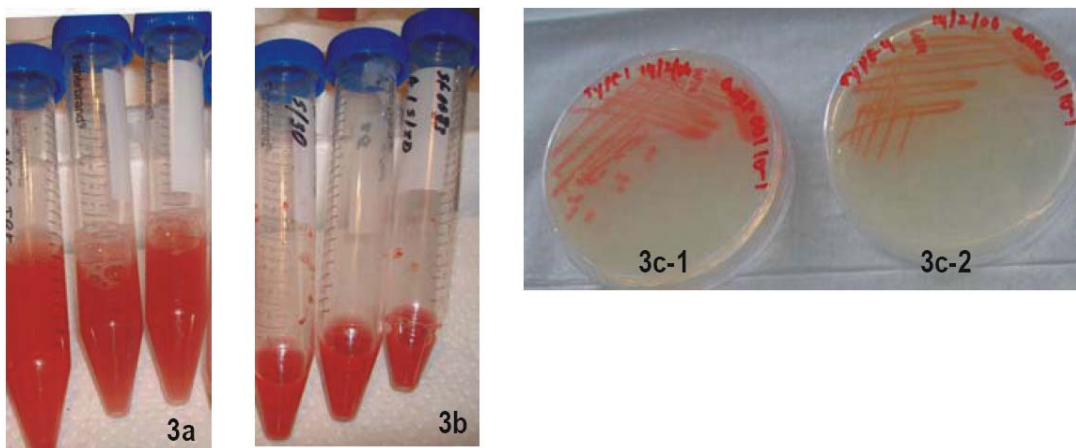


Figure 10.2 Selenium Reduction of Tailings Supernatant Waters (3a and 3b) and Plate Tests of Microbial Growth

Overall, the qualitative tests were very positive and provided a strong demonstration that biological selenium reduction is achievable in undiluted, fresh Wolverine tailings supernatant water. Additional testing was performed to demonstrate the selenium removal levels that could be obtained in a laboratory biotreatment system.

Quantitative selenium reduction tests were completed using a modified plug flow laboratory biotreatment system inoculated with the three microbial populations examined above and a batch treatment system. Tests were conducted at 20⁰ C using retention times of 12 and 24 hours. A quantitative 24-element suite was obtained for three samples; the influent solution and two 24 hour effluent samples; a quantitative selenium analysis was requested for the 12 hour effluent sample. Results are summarized in Table 10.2.

Table 10.2 Summary of Biological Reduction Test Results for Key Parameters in Wolverine Tailings Supernatant at 20°C

Parameter	Feed Concentration (mg/L)	@12 hours (mg/L)	@24 hours (mg/L)
Al	0.298	na	0.005
As	0.0148	na	0.0001
Cd	0.00492	na	0.00002
Cr	0.00157	na	0.0001
Cu	0.0638	na	0.00016
Fe	1.23	na	0.0008
Mn	0.111	na	0.00008
Pb	0.315	na	0.00001
Hg	0.00047	na	0.00005
Ni	0.0056	na	0.00008
Se	9.93	0.00138	0.00015
Ag	0.0018	na	0.00001
Zn	0.317	na	0.0089

na: not analyzed

Further column and batch testing has been completed using microbial isolates collected from sediments within Wolverine Creek. Optimization of nutrient additions and retention times is the recent focus of testing. Also, in 2007, four tests were conducted on two reactor types – a biochemical-enhanced material reactor and an electro-biochemical reactor. The Inotec

report *Treatability and Bench-scale Testing of Waters for Selenium Removal* (January 31, 2008) details the results of the 2007 testwork and recommendations for pilot plant testing. This report is provided in Appendix V.

Overall, the testing to date has been very successful, reducing contaminants to very low levels and demonstrating that biological selenium reduction to levels at or below 1 ppb is obtainable in tailings supernatant with the appropriate microbes, nutrients, and biotreatment system configuration.

10.2.2 Preliminary Design of the Biological Reduction System

A preliminary design schematic of the system of bioreactors used for the biological reduction of selenium is shown in Figure 10.3.

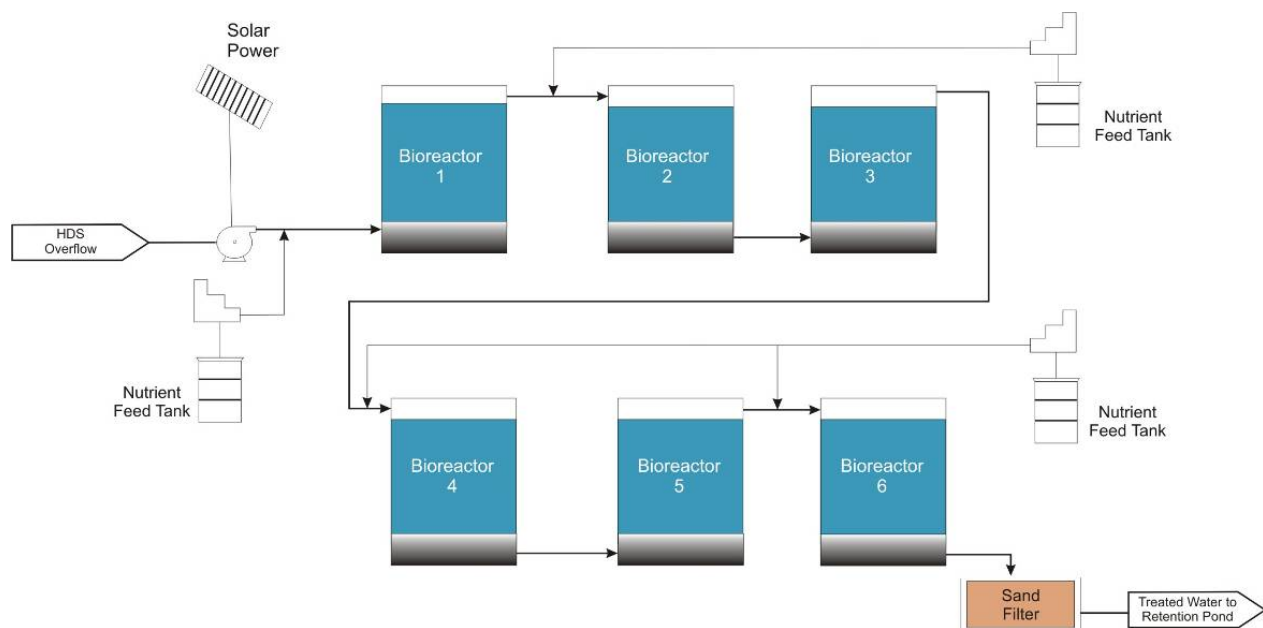


Figure 10.3 Schematic Design of the Bioreactor System for the Treatment of Selenium in Tailings Pond – High Density Sludge (HDS) Overflow Water

The bioreactor system will be located within the Industrial Complex area and will receive water from the HDS water treatment plant. The bioreactor can be designed to treat up to 15 L/s (~55 m³/h) of HDS or direct tailings water with 1 to 10 mg/L Se. Anticipated flow rates are roughly half this amount or 20 m³/h to 30 m³/h.

For these conditions, the system will consist of a series of six semi-buried concrete tanks with a combined void volume of 750 m³ or a total volume of 1,500 m³. At the expected flow rates (e.g. ~10 L/s or ~30 m³/h), this would provide a retention time of approximately 50 hours. In addition, several small capacity pumps will be required to circulate water and introduce nutrients to the influent.

The bioreactor tanks will contain a granular carbon substrate or comparable alternative. Water movement through the bioreactor system will occur in a modified plug up-flow configuration. The water from the HDS plant or tailings pond (influent) will receive a nutrient amendment designed to facilitate the growth of the microbial community inoculated on the carbon substrate. The water discharged from the bioreactor will be fed through a sand filter prior to discharge to a retention pond, where waters will be further tested prior to release to Go Creek.

As discussed, the ultimate design of the bioreactor system, the required nutrient amendments and optimal flow capacities need to be determined through a field-scale pilot study in which operating characteristics are optimized. Pilot plant studies will commence onsite in 2010 once the process plant has generated 'typical' supernatant. Based on the storage capacity of the tailings impoundment, water treatment plant operation is not required until after 2012.

11. CLOSURE

Reclamation and closure plans for closure of the tailings facility are documented in the approved *Wolverine Project Reclamation and Closure Plan* (2008-02). A revised Reclamation and Closure Plan is required by *QML-0006* to be submitted in December 2009, and updated plans for closure of the tailings facility will be based on as-built drawings.

Following mine operations, excess process water will continue to be treated and will naturally be replaced with runoff water, which, over a period of time, will return the water quality to baseline conditions. There is a potential that some water treatment for a period of a few years may be required to ensure stable impoundment water quality.

The tailings facility will be closed as a saturated facility with minimum water cover of 0.5 m as shown in Drawings D-3011 and D-3012. The main closure activities required pertain to dam safety, and long-term groundwater quality and surface water quality as outlined below.

11.1 Dam Safety

The dam has a minimum pseudo-static factor of safety of 1.15 for the 10,000 year seismic event and has a very low risk of geotechnical “failure”. Consequently, the main concerns with dam safety on closure are associated with erosion of the dam or blockage of the spillway. Accordingly, a long-term care and maintenance plan will be prepared to confirm that erosion is not occurring and the spillway is clear. Measures to mitigate these potential concerns include the following:

- Placement of a 10 m wide neutral rockfill, adjacent to the upstream crest of the dam. The rockfill will keep the “free water” away from the dam crest, further reducing the potential for water release even with a significant erosion event;
- The downstream slope of the dam will be revegetated (during operations as part of the progressive reclamation program) to minimize water and wind erosion; and
- The spillway will be located in an excavated channel lined with large riprap, and have a discharge capacity for the routed peak flow resulting from the 10,000-year rainfall plus snowmelt event.

11.2 Geochemical Stability and Surface Water Quality

On closure, a layer of granular borrow material will be laid over the impoundment ice in winter. When the ice melts, the material will form a stable cover over the tailings and reduce the potential for remobilization of tailings solids and porewater. A typical section through the impoundment on closure is shown in Drawing D-3011.

On closure the excess impoundment water could be in the order of 30,000 m³ to 150,000 m³, depending on the time of year, climatic conditions and pond management. Excess water will be treated and discharged. The impoundment water quality should return to near baseline conditions following treatment and removal of the excess water at closure and upon replenishing the pond with fresh water from the spring freshet. The potential for contaminated pore water, to mix with the impoundment water to a sufficient degree to impact water quality is considered to be low for the following reasons:

- There would be very little natural transfer of pore water because of the installed geosynthetic liner; and
- The potential quantity of pore water that could mix with the pond water is low; for example, if one assumes that 5% of the pore water in a 1 m thick granular borrow cover layer (1,000 m³) mixes with the pond water (100,000 m³), the dilution ratio would be 100:1.

11.3 Decommissioning of Water Management Infrastructure

The following work is required for decommissioning of the water management structures associated with the tailings impoundment, once the pond water can be directly discharged to the environment:

- Breaching of Ditch A to allow flow into the tailings pond and backfilling the section that is upstream of the Ultimate Spillway;
- Removal of Ditch B Diversion Ditch;
- Removal of the Seepage Dam, collection pond and spillway; and
- Grass seeding and planting in all areas disturbed during the implementation of the above works, as per the *Reclamation and Closure Plan*.

12. DAM SAFETY MONITORING PROGRAM

12.1 Dam Safety Monitoring and Instrumentation

There are four levels of monitoring that will occur to ensure dam safety. The physical and seepage conditions in the dam and area directly downstream of the dam will be monitored as follows:

- **Routine:** visual monitoring by mine personnel – daily during mine operations and every second month after mine closure until safe long term trends are indicated;
- **Intermediate:** visual monitoring by the site dam engineer and annual review of monitoring data and dam performance by the design engineer during operations and annually after closure;
- **Comprehensive:** Dam safety review by dam engineer – on first filling, prior to dam raising, prior to decommissioning and otherwise routinely every 5 years (even after decommissioning); and
- **Special Reviews:** site visit and review of monitoring data are required after the occurrence of any potentially damaging events (e.g., floods, earthquakes) or unusual observations (e.g., cracks, sinkhole formation).

The following instrumentation will be installed and monitored regularly:

- Two inclinometers located in the dam downstream shell to monitor dam foundation deformations in the overburden and bedrock for confirming dam stability. The inclinometers will be monitored two to three times during dam construction and dam raise periods. They will be protected from damage during construction and maintained for possible monitoring under appropriate circumstances, such as after a seismic event or for a comprehensive dam safety review;
- Four piezometers in the dam downstream shell to monitor damfill saturation level – monitored weekly during construction and dam raising, quarterly during operations, annually after closure;

- Ten survey monuments on the dam crest/downstream slope – monitored quarterly during operations and annually after closure;
- Four groundwater monitoring wells downstream and two upstream of the tailings facility, have been installed with screened sections located in the foundation soils and weathered bedrock unit. Samples will be collected quarterly during construction, monthly during operations and annually at closure;
- Monitoring of precipitation and hydrology during operations as per licence requirements;
- Survey of pond level – monthly during operations and annually after closure. This survey will be supplemented by additional information on quantities of tailings and tailings supernatant. Confirmation of all information related to impoundment storage will be required prior to dam raise and mine closure; and
- Bathymetric survey of pond – annually during operations. More detailed surveys will be required prior to dam raise and mine closure.

It is anticipated that the above instrumentation and monitoring scheme will be sufficient to identify the onset of potential instability. If signs of instability are detected, additional surveillance and remedial measures will be taken to safeguard the stability and integrity of the dam.

This monitoring program will confirm design conditions and monitor the “as-constructed” conditions of the tailings impoundment. This monitoring program is summarized in Table 12.1.

Table 12.1 Summary of Tailings Facility Monitoring Program

ITEM	PURPOSE	FREQUENCY
Dam survey monuments	Monitor potential dam foundation deformations.	Quarterly during operations, annually at closure
Inclinometers	Monitor potential dam foundation deformations.	2-3 times during dam construction and dam raise periods
Piezometers	Monitor foundation pore pressures.	Weekly during construction and dam raising, quarterly during operations, annually at closure
Groundwater monitoring wells	Monitor groundwater quality.	Quarterly during construction, monthly during operations, annually at closure
Bathymetry of impoundment	Confirm assumed densities for material storage and water balance.	Annually during operations.
Water flow	Confirm water balance.	Continuous
Impoundment water quality and level	Confirm actual water quality.	Monthly during operations and annually at closure

In addition to the above monitoring program, the following manuals will be prepared prior to the start up of mining operation:

- *Operation, Maintenance and Surveillance Manual*; and
- *Emergency Preparedness and Response Plan* (a preliminary draft of the plan is included in Appendix IV).

12.2 Adaptive Management Plan

Adaptive management measures with respect to impoundment excavation, liner foundation, dam monitoring, excess water, water shortage and impoundment seepage have been reviewed as they may be potential areas of change encountered during construction and operation phases. Table 10.2 summarizes the adaptive management measures to be taken in response the potential variances outlined.

Table 12.2 Tailings Facility Adaptive Management Plan

ITEM	POTENTIAL VARIANCE	ADAPTIVE MANAGEMENT MEASURES
Impoundment excavation	Groundwater level may vary in the excavation.	- Install additional drainage trenches and underdrains to lower the groundwater level and manage the potential for uplift pressures on the liner. - Reduce depth of excavation within the impoundment area and source borrow areas from outside the impoundment.
Foundation for liner	Material is very angular	- Place more liner bedding soils.
Dam monitoring	Inclinometers indicate movement.	- Assess source and mechanism of movement. - Place toe berm, if required, for stability.
	Piezometers indicate rise in water levels in the dam.	- Assess source and mechanism of movement. - Place toe berm, if required, for stability.
Water balance	Wet years	- Temporarily store more water in the impoundment. The dam stages allow for storage for several years. - Raise dam to store additional water.
	Dry years	- Reduce water treatment operations.
Impoundment seepage	Contaminated seepage reports to seepage collection pond.	- Activate seepage pond pumpback system.
	Contaminated seepage observed in groundwater monitoring wells.	- Carry out assessment of potential source of contamination and potential consequence of contamination. - Install pumpback wells, if required, to return water to the tailings pond.

13. SUMMARY AND RECOMMENDATIONS

This report presents the detail design of the tailings facility for the Wolverine Project. The design is based on the results of the site assessment and material characterization studies presented in this report. In 2007, the conceptual design was submitted to regulatory agencies for review and, as a result, this Plan incorporates review comments received. Construction of the facility is scheduled to start in 2009 and be operational in 2010.

The main recommendations for development of the tailings facility and related infrastructure include the following:

1. Diversion ditches should be constructed in early 2009 so that as much surface water as practical can be diverted around the construction area prior to spring freshet in 2009. Test pits will be excavated immediately prior to construction to confirm the excavation geometry and suitability of dam borrow materials.
2. Based on the content contained herein, construction technical specifications and *Issued for Construction* drawings will be prepared to guide the construction contractors.
3. A QA/QC program will be carried out during construction.
4. An Operations, Maintenance and Surveillance Manual will be prepared prior to facility operation.
5. The preliminary Emergency Response and Preparedness Plan will be updated prior to facility operation.
6. An as-built report will be submitted 60 days after completion of tailings facility construction, as per *QML-0006* requirements.

Yours truly,

KLOHN CRIPPEN BERGER LTD.

Daniel Klassen, P.Eng. (BC)

Geotechnical Engineer

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Project Manager

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APPENDIX I

Geotechnical Characterization

- **Part I – Geology**
- **Part II - Seismicity**
- **Part III – Liner Design & Seepage Analysis**
- **Part IV – Laboratory Testing**
- **Part V – Field Investigations**

APPENDIX II

Geochemical Characterization

APPENDIX III

Hydrology, Water Balance and Baseline Water Quality

- **Part I – Hydrology Data**
- **Part II – Water Balance Tables**
- **Part III – Water Quality Data**

APPENDIX IV

Preliminary Emergency Response and

PREPAREDNESS PLAN

APPENDIX V

Inotec Report:

Treatability and Bench-scale Bioreactor

Testing of Waters for Selenium Removal

January 31, 2008

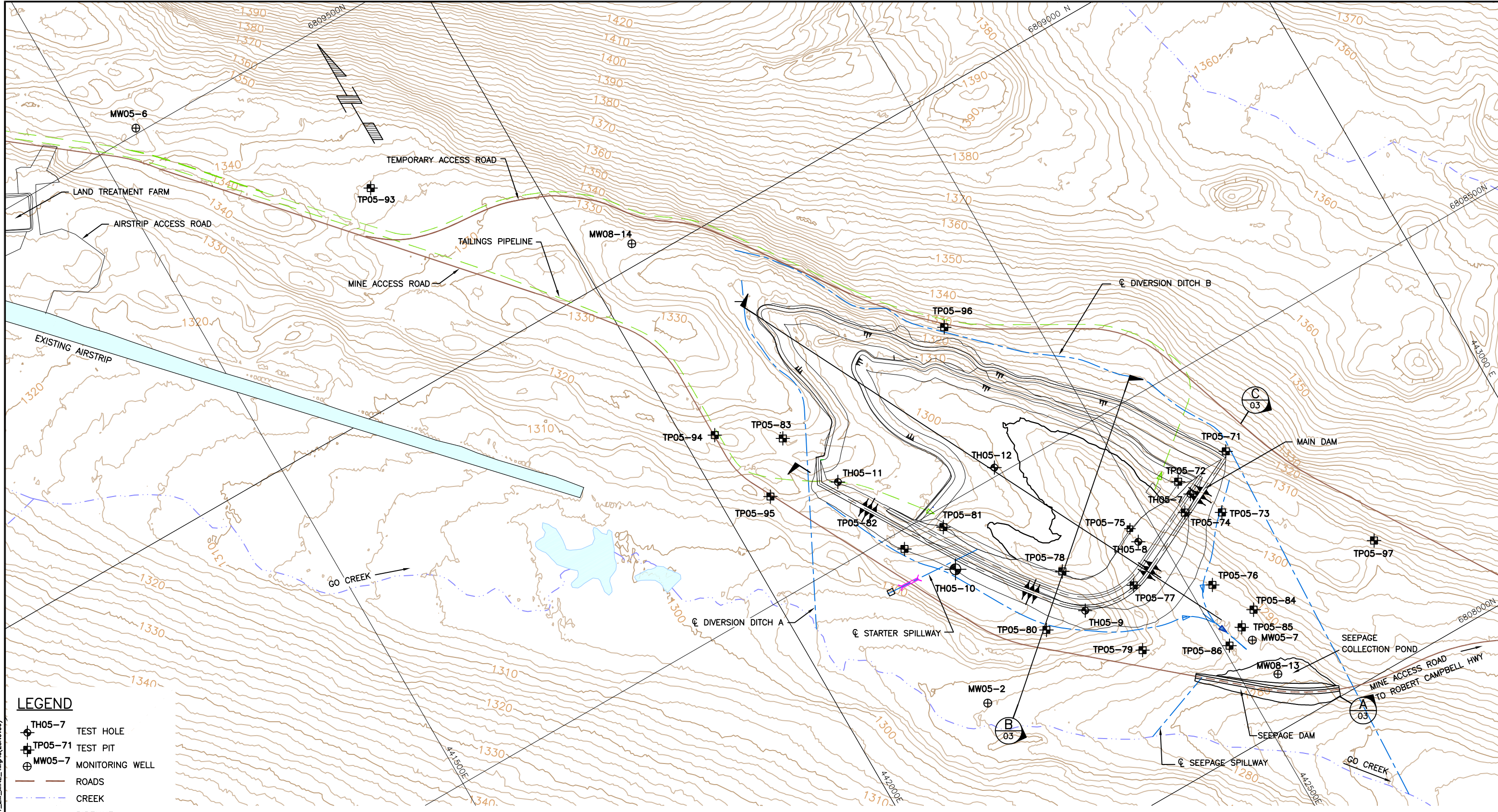
DRAWINGS

Drawing D-3001	General Arrangement
Drawing D-3002	Site Investigation Plan
Drawing D-3003	Subsoil Profiles
Drawing D-3004	Tailings Impoundment Plan and Storage Volumes
Drawing D-3005	Tailings Dam and Seepage Dam – Dam Sections
Drawing D-3006	Starter Impoundment Excavation and Fill – Plan
Drawing D-3007	Starter Impoundment Excavation and Fill – Sections
Drawing D-3008	Ultimate Impoundment Excavation and Fill – Plan
Drawing D-3009	Ultimate Impoundment Excavation and Fill Sections
Drawing D-3010	Starter Impoundment Schematic Sections
Drawing D-3011	Ultimate Impoundment Schematic Sections
Drawing D-3012	Impoundment – Closure Plan
Drawing D-3031	Starter Dam Spillway – Plan, Profile and Sections
Drawing D-3032	Diversion Ditch A – Plan, Profile and Sections
Drawing D-3033	Diversion Ditch B – Plan, Profile and Sections
Drawing D-3034	Closure Spillway – Plan, Profile and Sections

DRAWINGS

Drawing D-3001	General Arrangement
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Drawing D-3033	Diversion Ditch B Plan, Profile and Sections
Drawing D-3034	Closure Spillway – Plan, Profile and Sections

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- LEGEND**
- TH05-7 TEST HOLE
 - TP05-71 TEST PIT
 - MW05-7 MONITORING WELL
 - ROADS
 - CREEK
 - PIPELINE
 - DIVERSION DITCH

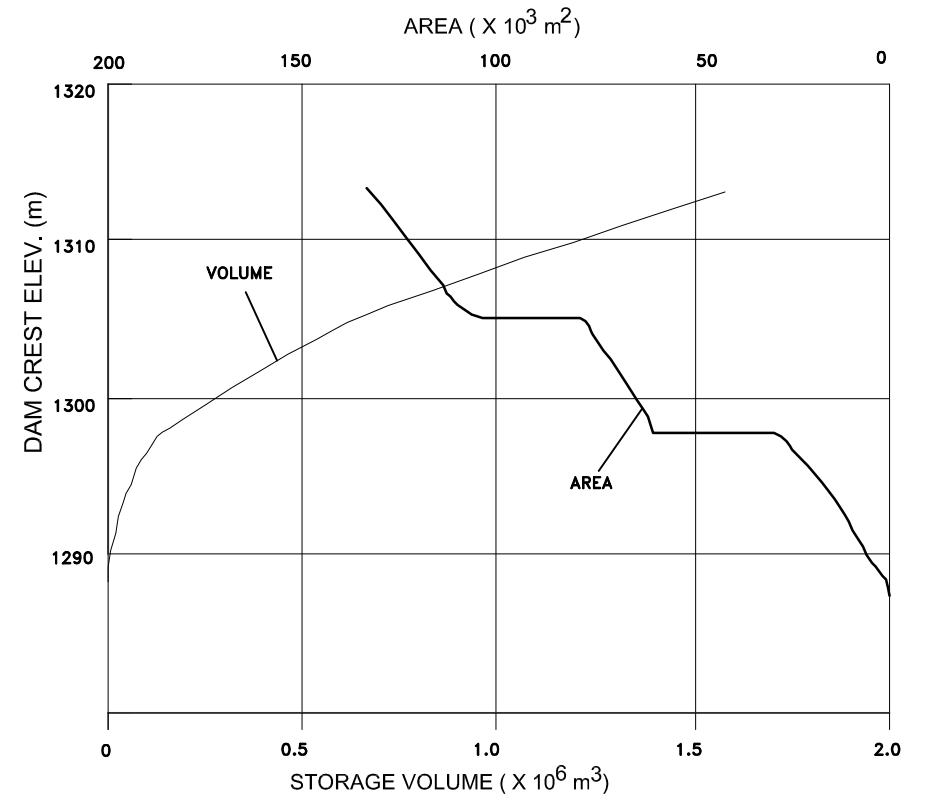
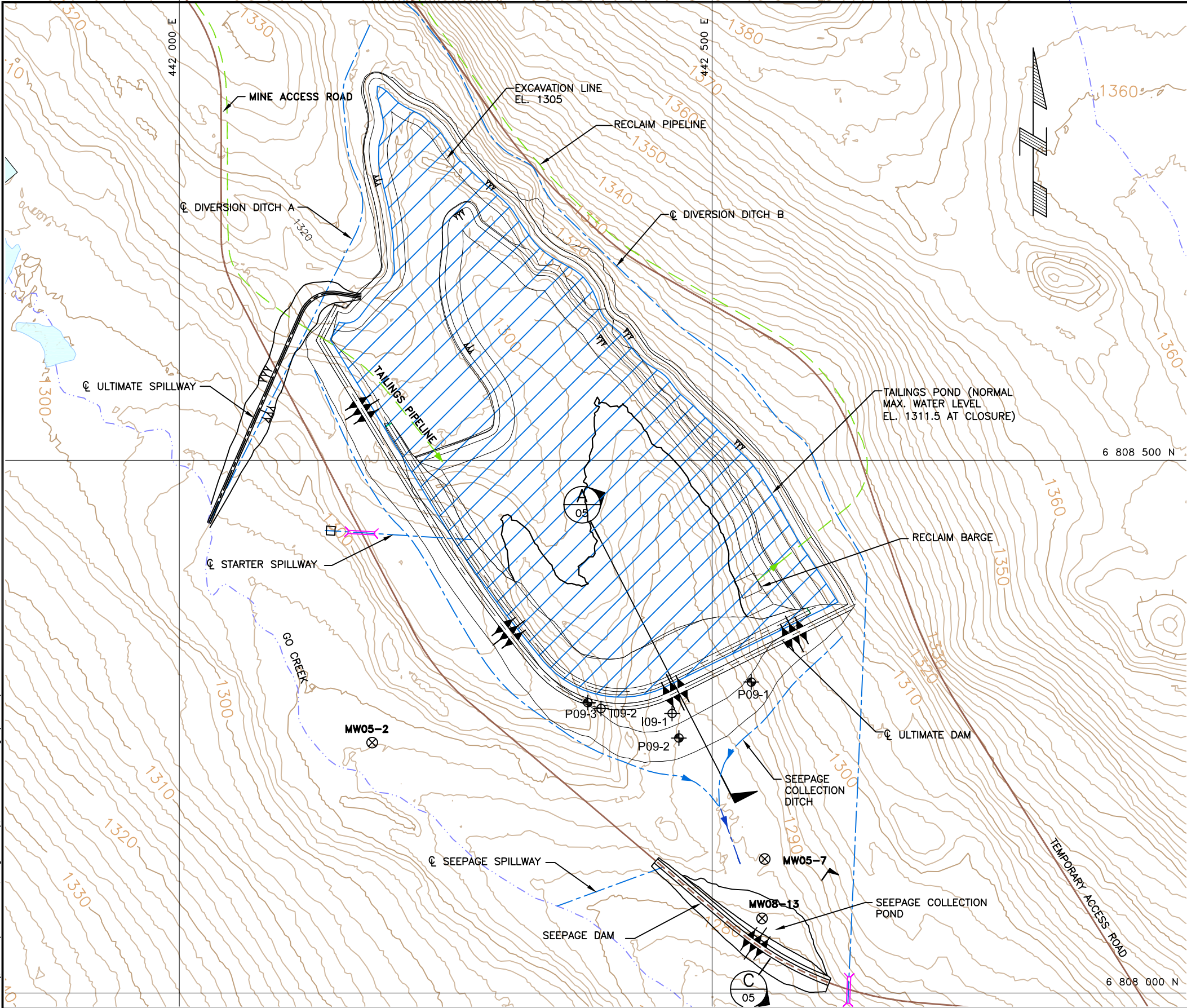
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TAILINGS IMPOUNDMENT STORAGE VERSUS DAM CREST ELEVATION

LEGEND

- ROADS
- CREEK
- PIPELINE
- DIVERSION OR COLLECTION DITCH, SPILLWAY
- CULVERT
- P09-1 PROPOSED DAM FOUNDATION PIEZOMETER
- I09-1 PROPOSED DAM FOUNDATION INCLINOMETER
- MW05-7 GROUNDWATER MONITORING WELL

NOTES

- SURFACE AREA SHOWN IN PLAN REFLECTS BORROW EXCAVATION WITHIN TAILINGS IMPOUNDMENT.
- IMPOUNDMENT VOLUME SHOWN IS STORAGE CAPACITY TO THE DAM CREST. FREEBOARD ALLOWANCE IS TO BE DEDUCTED WHEN DETERMINING THE AVAILABLE STORAGE CAPACITY.

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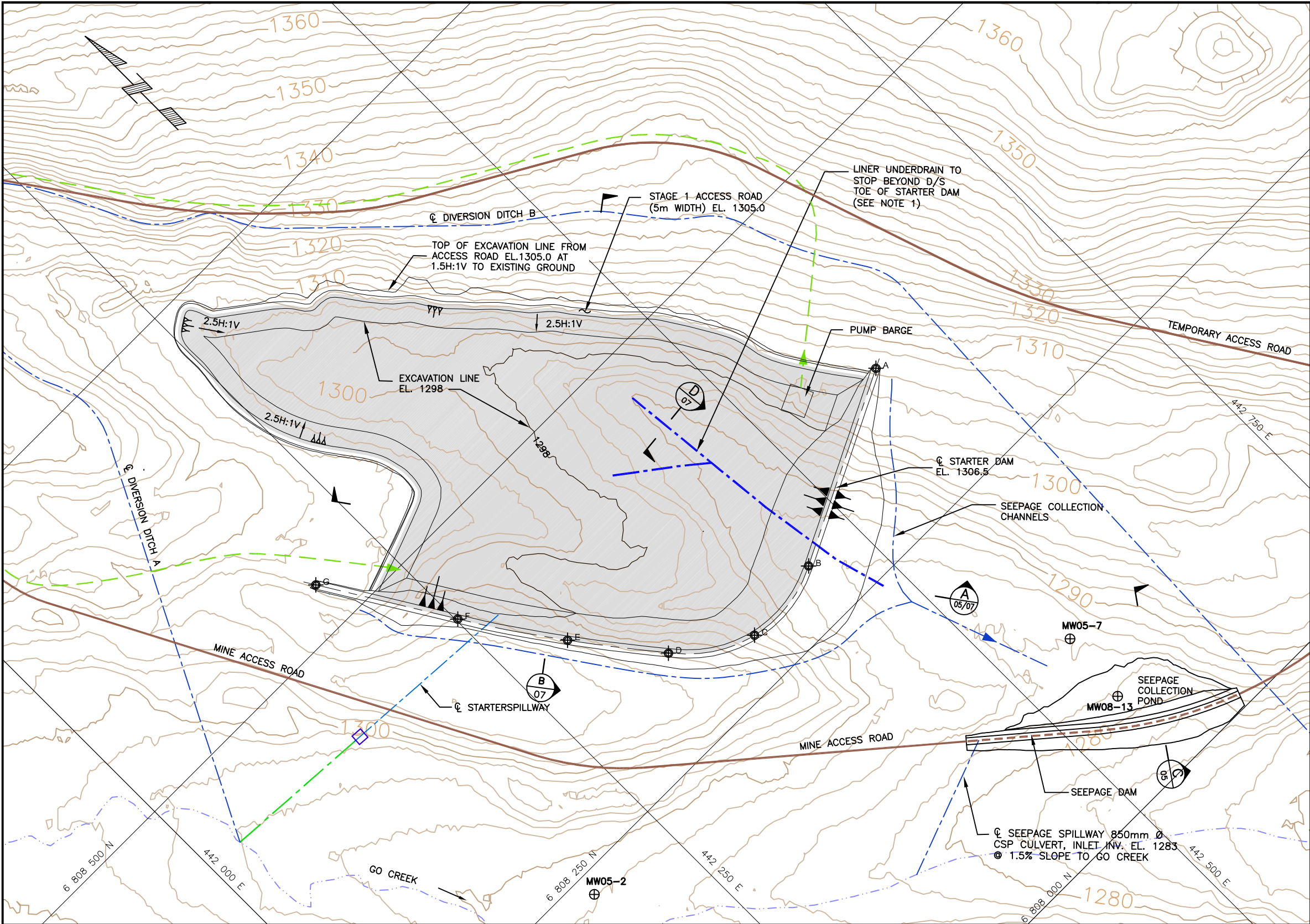
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Yukon Zinc
CORPORATION
WOLVERINE PROJECT
TAILINGS STORAGE FACILITY
TAILINGS IMPOUNDMENT -
PLAN AND STORAGE VOLUME



WORK POINTS		
No.	NORTHING	EASTING
A	6808358.95	442590.66
B	6808292.91	442456.28
C	6808285.21	442393.72
D	6808319.70	442340.96
E	6808377.49	442296.33
F	6808443.89	442251.38
G	6808533.25	442196.73

LEGEND

ROADS

CREEK

DIVERSION OR COLLECTION
DITCH, SPILLWAY

LINER UNDERDRAIN

OVERLAND FLOW

LINER AREA

MW05-7

GROUNDWATER MONITORING WELL

SURVEY STATION COORDINATES LISTED ABOVE

NOTES

1. LOCATION AND EXTENT OF LINER UNDERDRAIN WILL BE DETERMINED IN THE FIELD BY SITE ENGINEER, FOLLOWING THE LOWEST EXISTING DRAINAGE COURSE. THE UNDERDRAIN SHALL EXIT INTO A SOLID PIPE UNDER THE DAM AND INTO AN OPEN DITCH BEYOND THE DAM TOE.

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Yukon Zinc

CORPORATION

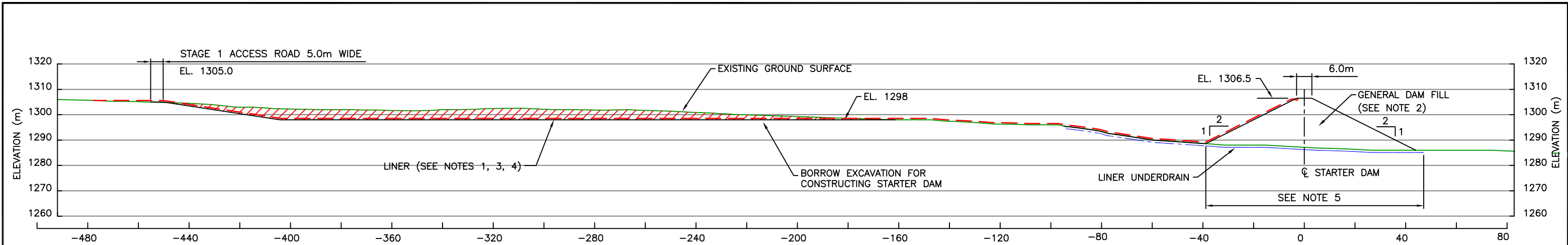
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TAILINGS STORAGE FACILITY

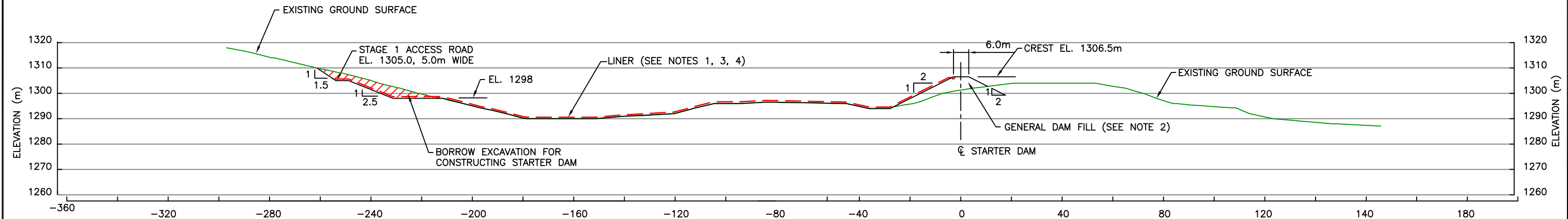
STARTER IMPOUNDMENT

EXCAVATION AND FILL PLAN

Klohn Crippen Berger



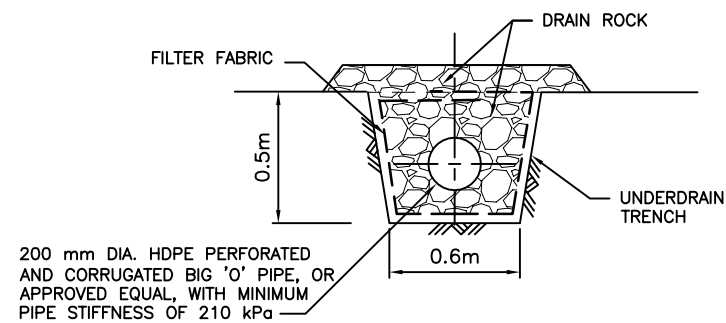
SECTION A (AT MAX VALLEY)
SCALE A
VERTICAL SCALE = HORIZONTAL SCALE



SECTION B (AT RIDGE TOP)
SCALE A
VERTICAL SCALE = HORIZONTAL SCALE

NOTES:

1. ALL LOOSE AND ORGANIC MATERIALS SHALL BE REMOVED, AND THE FOUNDATION SHALL BE PROFFROLLED WITH 6 PASSES WITH A 10 TON VIBRATORY ROLLER, AS DIRECTED BY THE ENGINEER. ALL FOUNDATION AREAS SHALL BE DRY AND APPROVED BY THE ENGINEER PRIOR TO PLACEMENT OF GENERAL FILL OR LINER.
2. GENERAL FILL TO CONSIST OF WELL-GRADED SILTY SAND AND GRAVEL BORROWED FROM IMPOUNDMENT EXCAVATION. FINER GENERAL FILL SHALL BE PLACED TOWARDS THE UPSTREAM SLOPE AS WELL AS ADJACENT TO THE GLACIAL TILL ZONE AND COARSER MATERIAL SHALL BE PLACED TOWARDS THE DOWNSTREAM SLOPE. MATERIAL SHALL BE PLACED IN 300 mm THICK LOOSE LIFTS, WATERED AS REQUIRED, AND COMPACTED TO 95% OF STANDARD PROCTOR DENSITY.
3. LINER FOUNDATION AREAS AND SLOPES SHALL BE PROFFROLLED WITH A SMOOTH DRUM COMPACTOR. ALL AREAS WITH COARSE ANGULAR MATERIALS SHALL BE COVERED WITH 150mm THICKNESS OF SCREENED SAND/GRAVEL, AS DIRECTED BY THE ENGINEER.
4. LINER SHALL CONSIST OF A 40mil ENVIRO-GEOSYNTHETIC LINER OR EQUIVALENT, AS APPROVED BY THE ENGINEER. LINER SHALL BE ANCHORED IN THE DAM CREST AND STAGE 1 ROAD IN A 0.6m DEEP TRENCH, BACKFILLED WITH COMPACTED FILL.
5. SOLID (NOT PERFORATED) UNDERDRAIN PIPE AND APPROVED IMPERVIOUS TRENCH BACKFILL SHALL BE USED BELOW THE DAM EMBANKMENT.

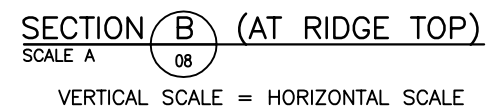
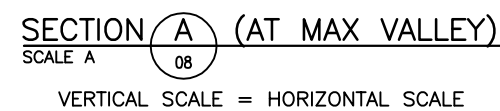


TYPICAL SECTION D LINER UNDERDRAIN
NTS

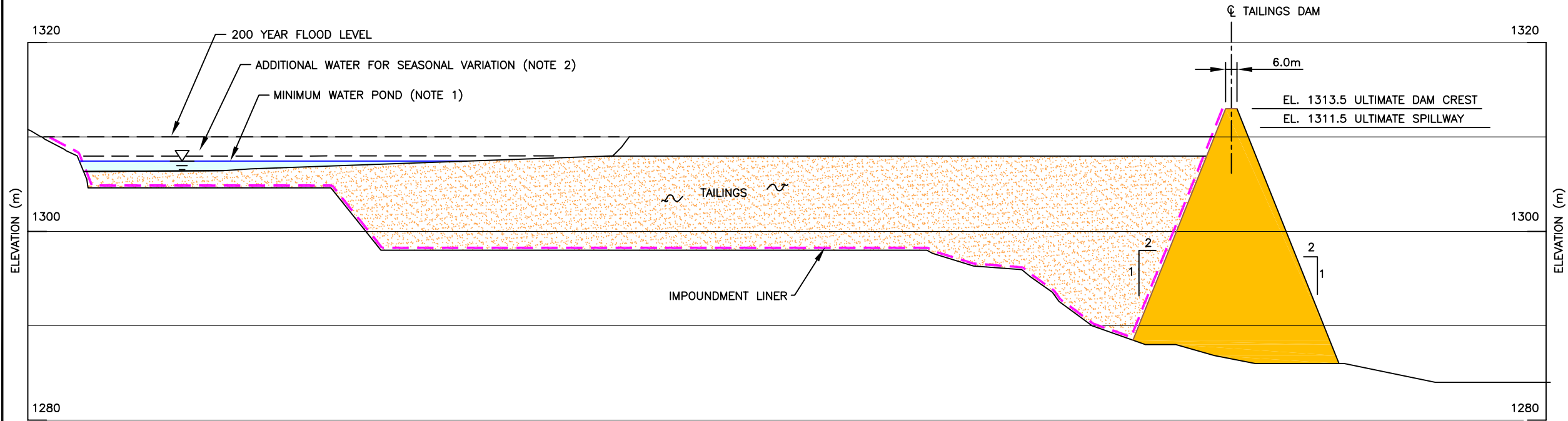
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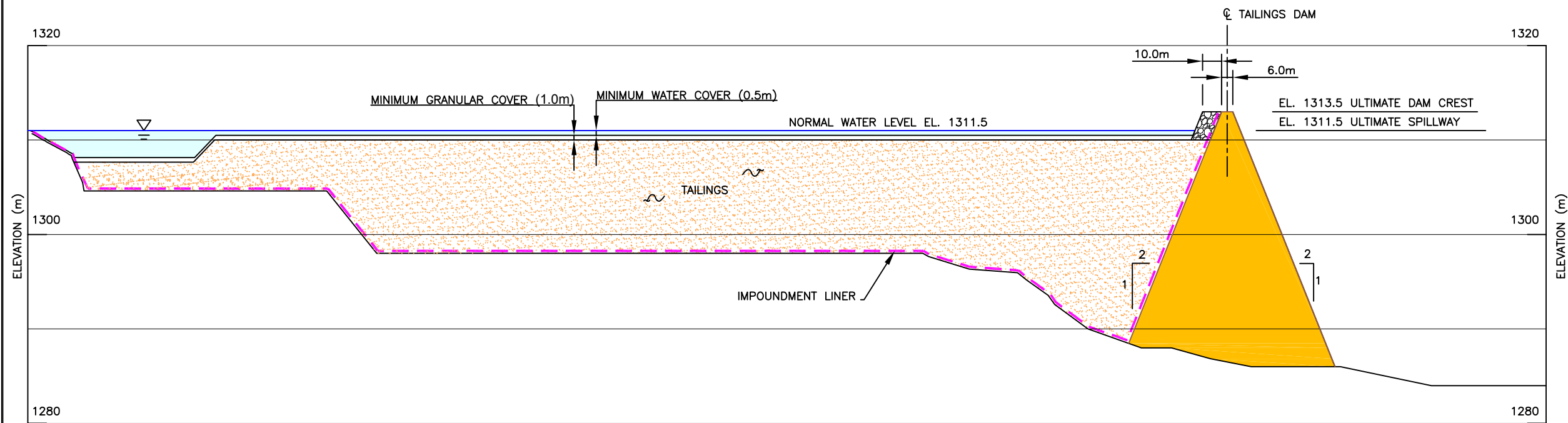
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[illegible]

Drawing File: M:\M09234A04-Wolverine Tailings Facility - Detail Design\400 Design\410 Drawings\c9\d-3000\wolverine-081217\ND-3011.dwg (awong)
Xrefs: ProgressStamp



TYPICAL SECTION YEAR 6



TYPICAL SECTION - CLOSURE

LEGEND

- SATURATED TAILINGS
- DAM EARTHFILL
- ROCKFILL

NOTES:

1. MINIMUM OPERATING POND ~ 40,000m³
2. SEASONAL STORAGE REQUIREMENT ~ 60,000m³
3. TRANSITION OF THE POND LOCATION FROM THE SOUTH SIDE WILL OCCUR IN APPROXIMATELY YEAR 7 TO A POND NEAR THE CLOSURE SPILLWAY (NORTH SIDE).

DRAFT

NOT FOR CONSTRUCTION

VERTICAL SCALE = 5X HORIZONTAL SCALE
HORIZONTAL SCALE 0 100 m

AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, THE REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL.

DWG. NO.	REFERENCE DRAWINGS

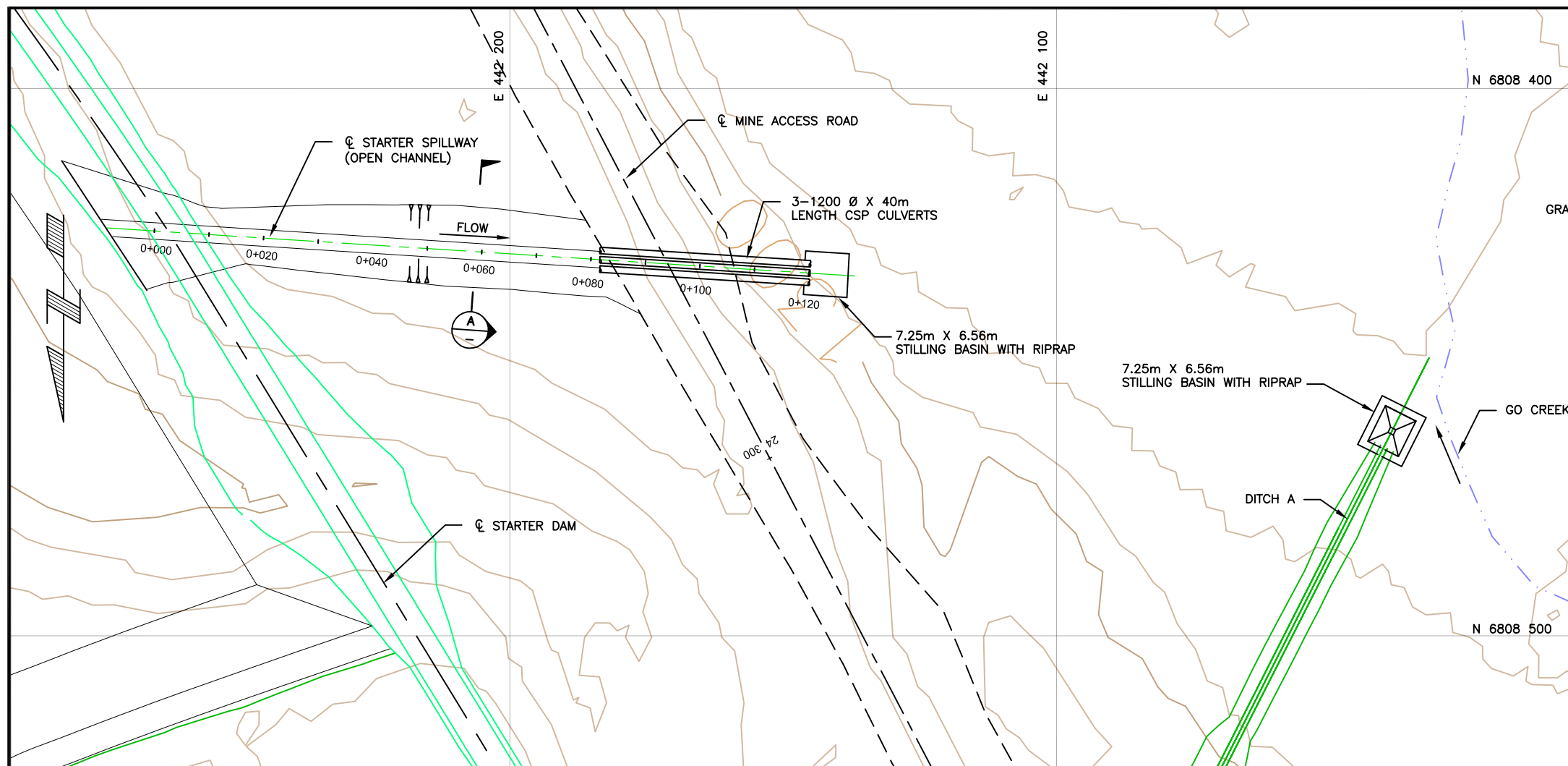
PROJECT	PROCESS	CIVIL	MECH.	STRUCT.	PIPING	SERVICES	ELECT.	INSTR.	NO	DESCRIPTION	BY	DATE

PROJECT	PROCESS	CIVIL	MECH.	STRUCT.	PIPING	SERVICES	ELECT.	INSTR.	NO	DESCRIPTION	BY	DATE

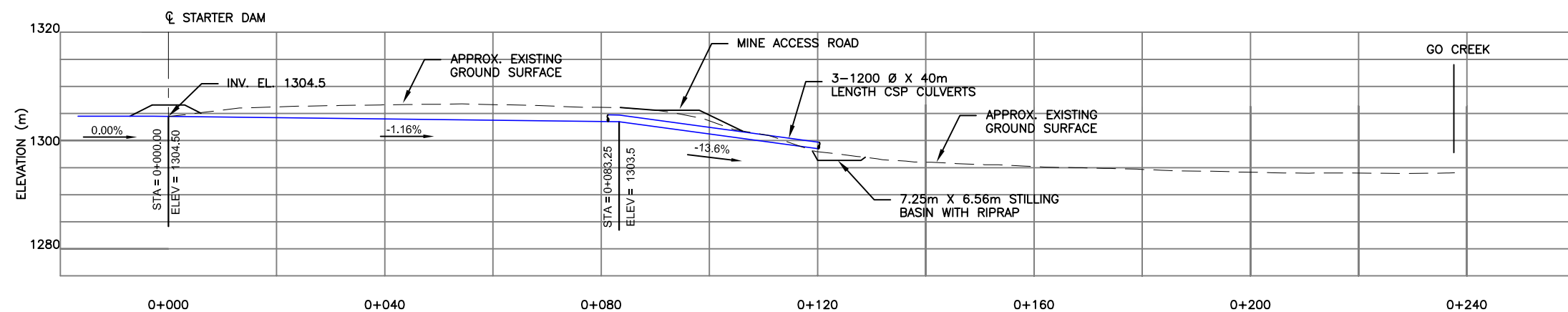
SECTION:	DATE
SCALE:	DEC 19/08
DESIGN. BY: DK	DEC 19/08
DRAWN BY: CYW	DEC 19/08
CHECK. BY: HM	---
APP. BY: HM	DEC 19/08

FILENAME:	PROJECT NUMBER	DRAWING NUMBER	REV.
-----	M09234A04	D-3011	A

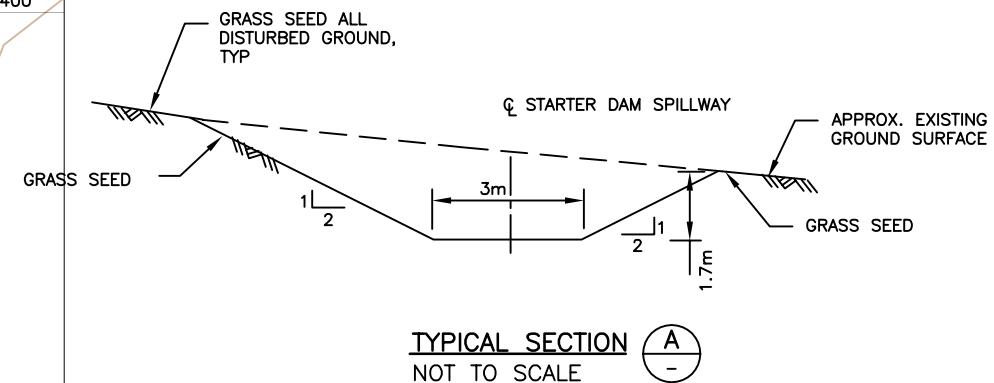
WOLVERINE PROJECT
TAILINGS STORAGE FACILITY
ULTIMATE IMPOUNDMENT
TYPICAL SECTIONS



PLAN
SCALE A



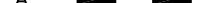
PROFILE - STARTER SPILLWAY
SCALE A



NOTES

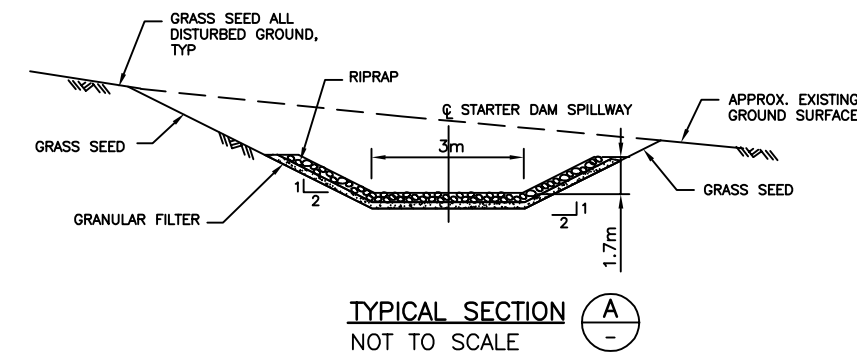
1. FOR GENERAL SITE ARRANGEMENT, SEE DWG. D-3001.
2. INVERT ELEVATIONS SHOWN ARE TO FINISHED CHANNEL BOTTOM.
3. FOR RIPRAP AND GRANULAR FILTER GRADATION AND LAYER THICKNESS, SEE TECHNICAL SPECIFICATIONS.

DRAFT **NOT FOR CONSTRUCTION**

SCALE A 

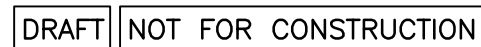
[illegible]

Scale: 1"=7(P5)
Drawing File: M:\M09234\02—Wolverine Feasibility Design & Enviro. Assess\400 Drawings\Feasibility—Study\071203—rev\Jan0208_d-401.dwg (cwrong)
Xrefs: Utilities\10Dec07



Material	Particle Size (mm)				Layer Thickness (mm)	
	D ₁₀₀	D ₈₅	D ₅₀	D ₁₅	Riprap	Filter
Riprap A	300	260	200	120	400	200 Filter 1
Riprap B	450	390	300	180	600	200 Filter 1
Riprap C	525	455	350	210	700	300 Filter 1
Riprap D	675	585	450	270	900	300 Filter 1
Riprap E	1200	1040	800	480	1600	300 Filter 1 + 400 Filter 2
Riprap F	1500	1300	1,000	600	2000	400 Filter 1 + 400 Filter 2
Filter 1	75	60 to 70	35 to 50	23 to 28	-	-
Filter 2	300	260	200	120	-	-

1. FOR GENERAL SITE ARRANGEMENT, SEE DWG. D-3001.
2. INVERT ELEVATIONS SHOWN ARE TO FINISHED CHANNEL BOTTOM.
3. FOR RIPRAP AND GRANULAR FILTER GRADATION AND LAYER THICKNESS, SEE TECHNICAL SPECIFICATIONS.

[illegible]