Mount Nansen
Options for Closure

Prepared for:
Assessment and Abandoned Mines Branch,
Department of Energy, Mines and Resources
Government of Yukon

Prepared by:
Lorax Environmental Services Ltd.
2289 Burrard St.
Vancouver, BC, V6J 3H9

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DRAFT

Table of Contents

Table of Contents

LIST OF FIGURES

LIST OF TABLES

1. Introduction

1. Introduction

1.1 Overview and Objectives

This document presents information in support of the evaluation of closure options for the Mount Nansen Mine, an abandoned gold and silver mine located 180 km north of Whitehorse (Yukon, Canada) and currently under the oversight of the Yukon Government (Figure 1.1-1). The report represents the synthesis of a large body of information generated since the site was abandoned in 1999. This report focuses on the technical evaluation of closure options, but also provides background information on the closure process, community engagement, and independent peer review.

The primary objective of this document is to provide the technical information necessary from which to evaluate the merits of the previously defined closure alternatives and ultimately select a preferred closure option for Mt. Nansen. This evaluation will be reviewed by Mt. Nansen stakeholders, including local communities, as well as federal, Yukon and First Nation governments. The design and performance of the closure options are specifically assessed with respect to geotechnical stability, water management, geochemistry, water quality, and costing. This document does not make recommendations with regards to a preferred closure option, nor does the report rank the options against specific closure criteria. Rather, the objective of this report is to provide the technical information required to form the basis for a closure decision framework.

The analysis presented in this report, and the level of detail provided with respect to design, performance and costing, has been conducted to the pre-feasibility level. In this context, geotechnical engineering and closure cost estimates are conceptual. Closure costs are defined as Class D estimates (or ASTM E2516-06 Class 5) and range from approximately -25% to +40% / +75%. Feasibility-scale information, which would include more detailed information with respect to final design specifications, implementation protocols, major equipment requirements, scheduling, and costing, will be generated for the final closure plan following selection of a preferred option or variation of options.

Discussion of risk is restricted to key geotechnical elements (*e.g.*, dam failure). For other components (geochemistry, water balance, hydrogeology), a formal risk assessment is not included. Rather, general discussions of uncertainty as they apply to performance are provided. The Yukon Government has proposed that a formalized risk assessment for all components be the topic of a forthcoming workshop involving all stakeholders following review of this document.

1.2 Report Structure

Following this introduction, relevant background information to the project is provided with respect to site history, closure issues, progressive remediation measures and site investigations (Chapter 2). The framework for mine closure is described in Chapter 3, which provides a chronology of the closure planning process, closure objectives and scheduling. Within Chapter 3, details of the community engagement process and independent peer review are presented. The history surrounding the development of the various closure alternatives is presented in Chapter 4, and provides a chronology detailing the options initially proposed in 2008 (Yukon Government, 2008), those further evaluated in 2009 (AECOM, 2010), and those alternatives carried forward for the prefeasibility evaluation presented herein.

Chapter 5 presents the results of the prefeasibility assessment with regards to the various short-listed closure options. For each closure alternative, the objectives, key assumptions, performance and uncertainty are discussed with respect to the various technical disciplines, including geotechnical, water management, geochemistry, water quality, and closure costing. Closure elements common to all closure options (mill site restoration, road decommissioning, *etc*.) are also described.

1.3 Acknowledgements and Supporting Documentation

The work summarized in this report has been carried out in collaboration with Gomm Environmental Engineering Consulting and AECOM. Altura Environmental Consulting (Altura) and Golder Associates have also provided key contributions to this report. Environmental Dynamics Incorporated (EDI) has also provided essential support with sample collection and water quality monitoring.

Several attachments are included with this report. These attachments are largely technical in nature and provide supporting information as follows:

Appendix A: Stakeholder Comments on Previous Closure Reporting (Little Salmon Carmacks First Nation, INAC, and IPRP)

Appendix B: Geochemical Characterization (Lorax Environmental Services Limited)

Appendix C: Geotechnical Engineering (AECOM), Water Management (AECOM and Golder Associates), and Costing (AECOM and Altura Environmental Consulting)

Appendix D: Climate and Hydrology Characterization (AECOM)

Appendix E: Hydrogeology Characterization (AECOM)

Appendix F: Water Balance and Water Quality Modeling (Gomm Environmental Engineering Consulting)

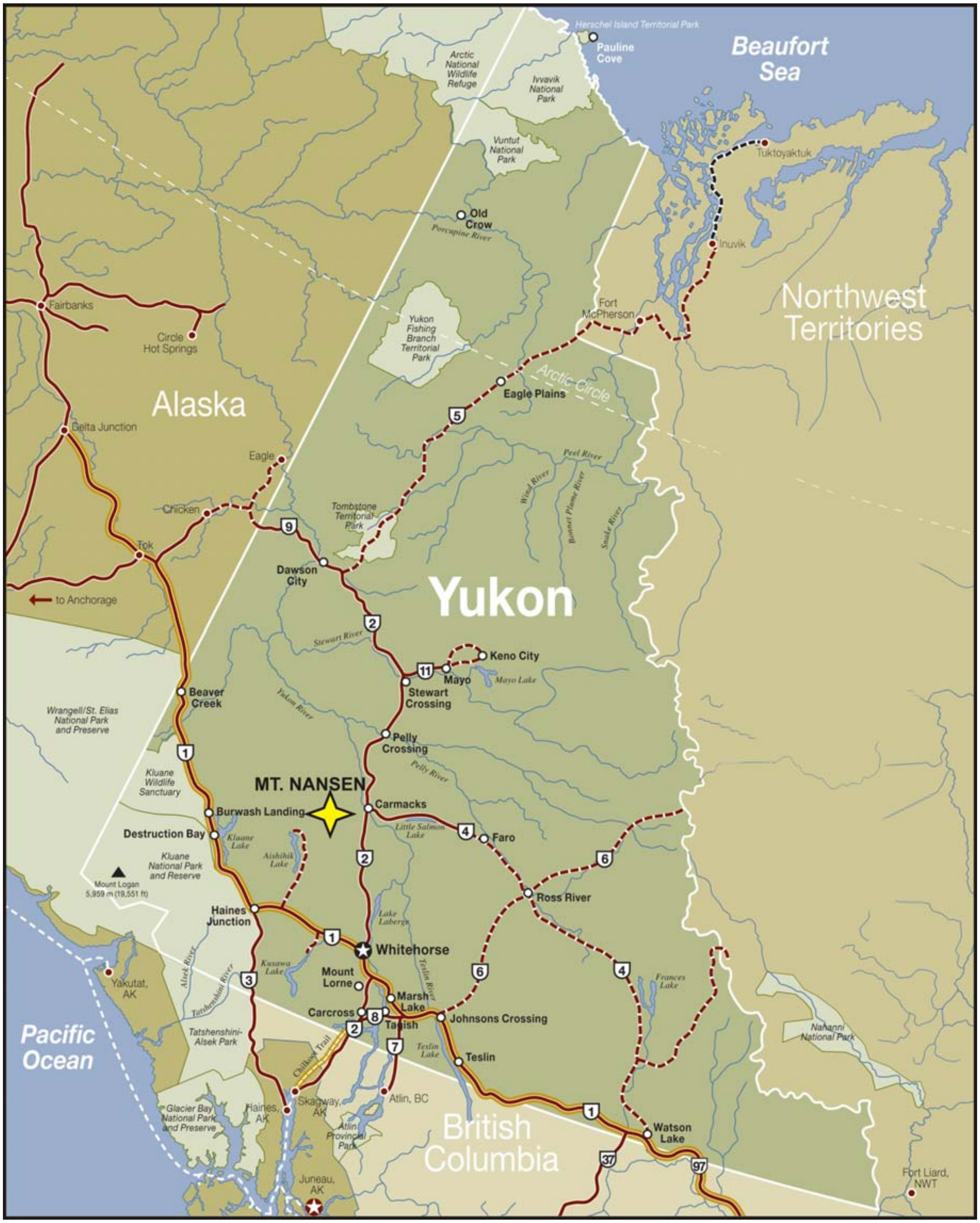


Figure 1.1-1: Mt. Nansen Site Location Map

2. Background

2. Background

2.1 Site Location and History

The Mt. Nansen Mine is an abandoned gold and silver mine located 60 km west of Carmacks, and 180 km north of Whitehorse (Yukon, Canada) (Figure 1.1-1). The current property covers approximately 1,200 ha and is within the Little Salmon Carmacks First Nation traditional territory. The mine is accessible year round by a 60 km long, all-weather road from Carmacks, Yukon.

Exploration in the Mt. Nansen project area commenced in the 1940s, with mining operations occurring over three discrete periods beginning in the late 1960's. Between 1968 and 1969, approximately 10,000 tonnes of flotation tailings were generated from ore mined from the Huestis and Webber underground developments. The operation closed down due to poor gold and silver recoveries. At this time, the Brown-McDade deposit was explored underground from an adit collared adjacent to Pony Creek. During the second period of mining between 1975 and 1976, approximately 5,000 tonnes of ore from the Huestis deposit were processed through the existing mill. Again, poor recoveries forced the premature closing of this operation. The last stage of active mining occurred between 1996 and 1999, during which time BYG Natural Resources Inc. (BYG) accessed ore from the Brown-McDade zone. This open pit operation processed approximately 269,000 tonnes of ore through the existing mill at a production rate of approximately 500 tonnes per day, producing approximately 35,700 ounces of gold. BYG ceased operations in February, 1999 due to difficulties meeting their water license requirements, lower than expected gold and silver recoveries, and an inability to meet required financial security payments. The BYG operation was further compounded by environmental concerns during the later stages of operations relating to the geotechnical and operational aspects of managing the tailings facility (*i.e.*, tailings dam), as well as a failure to meet effluent toxicity requirements.

Operations ceased in early February 1999 following the declaration of voluntary receivership by BYG, with D. Manning and Associates Inc. appointed as receiver for physical assets. Following resignation by D. Manning and Associates, responsibility was subsequently transferred to the federal Department of Indian Affairs and Northern Development (DIAND/INAC) as an abandoned site in August 1999. In April 2003, the Devolution Transfer Agreement between Canada and the Yukon came into effect and project management was transferred to the Government of Yukon (GY) who continues to oversee the care and maintenance for the site.

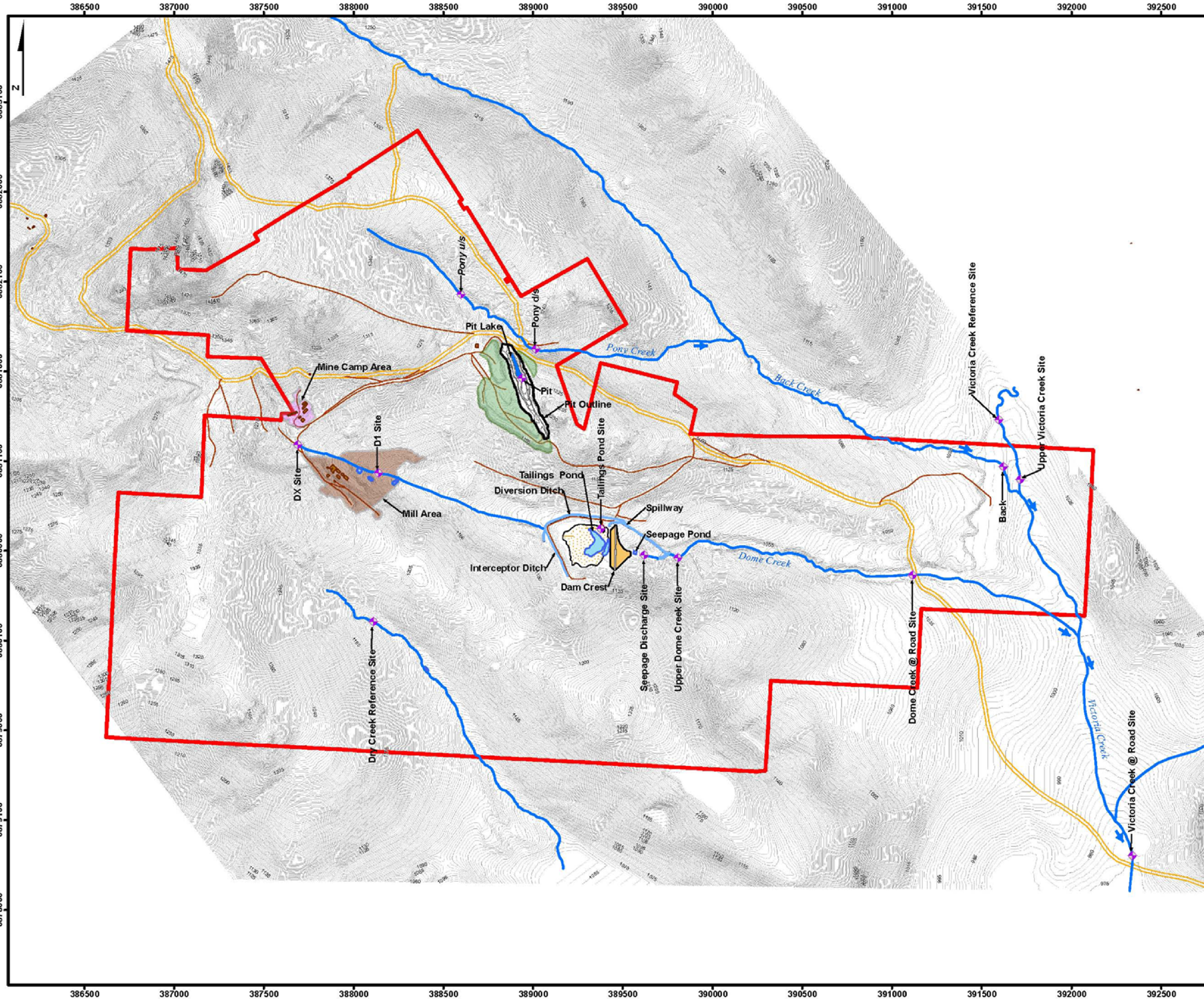
GY has enacted an Order-In-Council (OIC) placing a prohibition from staking (quartz and placer) over approximately 1,200 hectares of land covering the mine site footprint. Such measures will not permit re-staking this ground and thereby minimize interference with remedial efforts (Figure 2.1-1).

2.2 Closure Issues

The Mt. Nansen property is defined by the Mt. Nansen Order In Council (OIC) Boundary identified in the 2006 Yukon OIC (Figure 2.1-1). As detailed in the report "Options for Closure of Mt. Nansen" (Yukon, Energy, Mines and Resources, 2008), the primary closure issues include the stability of the tailings impoundment, water quality and site infrastructure. Related mine features are summarized in Table 2.1-1 and illustrated in Figure 2.1-1. Detailed discussions of the existing liabilities with respect to geochemical and geotechnical aspects are provided in Appendices B and C, respectively.

Table 2.1-1:
Summary of existing closure issues at Mt. Nansen Mine

Tailings Impoundment	• Tailings dam: potential for dam instability associated with inadequate construction (foundation stripping, compaction of fill, and beach development) and permafrost degradation. • Diversion structures and spillway: upgrades required to ensure adequate sizing and stability. • Seepage rate: higher than expected seepage rates due to inadequate tailings beach development and suspect or missing dam liner (per design). • Seepage water quality: metal leaching of arsenic associated with reductive dissolution in saturated zones. Potential for development of acid rock drainage in unsaturated zones.
Open Pit	• Potential hazard for people and wildlife. • Water quality: elevated levels of As, Cd, and Zn. • Current form not compatible with traditional land use.
Waste Rock / Ore	• Neutral mine drainage with elevated levels of Cd and Zn. • Potential for localized acid rock drainage (ore) • Angle of repose slopes are not compatible with traditional land use.
Mill Site	• Infrastructure: only partial decommissioning has occurred. • Potential for contaminated soils to be addressed. • Drainages from historic workings and/or mine waste contribute significantly to loadings of mine-related parameters to Dome Creek.



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Legend

- Surface Water Quality Stations
- Mine Road
- Public Road
- Mt. Nansen OIC Boundary
- Mill Area
- Mine Camp Area
- Tailings Dam
- Ponds
- Tailings
- Mine Infrastructure
- Pit Outline
- Waste Rock Area

Topography (Except Pit)

- Index (5m)
- Interm. (1m)

Meters: 0, 335, 670, 1,340

Data courtesy of AECOM — Figure for illustrative purposes only

SCALE:	1:20,000
DATE:	NOV 2nd, 2010
PROJECTION:	NAD_1983_UTM_Zone_8N
PROJECT MANAGER:	J.S.

PROJECT:
Mount Nansen Water Balance and Water Quality Predictions

TITLE: **Mount Nansen Mine Site Current Conditions and Surface Water Quality Monitoring Stations**

PROJECT No:	FIGURE No:
J907-4	**2.1-1**

LORAX ENVIRONMENTAL

2289 Burrard St. Vancouver, BC V6J 3H9
Phone: (604) 688-7173
Website: www.lorax.ca

2.3 Remediation Measured Completed to Date

A chronological summary of remediation measures completed to date at the Mt. Nansen property is presented in Table 2.2-2.

Table 2.2-2:
Summary of remediation measures completed to date at Mt. Nansen Mine

Mine Area	Remediation Measure	Year
Tailings Impoundment	• Water treatment to achieve water license discharge standards • Replacement of seepage control dyke. • Upgrading of emergency spillway. • Installation of seepage capture dam. • Installation of monitoring wells.	1999-2004 2000 2000/2001 2001 2009
Open Pit	• Installation of hydraulic plug in Pony Creek Adit to improve portal stability and reduce potential for hydraulic connection between pit and Pony Creek. • Installation of groundwater monitoring wells	2006 2007 & 2009
Waste Rock	• Relocation of ~5,000 m^3 of wasterock in Pony Creek area to open pit • Relocation of ~8,000 m^3 of low-grade ore stockpile to open pit	2008 2009
Mill Site	• Removal of hazardous chemicals • Demolition of mill crusher building • Huestis portal rehabilitation • Test filling of old exploration trench	2006 2009 2007 2008

2.4 Site Investigations

Since the shutdown of operations in 1999, numerous site investigations in support of closure planning for the site have been conducted during the care and maintenance period. The studies have examined various aspects relevant to site closure, including those relating to health and safety, economic potential, fish and wildlife management, terrestrial and aquatic effects, geotechnical stability, tailings and waste rock geochemistry, hydrology, hydrogeology and reclamation. Brief descriptions of the investigations and reports produced to date are provided by GY (2008). Copies of these documents are available for review from the Government of Yukon, Department of Energy, Mines, and Resources, Assessment and Abandoned Mines Branch.

Since 2008, numerous technical investigations have been completed and are incorporated into this closure synopsis. These evaluations include the technical appendices and their supporting documentation (Section 1.3), as well as additional technical evaluations referenced within this document.

3. Closure Planning Framework

3. Closure Planning Framework

3.1 Governance

In April 2003, management of the Mount Nansen Mine Site was devolved to the Government of Yukon (GY) with funding provided through the government of Canada. Mount Nansen is defined as a "Type II Site" as identified in the "Yukon Northern Affairs Program Devolution Transfer Agreement". Under the devolution transfer agreement, Canada, GY, and the Little Salmon/Carmacks First Nation (LSCFN) have agreed to cooperate in matters relating to the remediation of the site. Management of Type II Sites, including Mt. Nansen, is directed by the Type II Steering Committee which includes representatives from Indian and Northern Affairs Canada (INAC) and Government of Yukon, Department of Energy and Mines (GY).

In 2006, a contribution agreement was signed between GY and LSCFN to formally acknowedge cooperation between the two governments, and supporting their common involvement in the project. GY, LSCFN, and Canada continue to develop a final closure and remediation plan that will address the historical environmental liabilities associated with the Mt. Nansen property. Yukon, together with the LSCFN and Canada, are working towards a final closure and remediation plan to be submitted through the *Yukon Environmental and Socio-economic Assessment Act* (YESAA) process.

A technical working group involving Canada, LSCFN, and Yukon has been established to discuss technical and scientific studies and their implementation into the final closure and remediation plan. In this regard, a diverse team of technical consultants has conducted numerous investigations for the Mt. Nansen technical working group on a wide range of closure planning aspects and disciplines.

GY, LSCFN technical advisors, INAC, and the INAC Independent Peer Review Panel (IPRP) have provided feedback on previous closure reporting (AECOM, 2010). These comments have been incorporated into the following report and are included in Appendix A for reference. A summary and checklist of the most salient comments are also provided in Appendix A.

3.2 Closure Objectives

Closure objectives for the Mt. Nansen Project were established through stakeholder consultation and were developed to aid in the closure planning process. Closure objectives capture the interests and values of the stakeholders and include objectives that may not be recognized by all technical disciplines or assessments. A detailed discussion on closure objectives is provided in GY, 2008 (Section 4 and Appendix C).

Closure objectives were developed through the following input and consultation:

- LSCFN Traditional Knowledge and community values interviews;
- A mine tour and objectives discussion were held with Chief, Council, staff members, and other citizens to sequester feedback with regards to objectives for closure;
- A community meeting was held to identify community interests related to closure objectives;
- Advice and input was received from the LSCFN technical advisor;
- The Town of Carmacks (Mayor and Council) deferred to LSCFN regarding objective development;
- Mayor and Council have confirmed that community interests have been adequately covered from their perspective;
- GY departments and EMR Branches were consulted on GY objectives through the internal YESAA Practitioners' Forum; and
- Canada departments reported to INAC and included input from the Department of Fisheries and Oceans, Environment Canada, Health Canada, and INAC.

GY and INAC facilitated discussions with Canada departments with respect to the community-based development of closure objectives. INAC consensus was not met on all objectives; further, INAC expressed concerns regarding the feasibility of some of the community objectives.

Additional follow up was completed at subsequent community meetings to address outstanding or unresolved issues. The community objectives were then finalized by GY. The entire process for the development of closure objectives for the Mt. Nansen property took approximately 18 months.

Major closure objectives for the Mt. Nansen Project include the following:

- Protect human health and safety;
- Protect the environment including land, air, water, fish and wildlife;
- Return mine site to an acceptable state that reflects original use where possible;
- Maximize local, Yukon and First Nation benefits; and
- Reduce government liability and risk management.

Detailed descriptions of closure objectives are available in GY, 2008 (Section 4 and Appendix C).

3.3 Consultation

GY has maintained ongoing consultation with the Little Salmon/Carmacks First Nation (LSCFN), the broader community of Carmacks, and other government departments and agencies on the Mt. Nansen Project since 2003.

Little Salmon / Carmacks First Nation (LSCFN) and the Community of Carmacks

Between 2003 and 2006, the majority of consultation with LSCFN was maintained through the GY Lands Director. During this time, GY held regular community meetings to inform the LSCFN and to provide a venue for feedback. Yearly updates were also provided to the LSCFN Chief and Council. Traditional knowledge interviews and input to technical investigations were accomplished to the satisfaction of the LSCFN in 2005. Capacity limitations hindered LSCFN from more active involvement during this period.

In 2006, a full time coordinator and assistant were hired by GY to facilitate communication with the LSCFN. Regular community meetings, organized community mine tours, as well as local involvement and participation have nurtured collaborations. GY and LSCFN cooperate in the release of newsletters and articles in the local paper, and distribution of brochures and posters to the community which summarize the results of technical investigations.

LSCFN representatives also participate in on-going environmental monitoring at the site. GY staff and the LSCFN Coordinator update Chief and Council on a regular basis. Further, LSCFN technical advisors participate in closure planning workshops and are actively involved in the evaluation of closure options.

Other Governments and Agencies

Periodic updates on the progress and issues at Mt. Nansen are provided to GY Community Services, GY-Environment, DFO, Health Canada and Environment Canada. These and other departments are also contacted for input or discussion when pertinent issues or questions arise.

As funding for the site is provided by Canada under the Federal Contaminated Sites Action Plan, quarterly reports on the status of the mine site are prepared by the regional INAC Environment Directorate with information from the GY Project Manager. These reports include information on site employment, work hours, proportion of work conducted by First Nations and northerners, safety statistics, safety training, accidents or near misses, and a yearly work plan schedule review. Fourth quarter reporting includes additional information on remaining site liabilities and budget details. These reports are sent to relevant regional directors and INAC Headquarters in Ottawa.

4. Development of Closure Options

4. Development of Closure Options

4.1 Initial Proposed Closure Options

Initial closure options for the Mt. Nansen Site were outlined in a Government of the Yukon publication titled "*Options for Closure of Mt. Nansen Mine – Technical Review Version*" (GY, 2008). The purpose of this document was to identify viable closure options for consideration by stakeholders. The report included numerous closure options for the main components of the mine site, including the tailings storage facility (TSF), waste rock piles, and open pit. The options presented for the tailings included:

- Upgrade the dam and leave tailings in place with contouring and potential cover;
- Relocate tailings out of Dome Creek to a new facility adjacent to Dome Creek below the current TSF;
- Relocate tailings to the Brown-McDade open pit; or
- Freeze tailings in-situ.

The options presented for the open pit included:

- Leave the pit as is, with no infill;
- Partially backfill the pit with waste rock and/or tailings; or
- Completely backfill the pit with waste rock and/or tailings.

Each of the options for the tailings and the pit was assessed for technical feasibility and economical viability. As well, a preliminary risk assessment was presented.

4.2 Options Screening Evaluation

In March 2009, GY, AECOM, and Lorax hosted a workshop and data gap analysis with Mt. Nansen stakeholders. The objectives of the workshop were to identify and prioritize data gaps, as well as to discuss, identify, and screen viable closure options for further evaluation. The following five closure alternatives formed the basis of discussion during the workshop:

- 1 – Care and maintenance for entire site (Status Quo);

- 2 – Care and maintenance for the Tailings Storage Facility (TSF) with partial or complete pit backfill with waste rock;
- 3 – Upgrade TSF with partial or complete pit backfill with waste rock;
- 4 – Relocate all tailings to pit and decommission TSF with options to partially or completely backfill the open pit with waste rock; and
- 5 – Decommission TSF, restore Dome Creek, and create new TSF, with options to partially or completely backfill the open pit with waste rock.

4.2.1 Alternatives Excluded from Future Consideration

Status quo closure options (Alternative 1 and 2) were included on the alternatives list as a point of comparison or base case. During the March 2009 Workshop, consensus was achieved that care and maintenance of the TSF (*i.e.*, status quo) did not represent a viable closure for the Mount Nansen site. This conclusion was based on the following considerations:

- Residual geotechnical risks associated with the tailings dam:
  - Foundation built upon unstable permafrost; and
  - Diversion ditches and spillway construction are not suitable for closure and require seasonal maintenance.
- Residual geochemical risks associated with the tailings:
  - Due to water management considerations associated with dam stability, large portions of the tailings remain unsaturated and therefore pose a risk for development of acid mine drainage in the long-term.

Additional residual risks associated with the "status quo" include the following:

- Open pit (physical hazard);
- Pit lake (water quality);
- Pony Creek Adit (potential pathway for pit lake discharge to Pony Creek);
- Waste rock reclamation (regrade and revegetation);

- Mill contamination, demolition, and reclamation; and
- Site restoration and revegetation (exploration trenches, roads, mine camp, pipelines, power lines, and other infrastructure and clearings).

Closure Alternative 5 (relocation of the TSF to another impoundment in the Dome Creek catchment) was identified as a last resort alternative that should only be explored in the event Alternatives 3 and 4 were found to be unfeasible. Given the feasibility of Alternatives 3 and 4, Alternative 5 was excluded from further consideration. Further, consensus was achieved that Option 5 would not adequately address the geochemical and geotechnical residual risks associated with the tailings due to the following:

- Increase in overall tailings disturbance area;
- Feasibility of relocating fine-grained tailings to a hill-slope TSF;
- Long-term geotechnical stability for a hill-slope TSF underlain by permafrost; and
- Long-term geochemical stability of unsaturated tailings within a hill-slope TSF.

4.2.2 Alternatives Selected for Further Evaluation and Refinement

Following the data gap workshop, a planning workshop was hosted by AECOM, Whitehorse in April, 2009. Various consultants and Mt. Nansen stakeholders and/or their technical representatives participated in the workshop. The purpose of the planning workshop was to develop work plans to address data gaps identified previously, and to organize a staged approach for evaluating alternatives for closure. Based on stakeholder feedback during the March and April, 2009 workshops, four viable alternatives were selected for Mt. Nansen. These options were prioritized for further refinement, characterization, and evaluation as follows:

- 3A - Upgrade TSF (reinforce tailings dam and cover tailings) with no backfill of waste rock or open pit reclamation;
- 3B - Upgrade TSF (reinforce tailings dam and cover tailings), backfill open pit with waste rock;
- 4A – Excavate and relocated tailings (wet or dry) to the open pit, restore Dome Creek valley; and

- 4B - Excavate and relocated tailings (wet or dry) with waste rock to the open pit, restore Dome Creek valley.

Work plans were developed during the closure planning workshop (April, 2009) and implemented during the summer of 2009. The alternatives were evaluated in terms of geotechnical stability, geochemistry, climate and hydrology, hydrogeology, and potential impacts to surface water quality. The culmination of this work was summarized in a closure options evaluation by AECOM (2010) titled "*Overview of Mt. Nansen Closure Alternatives Characterization*". Although the work presented in AECOM (2010) helped to advance the overall process of selecting a preferred option, the residual risks and uncertainties presented within the report were deemed too significant to select a closure option for further advancement in the closure process.

4.3 Options Recommended for Prefeasibility Assessment

In order to advance the closure planning process, GY hosted a Mt. Nansen stakeholder workshop in April 2010 to develop a path forward. Representatives from AECOM, GEEC, and Lorax participated in the workshop in addition to the project stakeholders (GY, LSCFN, and INAC). During the workshop, the stakeholders expressed concern that the degree of uncertainty associated with several alternatives was too large and prevented meaningful comparison of closure alternatives to allow selection of a preferred option for closure. Detailed comments from the Mt. Nansen stakeholders are provide in Appendix A.

GY hosted a 2010 kickoff workshop in June, 2010. Representatives from AECOM, GEEC, and Lorax participated in the workshop in addition to the project stakeholders (GY, LSCFN, and INAC). Two notable outcomes from the workshop included: 1) further refinement of closure options; and 2) specific work plans for addressing areas of uncertainty. Refinement of the closure options resulted in specific details to the closure design (*e.g.*, tailings cover design) and resulted in a more focused plan to base future technical investigations (*e.g.*, tailings water balance). Specific work plans were devised to address specific areas of uncertainty. Further, an integrated approach between the various technical consultants was developed in an effort to provide a consistent, balanced evaluation of each options performance, risks, and benefits. A new naming convention for closure options was also developed as follows:

- Options 1A and 1B: Tailings Dam Upgrade with Water Cover (Option A denotes waste rock in place; Option B denotes pit backfill with waste rock);

- Options 2A and 2B: Tailings Dam Upgrade with Saturated Soil Cover (Option A denotes waste rock it in place; Option B denotes pit backfill with waste rock);
- Option 3: Tailings (Wet) Backfill into Pit with High Infiltration Cover, Waste Rock in Place; and
- Option 4: Tailings (Dry) and Waste Rock Backfill into Pit with Low Infiltration Cover.

The closure options listed above form the basis for the technical evaluation presented in this report. Closure options are presented in Chapter 5, and discussed with respect to purpose, performance, and uncertainty with respect to the following technical components: geotechnical engineering, water management, geochemistry, water balance (climate, hydrology, hydrogeology), and surface water quality. Conceptual estimates of capital closure costs are also provided.

5. Prefeasibility Assessment of Short-Listed Closure Options

5. Prefeasibility Assessment of Short-Listed Closure Options

This chapter provides a discussion of the prefeasibility level assessment of the short-listed closure options. The evaluation of each short-listed, closure option includes a discussion of the option objective or purpose, key assumptions, performance and uncertainty with respect to technical disciplines discussed below.

5.1 Assessment Methods

As outlined in Chapter 1, the objective of this document is not to make recommendations with respect to a preferred closure option, nor rank the closure options against various closure criteria. Rather, the primary objective is to provide the prerequisite information necessary for stakeholders to evaluate the relative merits and residual risks of the various closure alternatives. In this regard, the design and performance of the closure options were assessed with respect to five components, including:

- Mine waste geochemistry;
- Geotechnical engineering;
- Water management;
- Water balance and surface water quality; and
- Cost.

These criteria closely link to the closure objectives outlined in Section 3.2. Safety, as it relates to mine hazards (*e.g.,* open pit), is also considered. As part of the assessment for each option, the key assumptions, anticipated performance, and areas of uncertainty are described. These components have been summarized from technical reports in support of geochemistry (Appendix B), geotechnical aspects (Appendix C-1), hydrology (Appendix D), hydrogeology (Appendix E), water balance and quality modeling (Appendix F) and costing (Appendix C-1 and C-2). For a thorough analysis of each of these components, the reader is directed to the appropriate appendix.

The following chapter presents the results of the prefeasibility assessment of Common Closure Elements (Section 5.2), Current Condition (Status Quo) (Section 5.3), and short-listed closure options as introduced in Section 4.2 and summarized below:

- Section 5.4: Options 1A and 1B – Tailings Dam Upgrade with Water Cover (Option B denotes pit backfill with waste rock);

- Section 5.5: Options 2A and 2B: Tailings Dam Upgrade with Saturated Soil Cover (Option B denotes pit backfill with waste rock);
- Section 5.6: Option 3: Tailings (Wet) Backfill into Pit with High Infiltration Cover, Waste Rock in Place; and
- Section 5.7: Option 4: Tailings (Dry) and Waste Rock Backfill into Pit with Low Infiltration Cover.

5.1.1 Scope

Only those facilities, installations, and significant ground disturbances within the 'Mt. Nansen OIC Boundary' are considered. This limit, shown in Figure 2-1, is defined as the area bounded by existing quartz claims held by others, coupled with the perimeter identified in the 2006 Yukon Order in Council (O.I.C.). This Order in Council prohibits entry for prospecting or for the purposes of placer and quartz claim staking in order "to facilitate reclamation of the lands as a result of mining activity."

5.1.2 Approach

The analysis presented in this report, and the level of detail provided with respect to design, performance and costing, has been conducted to a pre-feasibility level. In this context, geotechnical engineering designs, remedial activities, and closure cost estimates are conceptual. Closure costs are defined as Class D estimates (or ASTM E2516-06 Class 5) and range from approximately -25% to +40% / +75%. Feasibility-scale information, which would include more detailed information with respect to final design specifications, implementation protocols, major equipment requirements, scheduling, and costing, will be generated for the final closure plan following selection of a preferred option or variation of options.

A surface water model has been devised using Goldsim to evaluate each closure option (Appendix F). The primary objective of the surface water model is to provide a basis for comparing the environmental merits and performance of each closure option with regards to surface water quality. The following approach was taken to best achieve this objective:

- Mill area contaminant loadings were excluded from the assessment in order to illustrate the differences between the closure options;
- Water quality predictions have been made for Victoria Creek downstream of the project where fish presence has been confirmed and where net loads from the mine coalesce; and

- A reasonable degree of conservatism has been built into the model in an effort to compare the options equally. Assumptions regarding model inputs and their conservatism are described for each option in the sections below.

Predicted water quality conditions are also compared to CCME guidelines for the protection of aquatic life (*e.g.,* CCME). An environmental effects assessment has not been conducted as part of this evaluation. Specifically, residual project and cumulative effects as they relate to aquatic resources are not discussed from the perspective of biological impact. Such an assessment would require consideration to a full suite of variables including site-specific factors that govern metal bioavailability, studies in support of site-specific water quality objectives, and site-specific species assemblages.

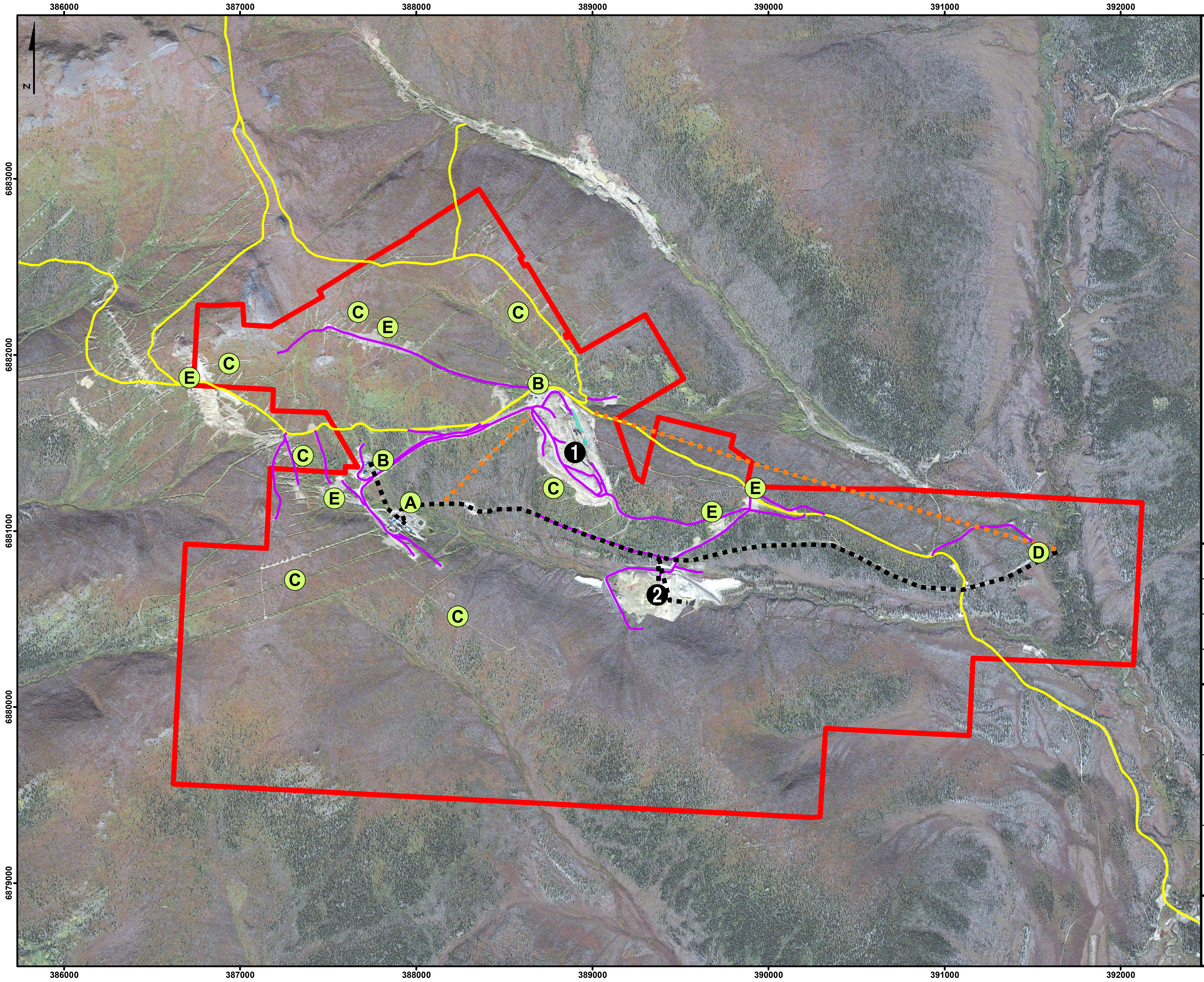
5.2 Closure Costing of Common Elements

5.2.1 Overview

The following section provides a description of common closure elements to the Mt. Nansen Mine Site. These elements are described separately as they are common to all closure options and variations for Mt. Nansen. A detailed inventory, evaluation, and capital cost estimate for closure is provided in Appendix C-2. Common closure elements have been defined by Government of Yukon (F. Patch, personnel communications, October 2010), are limited to features within the Mt. Nansen OIC Boundary (Section 5.1) as illustrated in Figure 5.2-1, and include the following:

- Mill Area;
- Camp and Site Ancillary Buildings (camp, mine shop, water storage tank building above camp);
- Roads;
- Exploration Trenches;
- Miscellaneous infrastructure (*e.g.*, power supply infrastructure, pipelines, Victoria Creek pump house, core storage areas); and
- Other Areas requiring revegetation and site restoration (*e.g.*, exploration clearings and adit disturbance areas, borrow areas, *etc.*)

Further the following assumptions have been made regarding the evaluation of Common Closure Elements:



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Legend

- 1 Open Pit and Waste Rock
- 2 Tailings
- Mine Road
- Public Road
- Mt. Nansen OIC Boundary

Common Elements

- A Mill
- B Camp and Ancillary Buildings
- C Exploration Trenches
- D Pump House
- E Clearings
- Powerlines (Active)
- Powerlines (Inactive)

Meters
0 350 700 1,400

SCALE:	1:20,000
DATE:	OCT 6th, 2010
PROJECTION:	NAD_1983_UTM_Zone_8N
PROJECT MANAGER:	J.S.

PROJECT:

Mt. Nansen 2010 Planning

TITLE:

Common Closure Elements

PROJECT No:	FIGURE No:
J907-4	**5.2-1**

LORAX ENVIRONMENTAL
2289 Burrard St.
Vancouver, BC, V6J 3H9
Phone: (604) 688-7173
Website: www.lorax.ca

- All facilities and workings will be fully decommissioned and will no longer see any use; hence buildings will be removed or demolished. Powerlines, pipelines, tanks and other ancillary equipment will be removed from service. Non-public exploration and mine roads will be decommissioned. It is recognized that it may be deemed appropriate to maintain or re-purpose certain buildings or infrastructure in support of on-going care and maintenance, or to provide services to other interested parties (*e.g.*, Little Salmon Carmacks First Nation).
- Assessments considered integral to carrying out the closure activity have been included in some areas as 'Pre-Closure' activities. It is important to note that these investigations are limited in scope and their assigned costs are not intended to include any required engineering, design, or detailed planning.
- Road and trail differentiation is based on information provided by Government of Yukon. Trails have been defined to require no specific closure measures.

An overview, general inventory, and 'Class D' cost estimate (see Section 1.3.3) for the Common Closure Elements are provided in the following sections. Common Element closure costs are conceptual and are defined as -25% to +75%.

5.2.1.1 Summary of Common Element Closure Costs

A summary of the estimated closure costs for the six Common Elements is provided in Table 5.2-1. Discussion of overview, approach, and uncertainty for each Common Closure Element is given in the following sections.

Table 5.2-1:
Summary of Estimated Closure Costs for Common Elements

		Pre-Closure Phase	Active Closure Phase
#	Component	Estimated Cost	Estimated Cost
1	**Mill Area**	$ 78,000	$ 2,190,000
2	**Camp and Ancillary Buildings**	$ 40,000	$ 390,000
3	**Roads**	$ 25,000	$ 210,000
4	**Exploration Trenches**	$ 15,000	$ 210,000
5	**Miscellaneous Infrastructure**	$ 15,000	$ 210,000
6	**Revegetation and Site Restoration of Other Areas**	$ 5,000	$ 210,000
	Subtotal	$ 178,000	$ 3,420,000
	TOTAL ESTIMATED COST		**$ 3,600,000**

5.2.2 Mill Area

5.2.2.1 Overview

The Mill Area is illustrated in Figure 5.2-2 and includes mill buildings, ponds, roads, platforms, equipment laydown areas, miscellaneous products, pipelines, and powerlines.

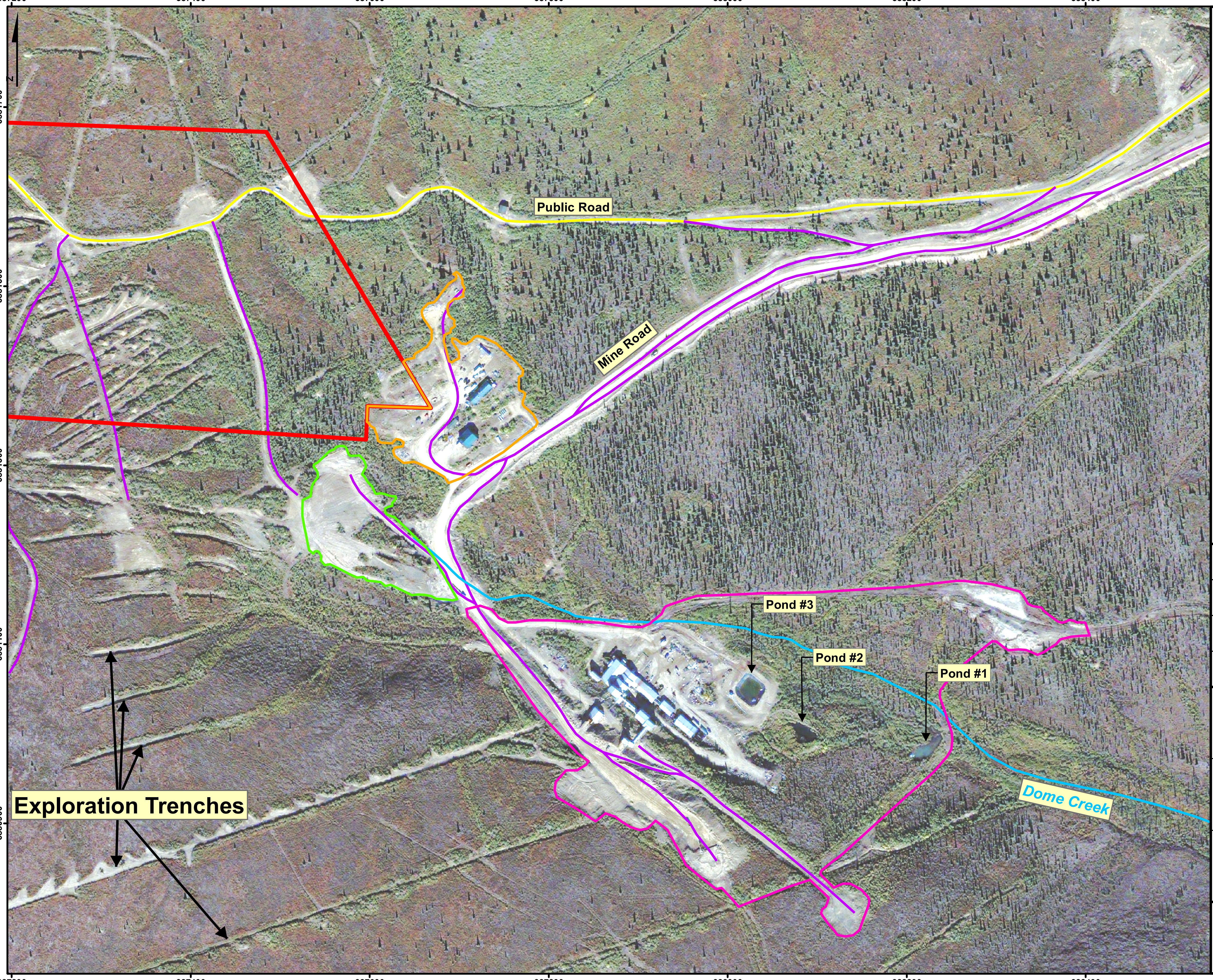
<u>Site History</u>

According to reports the Mill Area first saw significant use during two brief mining campaigns in the 1960's and 1970's (Conor Pacific, 2000). During that time approximately 22,000 tonnes of ore mined from the nearby Huestis workings was transported to the mill area and processed via froth flotation to produce a sulphide concentrate. Airphotos and company personnel report that at least some ore was brought to the mill via a lower adit which at one time daylighted just northwest of the mill buildings. Approximately 20,000 tonnes of tailings were reportedly discharged below the mill; the two remnant decant structures remain mainly intact in the naturally revegetated area downhill from the main mill platform (Pond #1 and #2). A third decant structure is visible in old air photographs and is now the site of a geomembrane-lined pond on the lower mill platform (Pond #3). This newer pond was used during the 1990's mining phase for water supply and after for cyanide treatment.

During preparation for mining in the 1990's the mill underwent retrofitting to accommodate a cyanidation circuit, thickener, and other updated process equipment. A set of diesel-powered generators was installed in part of the old warehouse building and remain in operation today.

<u>Previous Investigations</u>

Closure-related studies specific to the Mill Area include a site-wide Historical Review, Site Assessment, and Field Sampling Program (Conor Pacific, 2000), a Limited Phase 2 Environmental Site Assessment (Kearah & WERI, 2008), preliminary geochemical investigations (Altura 2009b, Lorax 2010a), and installation and monitoring of four shallow piezometers (AECOM, 2009). Water quality monitoring has been routinely conducted at stations DX, upstream of the mill area, and D1, just below the mill complex (EDI Environmental Dynamics, 2008).



CLIENT::

Yukon Government

Legend

- Mill Area
- Mine Camp
- Contoured Heustis Workings
- Mt. Nansen OIC Boundary
- Dome Creek
- Mine Road
- Public Road

Meters
0 70 140 280

SCALE:	1:4,000
DATE:	OCT 6th, 2010
PROJECTION:	NAD_1983_UTM_Zone_8N
PROJECT MANAGER:	J.S.

PROJECT:

Mt. Nansen 2010 Planning

TITLE:

Mill and Mine Camp Area

PROJECT No:	FIGURE No:
J907-4	5.2-2

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2289 Burrard St.
Vancouver, BC, V6J 3H9
Phone: (604) 688-7173
Website: www.lorax.ca

With respect to potential environmental liabilities, salient conclusions from the aforementioned studies include the following:

- Hazardous Products: most hazardous products inside mill and in main laydown areas have been removed, including asbestos and PCBs; however residual amounts hazardous materials remain in tanks and vessels within the mill. Groundwater monitoring of four Mill Area wells installed during 2009 has not identified detectable hydrocarbon concentrations.
- Tailings: Approximately 2,000 tonnes of the 20,000 tonnes of tailings has been identified in the easternmost pond (Pond #1) in the Mill Area. The tailings were reportedly reprocessed and discharged to the current TMA in the late 1990's (Brodie, 1998). A borehole log from 2009 suggests that tailings may also exist near Pond #2, but the nature and thickness of this material can not be confirmed.
- Water Flow Paths: Reconnaissance, excavations, and previous studies indicate that zones below the main mill platform and the vegetated zones below Pond #3 are within a shallow groundwater zone and effectively discharge to the Dome Creek watershed. Above this zone, a seep, possibly originating from the lower Huestis adit area, appears to contribute the primary load of constituents to Dome Creek.
- Water Quality: Dome Creek water quality shows increased Cd, Zn, As, and sulphate concentrations along the reach transecting the Mill Area. Mineralized material (ore) is likely contributing to the flux of metals to Dome Creek. Preliminary assessments suggest that the mineralized fill and a high-volume seep just west of the mill (possibly associated with the historic adit opening in this area as described above) are likely the primary contributors to Dome Creek metal loading in the vicinity of the mill. Further, the mill area appears to be the primary source of sulphate, Cd, and Zn to Dome Creek (the TMA is the primary source of As to Dome Creek). Investigations indicate that metal concentrations are partially attenuated downstream, possibly through co-precipitation with Fe-Mn oxide compounds (Lorax, 2010a).

5.2.2.2 Approach

<u>Objectives</u>

Specific objectives for Mill Area closure include the following:

- reduce zinc and cadmium loading to Dome Creek;
- minimize surface and near surface water flow through mill platform area;

- ensure that a complete inventory of mill tailings deposits is completed and where feasible, tailings are stored in a location offering long term physical and chemical stability (*e.g.*, open pit or current TMA);
- restore upper Dome Creek watercourse for long term physical stability;
- remove hazardous products;
- ensure treatment of hydrocarbon contaminated soil; and
- decommission and recycle/dispose of buildings.

Components, Assumptions, and Uncertainty

Based on site evaluations conducted to date, closure costing for the Mill Area considers the following main components and key assumptions given in Table 5.2-2.

Main assumptions and uncertainties affecting the Mill Area closure cost estimate include the following:

- Remediation of underground workings, including plugging of suspected adit(s);
- Water treatment costs. Costs for temporary sediment control measures have been assumed where potentially applicable, but since sampling of ponds indicates compliance with existing water license levels for metals, there is no allowance for additional water treatment;
- Removal of up to 1000m^3 of tailings;
- Additional landfill or cover material is not required;
- Removal of up to 6500 m^3 of mineralized material (this is considered a conservative approximation); and
- Minor amounts of remaining hazardous products require removal.

5.2.2.3 Closure Cost Estimate

The estimated closure cost for the Camp and Site Ancillary Buildings is approximately $2,268,000 (Table 5.2-1). Detailed closure cost estimates are provided in Table 3-3 of Appendix C-2.

Table 5.2-2:
Main Components and Key Assumptions for Closure Costing of the Mill Area

Component	**Key Assumptions**
Mill buildings	Minor amounts of residual hazardous products No asbestos, no PCB's Minor amounts of lead-containing paint
Old refuse disposal area principally containing non-hazardous waste with some hazardous waste	Minor amounts of hazardous products Remaining waste can be landfilled in-situ
Laydown areas containing metal, pipes, abandoned equipment, miscellaneous waste and consumables	Minor amounts of hazardous products
Three Ponds #1, #2, #3 (two earthen, one geomembrane lined). Pond #1 (earthen) confirmed to contain sulphide and metal-rich tailings	Apart from tailings identified in Pond #1, no other deposits of recoverable tailings Water in all ponds meets Water License effluent discharge requirements
Records indicate 20,000 to 25,000 tonnes of tailings were deposited in the mill area during the early phases of mine development (1960's and 1970's)	Preliminary investigations confirmed approximately 2000 tonnes of tailings are contained within Pond #1. Tailings were reportedly reprocessed and relocated to the current TMA. Cost estimates assume only 2000 tonnes of tailings will require relocation.
Fuel and miscellaneous petroleum product storage in concrete containment and fuel dispensing area	2 X 10,000 gallon (45,500L) diesel tanks Likelihood of hydrocarbon-contaminated soil and concrete
Mill Disturbance Area: rock fill platforms	4 ha, in a series of 5 platforms. Lower platform contains approximately 6500 m^3 of potentially ARD/ML material within or near the saturated zone and will require relocation
Dome Creek watercourse, some sectors with platforms and scrap metal pushed to the edge of the stream	Culvert, scrap metal to be removed from watercourse
Rail tanker reportedly with residual pressure and containing a minor amount of sulphur dioxide	0.08 L sulphur dioxide (Kearah and WERI, 2008)

5.2.3 Camp and Site Ancillary Buildings

5.2.3.1 Overview

The Camp and Site Ancillary Buildings include the main camp area along with the mine shop, adjacent bone-yard, and laydown areas, as well as the water storage tank above the camp. The main camp area is shown in Figure 5.2-2. Note that this area lies in close proximity to the OIC boundary, with some of the camp clearing lying outside of these limits.

It is understood that the main camp area was constructed in the 1960-70's mining era and then upgraded during the mid-1990's when several Atco®-style camp trailers were used to house mine employees. These trailers have since been removed from site.

The remaining camp kitchen, office/bunkhouse, and workshop are currently in use to support ongoing care and maintenance activities, and their upkeep is funded by the Government of Yukon. Water for camp use is supplied by a stand-alone water tank that is filled by water truck. A power line runs from the mill site for electricity. Most of the buried and on-surface water lines in the camp area are inactive. Domestic sewage is reportedly disposed of in a tank and drain field system, with the tank contents periodically pumped and transported off-site. The specific location of the system has not been confirmed for this estimate. Other materials in the vicinity of the camp include core storage areas, at least one shed in disrepair, and miscellaneous consumables. Propane and gasoline tanks are located in the lower platform of the camp area and are still in use.

The mine shop is unheated, and sees occasional use in supporting ongoing care and maintenance activities. Miscellaneous consumables, tools and components, the majority no longer in use, are stored within and around the building.

<u>Previous Investigations</u>

Conor Pacific (2000) included review of the Camp and Site Ancillary Building areas as part of their Historical Review, Site Assessment, and Field Sampling Program, however from review of other available documents it is not clear what aspects have since been remediated during the current care and maintenance phase. Conor Pacific notes above-ground fuel storage at both the camp area and the mine shop complex. Altura (2009c) noted a strong hydrocarbon odour in a geochemical investigation test pit in the road bed immediately below the camp, however to date no follow-up work has been completed to determine the source.

The Camp and Ancillary Building sites are assumed to have relatively low levels of potential environmental liability, nonetheless the following aspects are considered to apply to these areas: i) presence of localized hydrocarbon-contaminated soil, ii) presence of minor amounts of lead-containing paint, and iii) presence of minor amounts of hazardous products. It is understood from communication with Yukon Government Assessment and Abandoned Mines that no PCB-containing fixtures remain on site (F. Patch, personal communications, Oct, 2010). It is also assumed that no asbestos products are present (consistent with site assessment findings for the mill complex).

5.2.3.2 Approach

Objectives

Specific objectives to the Camp and Site Ancillary Buildings include:

- remove hazardous products;
- ensure treatment of hydrocarbon contaminated soil; and
- decommission and recycle/dispose of buildings.

Components, Assumptions, and Uncertainty

Based on site evaluations conducted to date, closure costing for the Mine Camp Area has been conducted for the main components and key assumptions listed in Table 5.2-3. The portion of the Camp Area clearing outside of the OIC boundary is not included in the closure cost estimate (Figure 5.2-2).

Since it is desirable to continue using the camp facilities while the major site work is being undertaken, the camp area would likely be decommissioned as late in the active closure phase as is feasible. Further, as mentioned previously it has been acknowledged that the camp facilities ultimately may not be decommissioned should a local or private party show interest in using, buying, and/or assuming liability for it (*e.g*., Little Salmon / Carmacks First Nation).

Main assumptions and uncertainties affecting the Mine Camp Area closure cost estimate include the following:

- Mine camp buildings may not require demolition in the event of a requirement for continuous site presence following active closure or a decision to cede the facility to a third party; and
- Limited assessments suggest that most hazardous products have been removed from site; however there appears to have been no systematic assessment for hydrocarbon-contaminated soil.

Table 5.2-3:
Main Components and Key Assumptions for Closure Costing of the Camp and Site Ancillary Buildings

Component	Key Assumptions
Camp Buildings: Kitchen, office/bunkhouse, workshop/garage	Minor amounts of residual hazardous products No asbestos, no PCB's Minor amounts of lead-containing paint (some buildings pre-date late 1970's ban)
Clearings, Camp area	2 ha, in a series of 4 platforms connected by roads Minor amounts of residual hazardous products, minor refuse to be removed Minor laydowns of supplies and small equipment Core storage in various areas
Fuel and Propane storage, lower camp platform	Gasoline in one 2000 gallon (4,550L) 'enviro tank', fuel dispensing equipment in current use - potential for hydrocarbon soil contamination from fuel dispensing 4 – 1000 lb. propane tanks, in current use
Water Tank Building, above camp adjacent to main Nansen road	35,500 gallon (161,500L) wood stave water tank housed in stand-alone building (T.W. Higgs, 1994), not in use; clearing 500 m^2
Mine Shop and laydown ('Ketza Construction Yard')	Metal clad building approximately 250m^2, Minor laydowns of supplies and small equipment, 1500m^2 metal and miscellaneous scrap yard to southeast, equipment parking platform to north, potential for hydrocarbon soil contamination due to maintenance activities and fuel tanks during mining; total 0.8ha area.

5.2.3.3 Inventory and Cost

The estimated closure cost for the Camp and Site Ancillary Buildings is approximately $430,000 (Table 5.2-1). Detailed closure cost estimates are provided in Table 3-5 of Appendix C-2.

5.2.4 Roads

5.2.4.1 Overview

<u>Site History</u>

As shown in Figure 5.2-1, there is an extensive network of roads in over the Mt. Nansen site, developed over the last 70 years to support mineral exploration as well as quartz and placer mining needs. The roads range from narrow temporary accesses for trenching campaigns to an approximately 15m-wide thoroughfare at one time used by mine haul trucks. The roads are in various states of repair and currently see different levels of use.

Certain thoroughfares through the Mt. Nansen OIC are used by other operations in the area and are designated as 'Public', and shown in Figure 5.2-1. These sections will remain active and will not be decommissioned and reclaimed as part of the Mt. Nansen site closure.

Previous Investigations

Conceptual closure and cost estimates for road decommissioning are based on Altura's general site familiarity as well as preliminary mapping information provided by Assessment and Abandoned Mines. No detailed mapping or ground-truthing of the more remote roads has been conducted to date, and their state of repair and environmental liability issues are largely unknown.

Roads are surfaced with locally-sourced material, have a highly compacted running surface, were typically constructed with cut and fill method, and in some sections are ditched with culverts installed. It is understood that there are no bridge crossings to be removed.

The 1.2 km mine haul road merits specific consideration in that the original road, a cut and fill structure, was substantially widened, straightened, and bermed in the late 1990's by dumping waste rock hauled from the Brown McDade pit (Altura, 2009c, 2009d). As a result, several sections of the haul road have long angle of repose slopes that cannot readily be resloped and integrated with the surrounding terrain. Haul road test pit characterization by Altura (2009c) indicated that:

- berm material, particularly along the eastern sector towards the mine, exhibits mixing with potentially reactive highly altered and sulphidic material;
- excess road bed could be suitable for use elsewhere as low-reactivity construction material (providing that there is field quality control and avoidance of berm material and zones near the mill); and
- soil and rock with a strong hydrocarbon odour were encountered in a test pit in the haul road bed below the camp, and it is considered likely that a minor amount of roadbed material will require soil remediation.

Many trails exist throughout the Mt. Nansen site. Trails are considered thoroughfares that are not passable by regular vehicle, have little or no constructed roadbed, and are largely vegetated.

5.2.4.2 Approach

Objectives

Specific objectives to closure of site Roads are:

- prevent future ingress by light vehicles or equipment
- minimize erosion
- encourage natural revegetation

Components, Assumptions, and Uncertainty

Components and key assumptions for the closure evaluation of site Roads are given in Table 5.2-4. Items not included in the closure cost estimate include:

- Trails (as noted in Section 3.1.2); and
- Public roads (Figure 5.2-1) which are thoroughfares within the Mt. Nansen OIC boundary that are utilized by other parties such as placer miners and hunters for accessing areas within and beyond the immediate Mt. Nansen site. Public roads will not be decommissioned as part of Mt. Nansen closure activities.

Main assumptions and uncertainties affecting reclamation of Roads within the Mt. Nansen OIC include the following:

- Road surfaces will be de-compacted to 0.8m depth and re-contoured to integrate with the surrounding terrain;
- Culverts will be removed, and water bars or other control structures will be created as required to minimize erosion and direct surface water and seepage through the disturbance;
- Surfaces will be left undulating and non-compacted, and as available, materials such as organics, natural coarse woody debris will be distributed over the final surface;
- Revegetation is assumed over approximately 10 percent of narrower road areas;
- Revegetation on the haul road is assumed to take place over 25 percent of the disturbance area owing to its slope and size; and
- An on-ground inventory of roads to be reclaimed has not yet been completed. All costing assumptions are based on satellite photo interpretation and general site knowledge.

Table 5.2-4:
Main Components and Key Assumptions for Closure Costing of Roads

Component	Key Assumptions
Public Roads	6.5 km within OIC Boundary No closure activities on these roads
Mine Roads	Total 11.6 km within OIC Boundary, not including haul road described below All Mine Roads to be ultimately decommissioned Minor amount of roadbed material will require hydrocarbon remediation All material geochemically stable
Haul Road	1.2 km of 15m-width haul road from mine shop to mill A portion of the berms (up to 1000m^3) potentially leachable material; all other haul road material insitu is considered to have minimal potential effect to water quality. Minor amount of roadbed material will require hydrocarbon remediation
Trails	No closure activities on trails

5.2.4.3 Inventory and Cost

The estimated closure cost for Mine Roads is approximately $235,000 (Table 5.2-1). Detailed closure cost estimates are provided in Table 3-7 of Appendix C-2.

5.2.5 Exploration Trenches

5.2.5.1 Overview

Numerous exploration trenches within the Mt. Nansen OIC have not been reclaimed by previous operators. Trenches are visible as long linear features, typically clustered around a mineralized zone of interest (Figures 5.2-1 and 5.2-2). Many trenches at the Mt. Nansen site are several hundred metres in length.

<u>Site History</u>

Most of the trenching was carried out from the mid-1980's through to the late 1990's. In general, trenching programs during this period entailed initial pre-stripping of the top 0.5m of vegetation and sub-soil with a bulldozer, and trenching to approximately 1 to 2m depth by 1m width with a large excavator. Sidecast material was typically piled on one or both sides of the exposed trenches. The Huestis zone trenches above the mill present a special reclamation challenge. They are very long and generally over 3m deep. These trenches were initially excavated with a dozer in the 1970's and deepened in the 1980's with an excavator. Some sections of these trenches were recently filled in as part of the care and maintenance activities and thus provide a valuable, field-truthed cost estimate.

Previous Investigations

No detailed mapping or ground-truthing of the Mt. Nansen exploration trenches has been conducted to date, and their current condition and environmental liability issues are largely unknown. Open trenches present a public safety hazard in those areas frequented for animal, plant and berry harvesting, and may cause alterations to wildlife movement patterns. Some trenches alter the drainage characteristics of the area, and thereby present ongoing erosion concerns. In rare cases, local water quality may be influenced by acid rock drainage and/or metal leaching from naturally occurring mineralization.

Due to mine development and other later workings, some trenched areas at Mt. Nansen are no longer easily accessible for heavy equipment to carry out reclamation activities. Thus, the decision to carry out relatively inaccessible trench-filling work should be weighed against the potential impacts from accessing them.

5.2.5.2 Approach

Objectives

Specific objectives to the closure of site Exploration Trenches are:

- protect public safety
- minimize erosion
- restore natural drainage characteristics as feasible
- encourage natural revegetation

Components, Assumptions, and Uncertainty

Components and key assumptions for the closure evaluation of site Exploration Trenches are given in Table 5.2-5.

Main assumptions and uncertainties affecting reclamation of Exploration Trenches within the Mt. Nansen OIC include the following:

- A rate of 75 equipment hours per kilometre has been applied to deeper trenches in the Heustis area above the mill;
- Due to potential impacts created by re-accessing some trenches, it is assumed that only 80 percent of the remaining 11km of trenches will be filled. A rate of 60 equipment hours per kilometre is applied to these areas;

- Trenches will be accessed via a temporary trail, utilizing existing trails and roads where possible.
- The trenches will be backfilled using available sidecast material, and recontoured to integrate as possible with the surrounding terrain;
- Water bars or other control features will be created as required to minimize erosion and direct surface water and seepage across the trenching disturbance into natural depressions or drainages;
- Backfilled surfaces will be left undulating and non-compacted, and as available, materials such as organics, natural coarse woody debris will distributed over the final surface;
- Due to the narrow linear nature of the disturbance, no re-vegetation activities are assumed, except in those areas requiring additional erosion control. For the purposes of costing, revegetation is assumed to take place over 2 percent of the trenches backfilled; and
- Field-truthing of exploration trenches for reclamation has been completed. All costing assumptions are based on satellite photo interpretation and general site knowledge.

Table 5.2-5:
Main Components and Key Assumptions for Closure Costing of Trenches

Component	Key Assumptions
Trenches	Approximately 15 linear km of total trenches within OIC Boundary
	2 linear km of deep trenches already backfilled during care and maintenance; 2 linear km of deep trenches remaining
	80% of outstanding 11 km can be feasibly backfilled
	Field verification required

5.2.5.3 Inventory and Cost

The estimated closure cost for Exploration Trenches is approximately $225,000 (Table 5.2-1). Detailed closure cost estimates are provided in Table 3-9 of Appendix C-2.

5.2.6 Miscellaneous Infrastructure

5.2.6.1 Overview

Other Common Element infrastructure and facilities include power supply infrastructure, pipelines and other specific facilities described in the following paragraphs.

Power Supply Infrastructure: these are existing line routes, both active and inactive, across the property, along with associated transformers and switchgear (Figure 5.2-1). The lines known to be active transmit power generated from the site generator facility located at the millsite and it is understood that they include: i) mill site to camp, ii) mill site to tailings pond and seepage pond, and iii) tailings pond to Victoria Creek pumphouse. Other lines are assumed to be inactive (condition unknown) include: i) mill site to mine shop, ii) camp to water tank, and iii) Pony Creek to Victoria Creek pumphouse. There is no systematic inventory of remaining powerline infrastructure nor switchgear, and it is understood that all remaining transformers on site are in service and located at the mill site, camp or Victoria Creek pumphouse areas.

Pipelines: main pipeline routes include those from Victoria Creek pumphouse to the tailings area, tailings area to the mill, and from the mill to camp and water tank areas. There are several intermediate pump shacks in the tailings area in various states of repair. There has been no systematic inventory of pipelines completed, and at least one, and in many cases two or three partial lines of pipes may be located along these routes. There are several other minor pipeline sections noted remaining within the mine, tailings, and camp areas; as well, there is potentially an older pipeline originally installed along the old powerline route from Victoria Creek to Pony Creek.

Victoria Creek Pumphouse: Victoria Creek pumphouse is located adjacent to Victoria Creek and approximately 2km east of the tailings impoundment. The facility was originally commissioned and used during the 1960's to 1970's mining periods for supply of fresh water for processing and for the camp. The facility is still used for filling the site water truck for supply of camp water. It is understood that water is supplied from a single artesian well with multi-staged submersible pump, and housed in a wood frame pumphouse (F. Patch, pers. comm., 2010; T.W. Higgs, 1994). The pumphouse is located in a clearing covering an approximately 1000 m^2 area.

Core Storage Areas: diamond drill core is stored in several locations at the old Pony Creek exploration camp, and at the mine camp area. The majority of the core storage areas have core boxes are well-labelled and intact. The boxes are either stacked or on racks that have fallen into disrepair.

5.2.6.2 Approach

<u>Objectives</u>

Objectives for closure of the Miscellaneous Infrastructure components are consistent with the over-arching site-wide criteria, and no specific objectives have been identified.

Components, Assumptions, and Uncertainties

Closure costing for Miscellaneous Infrastructure considers the main components and key assumptions given in Table 5.2-6.

Assumptions and uncertainties affecting the Miscellaneous Infrastructure closure cost estimate include the following:

- Power supply infrastructure will be deactivated by qualified industrial electricians, remnant power cable and switchgear will be removed, and disposed of along with general site waste, with recycling and salvage as feasible;
- Older power poles may be cut down at the base and bucked up to remain in the field, newer power poles may be salvageable, and are assumed to be cut off at the base and transported out of the field;
- Transformers will be salvaged or disposed of in accordance with applicable regulations ;
- Most powerline right-of-ways are narrow and infrequently used, and thus, minimal re-vegetation requirements are assumed;
- There is insufficient information to allow for further development of a closure strategy, in particular with respect to vehicular access to power line right-of-ways, and details on infrastructure remaining in the field. Thus for preliminary costing purposes a blanket allowance has been assumed;
- Above-surface pipelines along with remnant insulation and debris will be removed from the field to be disposed of or salvaged;
- Usable equipment in pump shacks will be salvaged, and the buildings removed from site and dismantled or salvaged;
- Minimal re-vegetation requirements are assumed. Due to insufficient information on remaining infrastructure and access, a blanket allowance has been assumed for preliminary costing purposes;
- Down-hole pump and piping will be removed from the artesian well at Victoria Creek and the well will be sealed;
- The pumphouse equipment will be removed form the site and salvaged or disposed of, along with the pumphouse building;
- The pumphouse clearing will be re-graded and left in a state conducive to promoting natural revegetation with a minor allowance for active re-vegetation;
- Where possible, intact drill core will be amalgamated to a common storage area: i) construction of a open, roofed storage shelter for long term preservation of the core

on site, and/or ii) transfer of representative intervals to the H. S. Bostock Core Library for long term archiving. Core that is to be no longer stored may be emptied from the boxes and placed in the Brown McDade waste rock pile. The boxes may then be disposed of along with other site wood refuse;

- An on-ground inventory of power lines and pipelines has not yet been completed. All costing assumptions are based on satellite photo interpretation, general site knowledge, and other limited information. Degree of access to these sites and the actual amount of cable and other infrastructure remaining in the field will greatly influence decommissioning cost. Additional site information is required; and
- It is understood that the water supply well at Victoria Creek is artesian, however no further details are available. The specific well decommissioning strategy and associated cost will greatly depend on the nature of the aquifer, well configuration, and closure requirements.

Table 5.2-6:
Main Components and Key Assumptions for Miscellaneous Infrastructure

Component	Key Assumptions
Power Supply Infrastructure	Active lines: approximately 5km Historical lines, condition unknown: approximately 4km No hazardous products Limited vehicular access Field verification required
Pipelines	5km of main pipeline routes plus 4 km of miscellaneous pipeline sections in other areas Multiple and/or partial segments of pipeline, majority above ground Pump shacks in various states of repair No hazardous products Limited vehicular access Field verification required
Victoria Creek Pumphouse	One artesian well (characteristics unknown), submersible multi-stage pump, pumphouse 1000 m^2 clearing
Core Storage Areas	Vehicular and heavy equipment access

5.2.6.3 Inventory and Cost

The estimated closure cost for Miscellaneous Infrastructure is approximately $225,000 (Table 5.2-1). Detailed closure cost estimates are provided in Table 3-11 of Appendix C-2.

5.2.7 Miscellaneous Clearings

5.2.7.1 Overview

Given the long mining and exploration history in the area, there are numerous clearings and minor disturbances within the Mt. Nansen OIC boundary that have revegetated naturally and for which site restoration is expected to be relatively simple. Restoration and revegetation of these areas is addressed in the section below.

5.2.7.2 Approach

Objectives

The objectives for remediation of Miscellaneous Clearings include site stabilization for erosion control and enhancement of on-going, natural revegetation. Most sites will require surface preparation including re-contouring, surface roughening, and partial revegetation.

Components, Assumptions, and Uncertainty

Based on available information, there are several sizeable clearings (≥1,000m^2) at the Mt. Nansen site including the following:

- o Over 8ha of clearing disturbance has been identified across the exploration and mining areas; and
- o Tailings diversion system and upstream and downstream borrow disturbances.

Main uncertainties affecting the Revegetation and Site Restoration of Other Areas closure cost estimate include:

- For costing purposes, 16ha of small clearing disturbance is assumed;
- Surface preparation (removal of minor debris, erosion and runoff control measures, de-compaction, re-contouring, surface roughening) is assumed at an average of 20 heavy equipment hours per hectare;
- Revegetation measures assume that owing to their small size that certain clearings will require minimal revegetation effort, at an assumed average of 15% of the disturbance area;

- An on-ground inventory of clearings to be reclaimed has not yet been completed. All costing assumptions are based on satellite photo interpretation and general site knowledge, and assume that remediation of these sites will be straightforward.
- It has been assumed that clearing areas do not contain refuse, hazardous waste, or hydrocarbon contamination requiring special management; and
- The projected disturbance for new or expanded borrow areas to be used for closure work has not been determined. While some conservatism is built into the current estimates, any significant additional borrow disturbance will require an added allowance for remediation.

5.2.7.3 Inventory and Cost

The estimated closure cost for Revegetation and Site Restoration of Other Areas is approximately $215,000 (Table 5.2-1). Detailed closure cost estimates are provided in Table 3-12 of Appendix C-2.

5.3 Current Condition (Status Quo)

Characterization of geotechnical and geochemical features of the Mount Nansen TSF demonstrate that the status quo at Mount Nansen is not acceptable for final closure. In terms of geotechnical considerations, site investigations conducted by AECOM (AECOM, 2008; 2010) have demonstrated that the tailings dam does not meet the requirements of the 2007 Canadian Dam Association (CDA) Guidelines. Based on the CDA Guidelines, the current facility was found to be inadequate with respect to: 1) stability under earthquake loading scenarios; and 2) the capacity and condition of the spillway. Thawing of permafrost beneath the dam and internal erosion of the dam has also contributed to settlement of the dam crest. These geotechnical aspects require remediation to ensure long-term stability. Secondary issues with regards to the performance of the diversion channel, interceptor ditch, and seepage through the dam were also identified as items requiring maintenance or remediation.

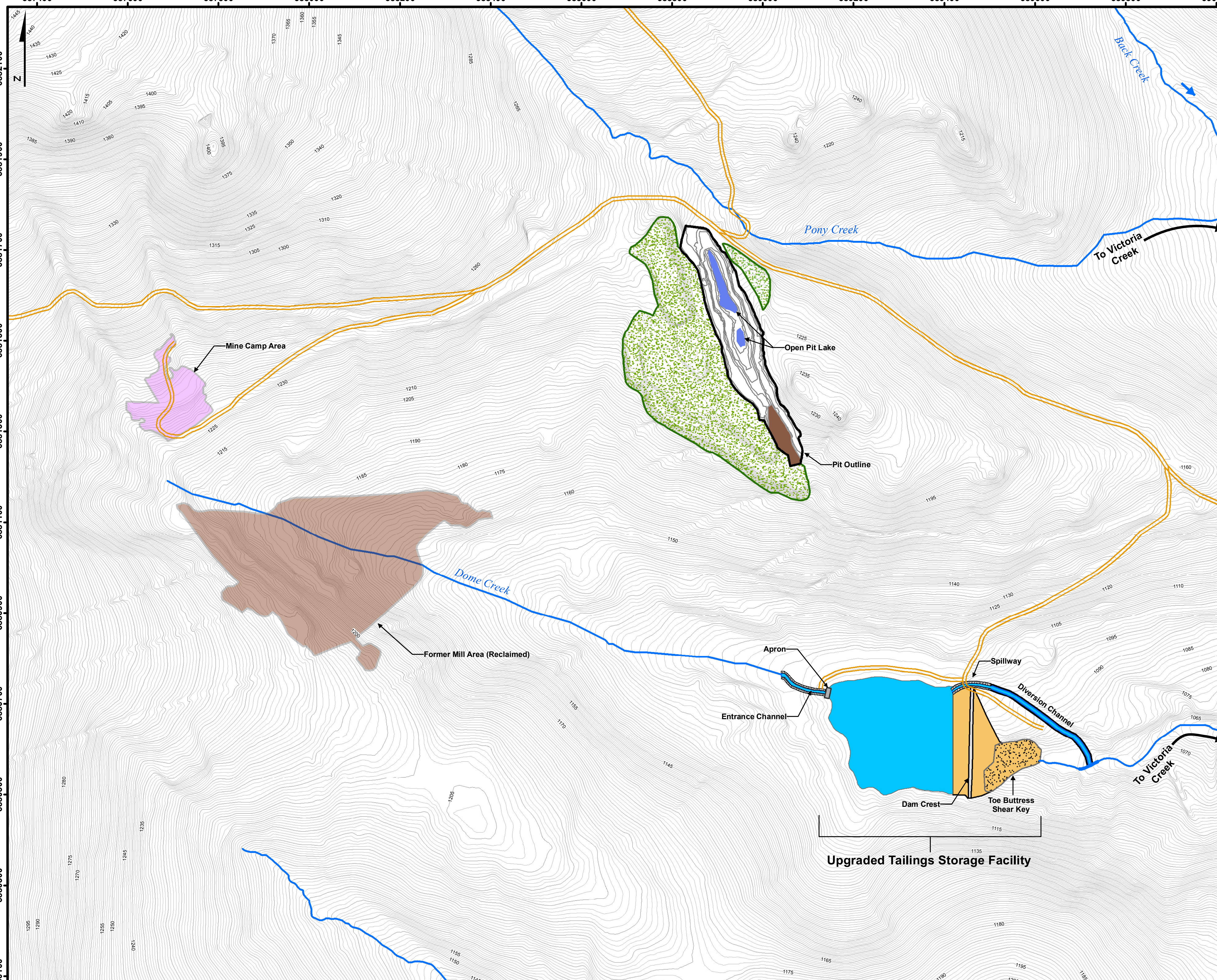
From a geochemical perspective, data in support of the metal leaching (ML) and acid rock drainage (ARD) assessment (Appendix B) indicate that the tailings materials have the potential to generate acidic drainages upon desaturation and exposure to oxygen. The development of acidic drainages is an unacceptable scenario given the predicted high levels of sulfate, trace elements (*e.g.*, As, Cd, Zn) and acidity in seepage waters under low pH conditions. In order to minimize the potential for ML/ARD, long-term management must ensure permanently saturated conditions and the current configuration of the TSF does not meet such requirements.

Given the considerations above, the status quo option was excluded from the options analysis and is not considered further in this report. Additional discussion regarding the development of closure options is provided in Chapter 4.

5.4 Options 1A and 1B: Tailings Dam Upgrade with Water Cover

5.4.1 Overview

Option 1 involves remediation of the existing tailings facility through upgrading of the dam structure and development of a permanent water cover over the tailings (Figure 5.4-1). Within this option, Option 1A maintains the waste rock piles in place (with possible re-grading) while Option 1B entails backfilling of waste rock into the open pit (Figure 5.4-2).



CLIENT:: Yukon Government

Legend

- Roads
- Watercourse
- Former Mill Area (Reclaimed)
- Mine Camp Area
- Dam Area
- Pit Outline
- Reclaimed Ore Area
- Reclaimed Waste Rock Dump
- Upgraded Tailings Impoundment (Water Cover)

Topography

- Index (5m)
- Interm (1m)

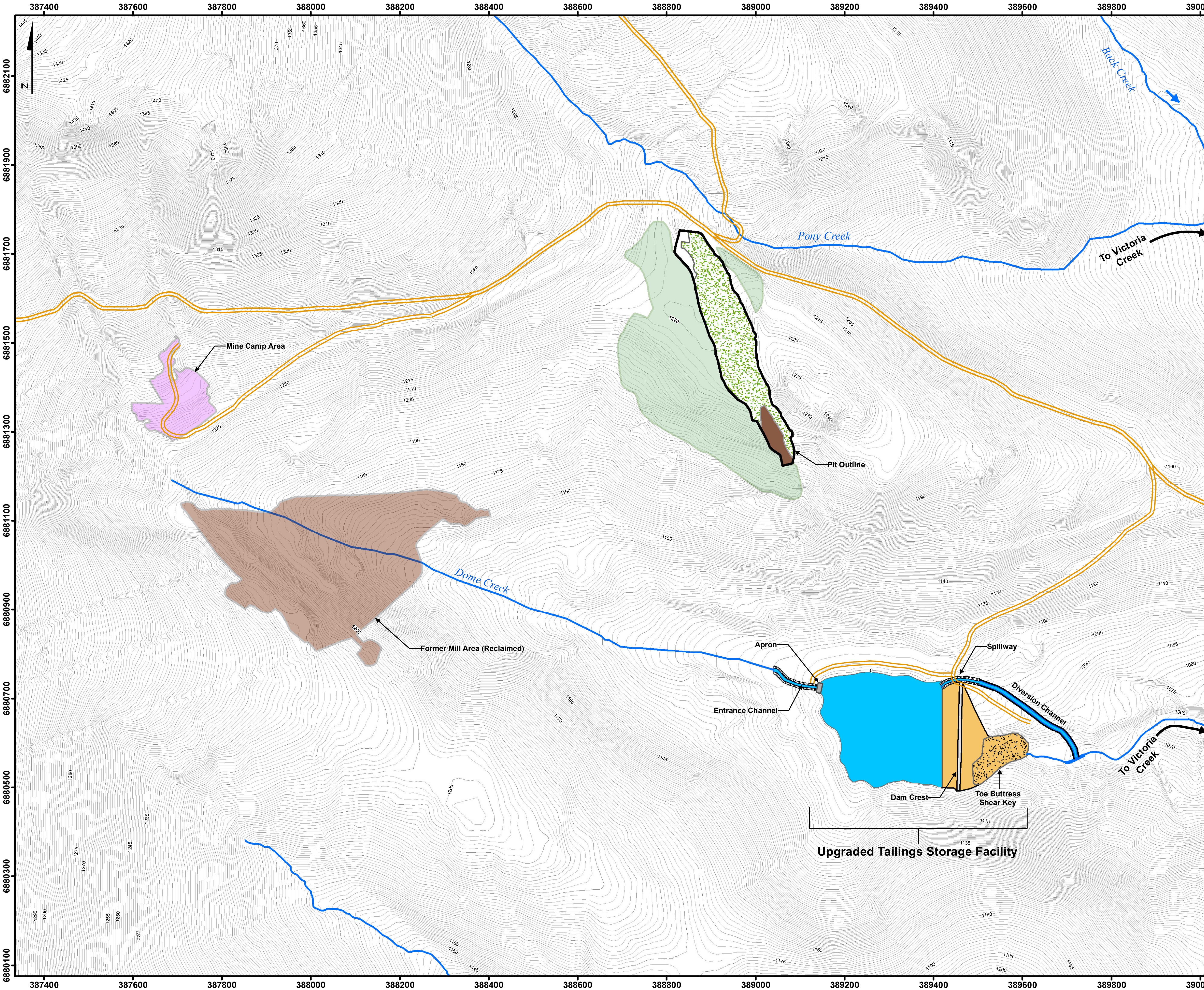
Meters: 0 150 300 600

Data courtesy of AECOM

Figure for illustrative purposes only

SCALE:	1:8,000
DATE:	OCT 22nd, 2010
PROJECTION:	NAD_1983_UTM_Zone_8N
PROJECT MANAGER:	J.S.
PROJECT:	**Mount Nansen Options for Closure**
TITLE:	**Closure option 1A: Tailings Dam Upgrade with Water Cover, Waste Rock in Place**
PROJECT No: **J907-4**	FIGURE No: **5.4-1**

LORAX ENVIRONMENTAL
2289 Burrard St.
Vancouver, BC, V6J 3H9
Phone: (604) 688-7173
Website: www.lorax.ca



CLIENT:: Yukon Government

Legend

- Roads
- Watercourse
- Former Mill Area (Reclaimed)
- Mine Camp Area
- Dam Area
- Former Waste Rock Dump Area (Reclaimed)
- Pit_Outline
- Reclaimed Ore Area
- Reclaimed Pit Backfill (Waste Rock)
- Upgraded Tailings Impoundment (Water Cover)

Topography

- Index (5m)
- Interm (1m)

Meters: 0 150 300 600

Data courtesy of AECOM

Figure for illustrative purposes only

SCALE:	1:8,000
DATE:	OCT 22nd, 2010
PROJECTION:	NAD_1983_UTM_Zone_8N
PROJECT MANAGER:	J.S.
PROJECT:	**Mount Nansen Options for Closure**
TITLE:	**Closure Option 1B: Tailings Dam Upgrade with Water Cover, Waste Rock Backfill into Pit**
PROJECT No: J907-4	FIGURE No: 5.4-2

LORAX ENVIRONMENTAL
2289 Burrard St.
Vancouver, BC, V6J 3H9
Phone: (604) 688-7173
Website: www.lorax.ca

The primary objectives of Option 1 are to:

1) Ensure the long-term geotechnical stability of the existing tailings dam;
2) Minimize the potential for tailings oxidation and ML/ARD through the maintenance of a permanent water cover and saturation of tailings solids; and
3) Restore the open pit area to a condition more compatible with the original land use via waste rock backfill (Option 1B only).

As part of Option 1, tailings will first be graded to allow placement of a 0.3 m sand diffusion-barrier layer. The purpose of the sand layer is to minimize contamination of the water cover from the underlying tailings, as well as to physically stabilize the tailings and prevent their erosion by water and/or wind. A permanent water cover will be maintained on the tailings through the diversion of flow from Dome Creek. Permanently saturated conditions will minimize the potential for sulfide mineral oxidation, thereby precluding the development of acidic drainages and associated metal leaching. A ponded area of 6 hectares (ha) will be created. The maximum water depth (~0.7 m) will be controlled by the elevation of the TSF spillway. Minimum water levels will be dominantly controlled by variations in inflows from Dome Creek; during dry periods, some exposure of the sand diffusion layer may occur.

As part of Option 1B, approximately 500,000 m^3 of waste rock will be backfilled to the open pit (Figure 5.4-2). This will result in the removal and re-location of all existing waste piles into the pit area. The top surface of the backfilled waste rock will graded to topography compatible with pre-mining land use and revegetated.

A summary of key elements associated with Options 1A and 1B is provided in Table 5.4-1. In the sections to follow, more detailed discussions are provided with respect to the design, performance and uncertainty relating to geotechnical measures, water management, geochemistry, water quality and cost.

Table 5.4-1:
Key closure elements associated with Option 1

Option	Closure Element	Description
1A and 1B	Placement of sand diffusion layer and water cover over the tailings.	A 0.3 m thick sand diffusion layer and 0.7 m water cover will be placed over the tailings. A water cover (6 ha in area) will be maintained over the sand layer to foster a permanently saturated environment for tailings storage, thereby minimizing the potential for tailings oxidation and associated ML/ARD. The combined sand and water cover will also serve to physically stabilize the tailings and minimize water/wind erosion and tailings resuspension.
1A and 1B	Remediation of existing tailings dam.	Upgrades to the existing tailings dam are required to ensure acceptable factors of safety for various loading conditions. Proposed measures are designed to ensure protection against dam failure resulting from overtopping, internal erosion (piping), slope instability, and liquefaction under seismic loading conditions.
1A and 1B	Diversion of Dome Creek into TSF.	In order to maintain saturated conditions within the tailings deposits, diversion of Dome Creek into the tailings pond will be required. This will require armouring of the Dome Creek outlet channel into the TSF.
1A and 1B	Upgrading of TSF spillway.	In order to meet flood-flow requirements, upgrading of the spillway from the tailings pond will be required. The spillway will be used to discharge water from the TSF and control the pond water elevation
1A and 1B	Upgrading of water diversion channel at TSF.	Additional armouring and upgrading of the diversion channel downstream of the emergency spillway may be required
1A and 1B	Tailings Dam Crest	The beach against the upstream face of the dam will be constructed with locally available sand. A layer of non acid generating waster rock will be placed over top to prevent wind and water erosion at the dam crest.
1A and 1B	TSF Seepage control	Two measures are proposed to decrease seepage through the tailings dam: 1) coarse tailings located against the face of the dam will be excavated and replaced with fine tailings; or 2) a liner will be installed between the tailings and dam face. Such measures are required to reduce seepage while maintaining tailings saturation.
1A	Waste rock	Waste rock will be left in place. Physical stability of existing waste rock piles will be assessed, re-graded, and re-vegetated as necessary.
1B	Waste rock and Open Pit	Waste rock will be backfilled into open pit to eliminate void and create landscape more compatible with original land use.

5.4.2 Geotechnical

5.4.2.1 Overview

A number of geotechnical considerations are associated with the evaluation of Option 1, the most important being related to dam stability and water management. A summary of the key considerations for Option 1 are:

- Stability and upgrading of the existing tailings dam and associated works to address the effects of liquefiable soils on the stability of the dam; minimizing seepage through the dam; and upgrading the dam spillway to safely pass potential flood flows;
- Upgrading and sizing of water diversion structures associated with the existing tailings management area;
- Assessing stability and contouring remaining waste rock piles; and
- Placing and contouring waste rock into open pit.

Details of the geotechnical assessment of Option 1 are provided in Appendix C-1 and the most salient components are summarized below.

<u>Upgrades to Dam and Stability Analysis</u>

As stated previously, Option 1 (*e.g.*, 1A and 1B) requires that the existing dam undergo a number of upgrades to increase the factors of safety (FS) for dam stability under a wide range of potential loading conditions. Determining the appropriate design factors of safety (FS), in order to ensure dam stability in perpetuity requires that the dam structure be appropriately classified in accordance with the Canadian Dam Association's, (CDA) *Dam Safety Guidelines* (CDA, 2007). For Option 1, a preliminary classification of *High* consequence facility has been assigned to the Mount Nansen tailings structure. The dam classification of *High* consequence dictates the seismic loading factors for slope stability analysis, design flows (spillway design), and the frequency for dam safety reviews and maintenance and operations.

Existing Dam Stability Characterization

In order to determine the requirements for upgrading the current dam configuration, a stability analysis and assessment of the *existing* (*i.e.*, non-upgraded) tailings dam was performed considering both static (*e.g.,* existing seepage) loads and potential seismic loadings. With respect to the latter, peak ground accelerations (PGA) for the mine site area were estimated using the current seismic hazard model and information developed by the Geological Survey of Canada for the 2005 Edition of the National Building Code of Canada. A peak (horizontal) ground acceleration of 0.11g, representing a predicted return period of 1 in 2,500, was considered for the pseudo-static loading and this value is consistent with a *High* consequence classification. The CDA (2007) guidelines allow a minimum factor of safety of 1.0 for the pseudo-static loading case for dams with a classification of *High*. For the purposes of assessing existing dam stability at Mt. Nansen, a slightly more conservative factor of safety of 1.1 was assumed for subsequent analysis. A summary of the required factors of safety for dam slope stability for static and pseudo-static loads are summarized in Table 5.4-2 below.

Table 5.4-2:
Loading Cases for Slope Stability Analysis

Case	Loading Condition	Peak Ground Acceleration (return period)	Dam Classification	Minimum FS Against Slope Instability
Static	Steady-state seepage	not applicable (NA)	NA	1.5
Pseudo-static	Earthquake	0.11g (1 in 2,500 yrs)	High	1.1[a]
Static	Post-earthquake	NA	NA	1.2

a: CDA (2007) Guidelines allow a minimum FS of 1.0 for this loading case

In performing stability analysis of the existing tailings dam configuration, a typical stratigraphic profile, perpendicular to the dam center-line was developed. Groundwater elevations through the dam were conservatively assumed to be at levels coincident with the highest levels recorded historically.

The engineering properties of the profile soil units used in the stability analysis are summarized in Table 5.4-3. Soil properties were developed based on engineering judgment and the results if *in situ* testing. Based on the results of previous cone penetrometer and standard penetration testing, any thawed foundation soils beneath the dam were considered to be liquefiable. Residual soil strengths were assigned for the liquefiable soil units for post earthquake analysis in accordance with recommendations in the 2007 CDA guidelines, which cross-reference the methodology outlined in the Canadian Foundation manual (CFM, 200). In this case, the critical soil strengths are input into the stability model as residual cohesive strengths.

Table 5.4-3:
Soil Properties Used in Slope Stability Analysis

Soil Unit	Unit Weight (kN/m^3)	Friction Angle (deg)	Cohesion c' (kPa)
Tailings	18.6	28	0
Tailings (Post Earthquake)	18.6	0	9
Compacted Dam Fill	19.5	34	0
Foundation Soil (thawed)	19	28	0
Foundation Soil (Post Earthquake)	19	0	14.4
Rock Fill	21	45	0

Based on the assumed piezometric conditions, seismic loadings and soil properties outlined above, the factor of safety for each of the loading cases was calculated and compared to the required minimum factor of safety to assess the current dam stability in the absence of any upgrades. Results of this analysis are summarized in Table 5.4-4.

Table 5.4-4:
Calculated Factors of Safety for Existing Dam Configuration

Case	Loading Condition	Minimum Acceptable Factor of Safety	Calculated Factor of Safety
Static	Steady state seepage	1.5	1.74
Pseudo Static (PGA 0.11g)	Earthquake	1.1	1.12
Static	Post Earthquake	1.2	0.56

As shown, the existing tailings dam has an adequate factor of safety (>1.7) for the steady state seepage condition assuming high groundwater levels through the dam. Under seismic (pseudo-static) loading conditions, the factor of safety for a 1 in 2,500-yr return period earthquake is 1.12 and exceeds the minimum factor of safety of 1.1. However, the calculated factor of safety for the post-earthquake loading condition is only 0.56 and well below the minimum FS of 1.2. For this latter reason, dam upgrading alternatives were evaluated to determine the requirements for ensuring dam stability at closure under expected and potential loading conditions.

Dam Upgrades

A combination of dam buttressing and ground improvement techniques will be required in order to improve the factors of safety for the dam, primarily for the post-earthquake conditions. While the inclusion of a toe buttress in the upgrade design increases the calculated factors of safety for the static and pseudo-static loading condition, it is largely ineffective in improving the factor of safety for post earthquake conditions where the operating strength of the liquefiable soil layer does not behave as a frictional soil. As such, the additional overburden pressure provided by the toe buttress does not effectively increase soil strength.

To address the latter, the inclusion of a shear key in the upgrade design will be necessary in order to achieve an acceptable factor of safety for the dam. The shear key would essentially replace a portion of the thawed and potentially liquefiable soil with higher strength material beneath the toe of the toe buttress. The shear key could consist of either high strength granular material in a thawed state or frozen foundation material. Enough material must be placed above the shear key to prevent a failure surface from exiting above (rather than passing through it). The material above the shear key could consist of waste rock or other suitable granular material. A fundamental requirement of the shear key is that it be keyed into frozen soil and that the permafrost is protected against thawing to guard against the slip surface running below the bottom of the key. Collectively, any theoretical failure (slip) surface must then pass through the shear key; it is for this reason that the presence of a shear key increases the factor of safety.

Because the shear key must be keyed into frozen ground, protection against thawing of the permafrost is a critical component of the shear key design and some form of long-term maintenance of the permafrost is required. For the prefeasibility assessment, the use of thermosyphons to maintain frozen foundation and/or permafrost conditions has been assumed. In support of this assumption, a thermal analysis was conducted by Naviq Consulting in the summer of 2010 to assess the feasibility of developing and maintaining permafrost freeze-back in the thawed foundation and into the toe berm (Appendix I of Appendix C-1). The analysis demonstrated that thermosyphons would be able to freeze the currently thawed ground and maintain a frozen condition. Global warming was considered with an assumed rate of temperature increase for the mean annual temperature of 0.08˚C/year based on the temperature trend since the 1960's. Results indicated that while thermosyphons would be able to provide the necessary freeze-back, they would be a permanent requirement with regular maintenance, monitoring, and replacement. A more detailed discussion of the warming sensitivity analysis is provided in Appendix C-1.

Drainage is another key consideration for the shear key. Measured ground settlements (from observations of monitoring pins) are greater than would be expected from permafrost degradation alone and it is possible that the settlement is related to internal erosion, an observation that warrants close monitoring during subsequent condition assessments. Upgrading the dam therefore includes the placement of a drainage filter against the downslope face of the dam to reduce the potential for internal erosion. A weighted granular or geosynthetic filter would be suitable. The bottom layer of rockfill in the shear key would be graded to provide a low resistance drainage path.

Stability Analysis of Upgraded Dam

A stability analysis was conducted on the upgraded dam that included the following design modifications:

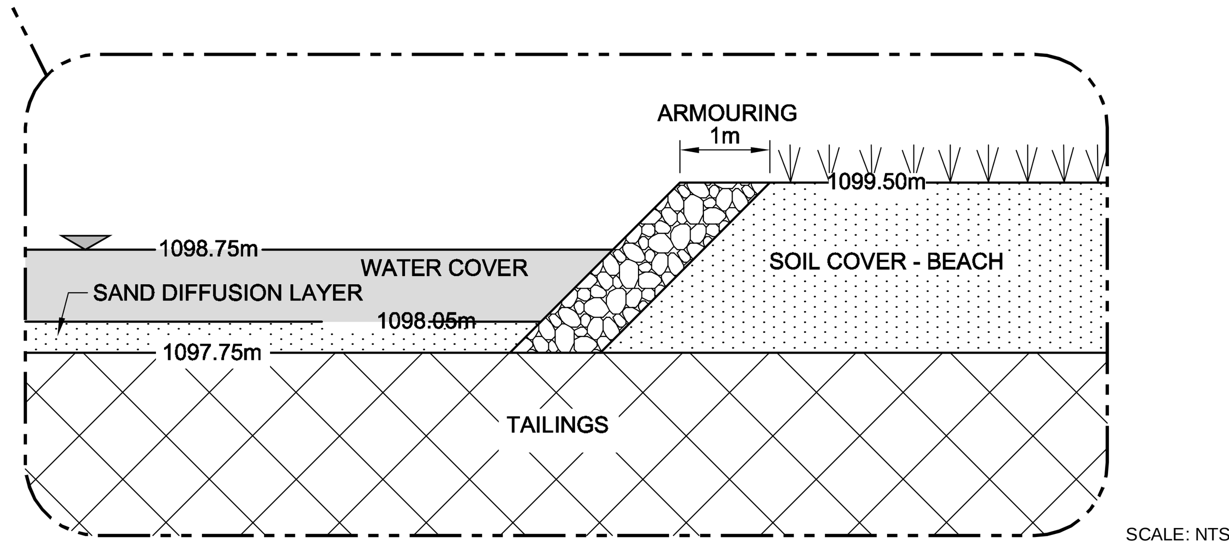
- Toe berm construction against the downstream face of the existing dam;
- Drainage filter on downslope face of the dam along the interface of the dam and toe buttress;
- Construction of a shear key with thermosyphons to ensure maintenance of frozen ground and/or permafrost. Shear key can include granular fill or frozen foundation.

The results of the stability analysis for the upgraded dam is provided in Table 5.4-5 and compares the calculated factors of safety for the upgraded dam with the existing dam. As illustrated, the upgraded dam satisfies the minimum factors of safety for all loading cases evaluated and raises the factors of safety for the static and pseudo static case well above the minimum values. The configuration of Option 1 with respect to the dam and the proposed dam upgrades is presented in Figure 5.4-3.

Table 5.4-5:
Comparison of Calculated Factors of Safety for Existing and Upgraded Dam

		Factor of Safety		
Case	**Loading Condition**	**Minimum Acceptable**	**Existing Dam Condition**	**Upgraded Dam with Toe Butress and Granular Shear Key**
Static	Steady state seepage	1.5	1.74	2.62
Pseudo Static (PGA 0.11g)	Earthquake	1.1	1.12	1.6
Static	Post Earthquake	1.2	0.56	1.26

PROFILE A



DRAFT

Government of Yukon
Mt. Nansen Closure Alternatives Characterization

Option 1
Site Plan & Profile
Drawing - 01

Figure 5.4-3

AECOM

Sand Diffusion and Water Cover

As described previously, a 0.3 m thick layer of coarse sand material will be directly laid on top of the tailings material. In addition, a 0.7 m deep water cover will be maintained over top of the sand diffusion barrier in order to maintain the tailings underwater and prevent the onset of tailings oxidation. The purpose of the sand layer is to provide a coarse cover material within the water cover to prevent the resuspension of tailings from wind or wave action.

A beach area will be formed between the crest of the upgraded dam and the water elevation within the impoundment. The optimal width of the beach would be determined in the detailed design stage, but a 50 m width is reasonable based on the current analysis.

Waste Rock Stability

The bulk of the existing waste rock piles will remain in place for closure Option 1A, although some waste rock will be used for other construction activities (*e.g.,* constructing the toe-berm, and spillway armouring). Some additional grading will be required to improve the stability of the piles. Currently the slopes of the waste rock piles are at the angle of repose, which yields a calculated factor of safety of unity (1), under static conditions above the water table. Long-term stability, considering various loading conditions, would require an increased factor of safety that would be determined during detailed design. For the purposes of the present assessment, waste rock regrading for Option 1A has been assumed and included in the cost assessment.

For Option 1B, the waste rock piles will be relocated into the pit. The placement of the waste rock will be subject to minimal sorting, placement and compaction criteria, except that the rock placed at the bottom of the pit, below the water table should be selected to ensure low metal mobility (Appendix B). The surface of the waste rock in the pit will be contoured in such a way as to promote drainage of surface water out of the pit, and to minimize or eliminate the remaining high-wall. To the extent possible, vegetation would be established on the surface of the waste rock. The re-exposed natural ground surface beneath the current waste rock piles would also be vegetated.

Pit Wall Stability

The pit walls consist of weathered rock. The talus accumulated on the benches and at the base of the pit confirms that there has been ongoing spawling and erosion of the pit walls. No large-scale instability of the pit walls was noted but evidence such as a tension cracks may have been obscured by overburden and weathered rock.

The condition of the pit walls should be considered in more detail during subsequent design stages. A program of scaling is recommended to remove the loose and marginally stable rock from the pit walls. Some blasting and re-grading may also be required to improve the stability conditions of the pit walls and have been factored in the cost analysis for Option 1A.

5.4.2.2 Key Assumptions

The key assumptions employed in the geotechnical evaluation of Option 1A and 1B are as follows:

- The existing dam has an appropriate classification of *High* consequence;
- The dam factors of safety for various loading scenarios can be improved through construction of a toe buttress and shear key;
- Future thawing or degradation of the permafrost can be halted through the use of thermosyphons to maintain frozen ground conditions;
- If thawing cannot be arrested and/or freezing impracticable with thermosyphons, other ground improvement measures will be technically feasible; and
- Coarse tailings currently against the dam face can be removed and replaced with finer tailings (or comparably low permeability material) to limit seepage through the dam and maintain all tailings in a saturated state.

5.4.2.3 Performance and Uncertainty

There are a number of regular operations and maintenance items that must be considered with respect to ensuring adequate performance of Option 1 and include the following:

- Dam safety reviews will need to be conducted at the minimum intervals as specified by the Canadian Dam Association Guidelines.
- Dam maintenance and toe-berm maintenance will be required on a regular basis
- Some maintenance is anticipated for the water cover over several years following construction. An area of concern will be against the tailings dam where the coarse tails will be replaced with the fine tails. Some settlement would be expected in this area.
- Deformations should be monitored at regular intervals after the construction of remedial measures to identify changes in the performance of the dam, and determine the effectiveness of the stabilization work and seepage filters.

- Thermistors should be monitored at regular intervals (seasonally or more regularly with a data logger) to determine the performance of the thermosyphons at the toe berm. Ongoing changes in the thermal regime at other locations are also of interest with respect to seepage and dam stability.
- Water levels: Surface and groundwater levels are important indicators of the performance of the remedial works. Regular monitoring should be maintained until a steady-state condition develops (considering seasonal effects) and satisfactory performance is achieved.
- The physical stability of the waste rock piles should be considered as part of site inspections.
- The pit should be inspected at regular intervals to assess the condition and stability of the pit walls. Some regular maintenance may be required if the pit walls are considered to pose a risk to the public. The perimeter safety barrier (ditch and berm) and signage should be maintained in good condition.
- Because of the maintenance requirements described above, access to the site should be maintained to accommodate the maintenance, and monitoring programs.

The principal uncertainties with respect to successful implementation of Option 1A and 1B from a geotechnical perspective relate to the ability to upgrade the dam sufficiently to ensure stability in perpetuity and the safe storage of saturated tailings. The most important aspect to increasing dam stability is the success of the toe buttress and underlying shear key to offset the presence of liquefiable soils within the foundation of the dam. In order for the shear key to perform as designed, the shear key must be keyed into frozen ground that remains frozen. The extent of, and impacts related to, continued global warming are poorly understood and difficult to predict with existing modeling tools. The ability of thermosyphons to maintain frozen conditions under a warmer climate regime are unknown and long-term monitoring of performance will be integral to the success of Option 1A and 1B.

Also important is the ability to control and limit seepage through the dam, particularly under the saturated conditions specified in Option 1A and 1B. Uncertainty exists in the ability to improve the dam face seepage characteristics by replacing coarse tailings with fine tailings.

The long term integrity of the sand diffusion cover is also uncertain under the climate conditions at Mt. Nansen. Winter freeze-up typically produces ice thickness well in excess of 1 m, suggesting that frozen conditions will likely extend through the water cover and into a portion of the sand diffusion layer. During spring thaw and ice break-up, portions of the sand diffusion cover may be displaced and redeposited at another location within the impoundment, leaving sections of the tailings without a sand cover. This could potentially result in tailings resuspension during the ice-free periods.

5.4.3 Water Management

5.4.3.1 Overview

Water management assumptions, uncertainties and risks for Option 1A and B are discussed in the next two sections. The overview and description found here also applies directly to Options 2A and B.

As shown in Figure 5.4-3 a permanent saturated cover will be maintained on the tailings by diverting flows from Dome Creek into the impoundment. A ponded area of 6 hectares (ha) will be created, where the maximum water depth (~0.7 m) will be controlled by the elevation of the outflow spillway. Based on an area of 6 ha (60,000 m^2) and a maximum water depth of 0.7 m, a volume on the order of 70,000 m^3 will be available to maintain saturation conditions throughout the year. The water requirements for the saturated soil cover (Option 2) are less than for a water cover (Option 1) due to reduction in evaporation.

Though the impacts on Dome Creek are anticipated to be small (*i.e.*, ponded area compared to Upper Dome Creek catchment area), evaporation rates from the water cover can be expected to exceed rates from the land surface. The introduction of water cover, a higher dam crest (change in storage capacity), and the Dome Creek diversion would continue to “dampen” the Dome Creek hydrograph downstream of the site compared to a pre-mine situation. The effects of such changes on the flow regime of the creek are likely minimal and may in fact increase stream-bank stability. Furthermore, results from hydrogeological studies suggest that changes to groundwater flows would be minimal at the TSF post-implementation of this option.

For Option 1B, the addition of waste rock to the pit lake will have an influence on its water balance. Rates of evaporation from the open water surface would diminish, and the presence of rock (decrease in storage) may influence local water levels. At this time, the effects of changing surface water catchments around the pit on groundwater levels, groundwater divide, and groundwater flow is not known with certainty. Of particular concern is the susceptibility of the pit to overflow into Pony Creek via the Pony Creek Adit. As a precaution, costs estimates have been made to further seal the adit prior to pit backfill.

5.4.3.2 Key Assumptions

From a water management perspective, the success of this option is contingent on tailings pond water balance (*i.e.*, hydrology and water balance, Section 5.4.5) and includes the management of seepage water through the tailings mass and through the tailings dam, and on the design, monitoring and maintenance of water management structures/controls at the site (dam and crest, spillway, diversion structure, channels). The following assumptions relate most strongly to site hydrology, water management, and the required water infrastructure for the site:

Seepage Control

Seepage through the dam occurs under existing conditions and could potentially increase with increased pond water levels expected under Option 1. Moreover, increased seepage through the dam face could also result in the potential drying out of tailings near the upstream face of the dam. This material is more permeable than the majority of tailings in the impoundment. As such, Option 1A and 1B needs to include measures to reduce seepage rates through the tailings dam at closure.

A 2-dimensional seepage analysis was performed for the tailings dam (Appendix C-1 and Appendix H within that document) for the existing condition to characterize seepage through the dam and evaluate the effects of seepage control strategies. The analysis indicated that a significant reduction in seepage through the dam could occur by either replacing the zone of coarse tailings (against the dam face) with finer tailings, or by installing a seepage barrier along the upslope face of the dam. Either of these improvements would require the excavation and replacement a volume of tailings and or the use of lower permeability material.

Spillway Upgrading

Option 1 requires upgrading of the dam closure spillway in order to safely pass flood flows through and over the impoundment. Peak flow rate and volume estimates were computed for the tailings pond to evaluate the necessary spillway upgrading for closure Options 1A and 1B.

Based on the classification of *High* consequence, the CDA (2007) requires that the Inflow Design Flood (IDF) should be estimated as 1/3 between the 1,000-year event and the Probable Maximum Flood (PMF). The precipitation records from the Environment Canada meteorological gauging station at Carmacks, Yukon were used to estimate the peak flow rate and volume for the 1,000-year, 10,000-year, IDF, and PMF events (Appendix D). The recorded rainfall records at the Carmacks gauge have been adjusted to estimate the rainfall depth at the Mount Nansen mine site based on a regression analysis (Appendix D).

The 1000-year and 10,000-year rainfall intensities have been extrapolated from the Intensity-Duration-Frequency curves at the Carmacks gauge provided by Environment Canada. The Environment Canada estimated 2, 5, 10, 25, 50, and 100 year rainfall intensities were plotted to obtain regression equations for various storm durations. The regression equations were used to approximate the 1,000-year and 10,000 year rainfall intensities for various storm durations. It should be noted that CDA discourages the extrapolation of flood statistics beyond the 1,000-year event and the 10,000 year event has been provided for the sake of analysis.

The Probable Maximum Precipitation (PMP) was used to develop the PMF. The PMP was computed using the maximum annual 24-hour rainfall records adjusted from Carmacks gauge. Details of the approach are described in Appendix C-1.

A 6-hour storm duration has been assumed for the analysis and in the determination of appropriate spillway dimensions. The assumed 6 hour storm duration peak flow rate for the 1000 year, 10,000 year, Probable Maximum Flood (PMF), and Inflow Design Flood (IDF) have been estimated as 4.0 m^3/s, 4.8 m^3/s, 12.5 m^3/s, and 6.8 m^3/s, respectively. The assumed 6-hour storm duration volumes for the 1,000 year, 10,000 year, PMF, and IDF have been estimated as 89,000 m^3, 107,000 m^3, 281,500 m^3, and 153,000 m^3, respectively. Further details are provided in Appendix C-1.

To pass these flows and volumes, various potential spillway widths of 5 m, 7 m and 10 m were analyzed for the tailings pond based on the estimated peak flow rates and volumes for the above noted events. The maximum allowable water level rise in the tailings pond has been assumed as 1 m. The results of the modeling for various spillway widths and design flow events are summarized in Table 5.4-6.

Table 5.4-6:
Summary Results of Tailings Pond Spillway Modeling

Design Event	Spillway Width (m)	Peak Inflow (m^3/s)	Inflow Volume (m^3)	Peak Spillway Outflow (m^3/s)	Maximum Water Level Rise (m)
1,000 - year	5	4	89,000	2.8	0.5
	7			3.1	0.4
	10			3.4	0.3
10,000 - year	5	4.8	107,000	3.5	0.6
	7			3.8	0.5
	10			4.1	0.4
Inflow Design Flood	5	6.8	153,000	5.2	0.7
	7			5.6	0.6
	10			6	0.5
Probable Maximum Flood	5	12.5	281,000	10.3	1.1
	7			11	0.9
	10			11.5	0.8

Based on the above analysis, an upgraded spillway of 5 m width has been selected in the conceptual design to safely pass the IDF. Assuming that a minimum of 0.5 m of remaining freeboard would be required at this flow, the spillway channel would have to be at least 1.2 m below the tailings dam crest. The final spillway elevation will be dependent upon the final cover design.

Dome Creek Diversion and Downstream Diversion Channel Upgrading

Based on water balance modeling for the site (GEEC 2010), it has been determined that in order to maintain a water cover over the tailings for Option 1, it will be necessary to divert the flows in Dome Creek to the tailings impoundment. To accommodate this, the diversion channel upstream of the spillway will be backfilled and graded to fit the natural slope contours. Armouring of the Dome Creek inlet to the tailings facility will be necessary (Figure 5.4-3) to avoid erosion of the tailings material.

The diversion channel, downstream of the tailings impoundment spillway for Option 1, will likely require upgrading with additional armouring. In addition, drop structures in the steeper sections of the diversion channel will also likely require upgrades to maintain acceptable flow velocities and these upgrades have been included in the cost assessment.

Open Pit Lake and Pony Creek Adit (Option 1B)

As part of Option 1B, approximately 510,000 m^3 of waste rock will be backfilled to the open pit (Figure 5-4). Of interest from a water management and cost perspective, is the relationship between water levels in the pit and the overflow elevation of Pony Creek adit. The addition of waste rock to the pit lake would reduce available storage and alter the influence the water balance of the pit site (*e.g.*, evaporation from waste rock is anticipated to be lower than from an open water surface). The pit lake is presently situated at a topographic high (*i.e.*, drainage area that influences the pit is small), and historical data show a disconnection between the pit lake surface and adit. However, it is not clear whether addition of waste rock will affect pit water levels appreciably. It is reasonable to assume that changes associated with this option will not cause the pit lake to overflow into the adit (and then Pony Creek). As a contingency, costs associated with sealing the adit have been provided.

5.4.3.3 Performance and Uncertainty

The primary performance issues, uncertainties and risks for Option 1 and 2 include dam failure, spillway failure and cover efficacy.

Tailings Dam and Spillway Considerations

- Performance and uncertainty is directly linked to the success of the approach taken to decrease seepage rates, reduce the volume of unsaturated tailings, and decrease porewater pressures in the tailings dam (*i.e.*, use of liner or tailings blend).
- Water management assumptions that pertain to current/past conditions (*e.g.*, air temperature, precipitation, permafrost thickness and extent) cannot be extrapolated to the future with certainty.

Cover System

- The performance of the cover system is inextricably linked to the water management plan for the site (*i.e.*, the plan that governs the design, construction, maintenance and monitoring of infrastructure). Much like the performance of the tailings dam, unforeseen maintenance costs may be incurred to repair or enhance performance of the cover system.
- Performance of the cover is dependent on efficacy under a wide range of environmental conditions (*e.g.*, warmer climate where the likelihood of winter discharge events increases).

Water Diversion Structures and Channels

- New water diversion structures will require regulatory approval, as well as routine maintenance.

5.4.4 Geochemistry

5.4.4.1 Overview

Source terms describing drainage chemistry predictions were developed for the tailings in the impoundment, pit lake, and waste rock stored subaerially (1A and 1B) and saturated in the pit (1B). The development of these source terms and a description of existing geochemical conditions are discussed in detail in Appendix B. Acid base accounting and laboratory-based kinetic experiments indicate that the tailings are potentially acid generating. In other words, acidic drainages and associated metal leaching are likely to develop if the tailings are exposed to oxygen over extensive periods of time. In this regard, the primary objective of Options 1A and 1B is to maintain the tailings in a saturated state to preclude the development of acidic drainages. In contrast to the tailings, the waste rock piles are already extensively oxidized and are categorized primarily as non-acid generating.

From a geochemical standpoint, Option 1A closely resembles the *status quo* (*i.e.*, tailings and wasterock left in place)). In Option 1B, the waste rock is moved to the pit where a portion will reside below the water table. The transfer of waste rock from subaerial conditions (oxidizing environment) to saturated conditions (reducing environment) will affect mineral solubility equilibria, potentially resulting in the release of metals. A significant portion of waste rock will also remain above the water table and subaerially exposed. Therefore, the chemistry of the drainage from the pit will be dictated by a combination of geochemical processes occurring in both unsaturated and saturated waste rock environments. To incorporate conservatism into the waste rock source terms under Option 1B, the saturated and unsaturated values for each parameter were compared and the highest value was selected as the backfilled waste rock source term.

5.4.4.2 Key Assumptions

Numerous assumptions were made in deriving source terms for Options 1A and 1B as described below.

<u>Option 1A:</u>

- The geochemical mechanisms that currently dominate remobilization and attenuation within the tailings impoundment, waste rock piles, and pit lake, will continue to be the dominant mechanisms controlling metal mobility in the future;
- All components (pit lake, tailings, and waste rock) have reached pseudo-equilibrium and shifts in this equilibrium state will be minimal with time;
- The groundwater flow paths through the tailings will remain constant (*i.e.,* neither dam upgrades nor degradation of permafrost will significantly alter the groundwater flowpath through and under the impoundment);
- Tailings will remain saturated and will not produce acidic drainage;
- A small diffusive flux of As, Mn, and sulfate (only) from the tailings to the overlying water cover is expected;
- The unsaturated ore field bin, upon which ore source terms were based, is representative of long-term drainage from unsaturated ore; and
- Waste rock is non-acid generating.

<u>Option 1B:</u>

The relocation of waste rock to the pit as part of Option 1B introduces a further set of assumptions with respect to waste rock behaviour:

- As the waste rock is excavated and relocated to the pit, the organic soils underlying the piles will be relocated into the pit along with the waste rock. A portion of the waste rock placed in the pit will be below the water table and saturated. Under these conditions (saturated and presence of organics) suboxic conditions will develop in waste rock pore spaces;
- Metals associated with extensively oxidized waste rock materials are primarily associated with soluble and oxide phases which will be subject to dissolution following submergence and exposure to suboxic conditions;
- Source terms for the saturated waste rock were developed using data generated from the saturated waste rock field bin. This assumes that the field bin has reached an equilibrium state that will be representative of the suboxic conditions that are likely to develop within the pit environment;
- The waste rock stored in the pit above the water table (unsaturated conditions) is assumed to exhibit drainage similar to the current subaerially exposed waste rock piles; and
- The chemistry of the drainage from the pit is dictated by a combination of geochemical processes occurring within both unsaturated and saturated waste rock.

5.4.4.3 Performance and Uncertainty

The source terms developed for each mine component under Options 1A and 1B are provided in Table 5.4-7. The degree of uncertainty associated with the source terms derived for the tailings, waste rock, and the pit lake under Option 1A is low relative to

Table 5.4-7: Options 1A and 1B Geochemical Source Terms (mg/L)

Parameter	Conservative Best Estimate						Worst Case					
	Tailings Impoundment		*Pit*		Waste Rock Pile (1A)	Ore	*Tailings Impoundment*		*Pit*		Waste Rock Pile (1A)	Ore
	Seepage	Diffusive Flux (mg/m^2/day)	Lake (1A)	Waste Rock (1B)			Seepage	Diffusive Flux (mg/m^2/day)	Lake (1A)	Waste Rock (1B)		
Ca	241	-	385	368	368	431	24	-	470	346	346	431
Mg	33	-	124	93	93	297	5	-	163	91	91	297
As	0.04	0.1	0.02	0.1	0.007	0.03	0.3	0.1	0.08	1	0.02	0.04
Cd	0.0009	-	0.02	0.03	0.03	0.09	0.002	-	0.03	0.2	0.2	0.2
Cu	0.009	-	0.03	0.04	0.04	0.02	0.02	-	0.09	0.2	0.2	0.04
Fe	13	-	0.5	2	0.01	0.03	40	-	3.0	5	0.06	0.05
Mn	8	0.1	3	143	5	49	10	0.1	7	181	29	97
Zn	0.02	-	2	5	5	10	0.1	-	3	34	34	31
Sulfate	663	49	1230	2040	1530	2265	1380	49	1690	2940	2940	2680
Ammonia	6	-	0.2	1	0.03	0.03	12	-	0.4	2	0.1	0.09
CN (Tot)	0.7	-	-	-	-	-	0.5	-	-	-	-	-
WAD CN	0.03	-	-	-	-	-	0.2	-	-	-	-	-
Cyanate	2	-	-	-	-	-	18	-	-	-	-	-
Nitrate	3	-	2	0.3	2	0.3	10	-	4	1	10	0.9
Nitrite	0.3	-	0.06	0.1	0.02	0.08	0.6	-	0.3	0.4	0.4	0.1

Notes:
Under the Waste Rock 1B column shaded cells represent terms dominated by unsaturated chemistry, non-shaded cells represent terms dominated by saturated chemistry

Options 3 and 4 due to the fact that there is a large historic dataset from which the source terms were derived. Specifically, the existing data set provide considerable insight into the geochemical mechanisms controlling the remobilization and attenuation of contaminants of concern.

The principal uncertainties associated with Option 1A relate to whether the geochemical processes observed over the past 3-10 years accurately represent a robust proxy for future conditions in the long-term (decadal to century time scales). In particular, the attenuation of As and other trace elements within zones of sulfate reduction has a pronounced effect in minimizing loadings from the tailings facility. Uncertainty also relates to potential changes in seepage flow paths. For example, if dam upgrades or the degradation of permafrost alter groundwater flowpaths through the impoundment, there is the possibility that the attenuation of As and other metals may decrease. Similarly, if the pit lake undergoes significant fluctuations in the water table elevation it may be possible to see higher metal loadings due to increased sulfide oxidation rates during extremely low lake levels, and flushing of soluble metal-bearing phases during periods of high lake levels.

Source terms for the subaerially exposed waste rock (Options 1A and 1B) were derived from data for natural seeps emanating from waste piles on site. These seeps have not been disturbed by construction or human activity, have potentially been active for up to 10 years, and serve as a representative measure of natural weathering processes. Given these considerations, there is a reasonable degree of confidence with regards to the long-term drainage characteristics of subaerially exposed waste rock.

With regards to the waste rock stored in a saturated state below the water table (Option 1B), suboxic conditions are predicted to develop within waste rock pore spaces. To some degree, organic soils underlying the waste rock will inadvertently be transported with the waste rock to the pit. This material will further contribute to the development of suboxic conditions through oxidation of the organic components. Source terms for the saturated waste rock were derived from data collected from waste rock + organics field bin that has evolved from oxic to suboxic conditions. It is not clear if this field bin has reached steady-state redox conditions, and therefore there is some uncertainty with regards to the potential for metal release from these materials under strongly suboxic conditions. Under conditions of more pronounced suboxia, for example, arsenic concentrations in waste rock drainages could be expected to be higher than those values currently observed in the field bin.

Low-grade ore exists as backfill above the southern end of the open pit; however, no drainage chemistry is available from this material as no visible seeps have been identified. To compensate for the absence of field data, a field bin was constructed which maintains low-grade ore materials in an unsaturated condition. Data collected for this bin were used to derive source terms for the unsaturated ore material. There is significant uncertainty around the usage of drainage chemistry from the field bins in general due to the fact that only 1 year of drainage chemistry has been collected since their installation in July 2009. Based on the drainage chemistry observed to date, it does not appear that the unsaturated ore bin has reached equilibrium and therefore may not be representative of longer-term drainage conditions; further data collection is required to constrain the existing uncertainty.

5.4.5 Surface Water Quality

5.4.5.1 Overview

A water balance and water quality model was developed in Goldsim to support the assessment of closure Option 1A and 1B (Appendix F). Key inputs to the model included precipitation and water quality chemistry from the various source terms (*e.g.*, tailings seepage, waste rock, ore, background Victoria Creek, *etc*.) For each option, a total of six different model scenarios were run, including combinations of two different source term chemistry estimates (Conservative Best Estimate and Worst Case) and three precipitation conditions (dry, average and wet year). The Conservative Best Estimate and Worst Case predictions reflect the range in source concentrations used in the model (Appendix B). For each scenario, the model was run on a monthly time step for a calendar year (12 months).

The overarching objective of the water balance and water quality modeling was to provide a tool to directly compare the environmental merits and performance of each closure option. To this end, and in order to best illustrate the differences between the closure options with regards to water quality, mill area contaminant loadings were excluded from the assessment. Currently, mill area loadings are a dominant control on downstream water quality and inclusion would obscure the differences in final water quality under the proposed closure scenarios. For these reasons - in concert with the fact that the mill area is a common closure element to all options and will be remediated (Section 5.2) - mill area loadings were ignored in order to differentiate resultant water quality effects from each of the closure options.

In order to illustrate the predicted performance of the various options, emphasis was placed on arsenic, sulfate, cadmium and zinc, since these constituents are the primary parameters of concern. Water quality predictions for the above parameters are considered long-term or steady-state estimates. Details of the water balance and water quality model, including model configuration, assumptions and results, are provided in

Appendix F. For the summary presented herein, only the Conservative Best Estimate results from the model are presented; all data are described and presented in Appendix F.

For Option 1A and 1B, the model integrates the mine-related loadings and flows in the receiving environment. The mine site related sources that may contribute contaminant loadings to the receiving environment for Option 1A and 1B are summarized below.

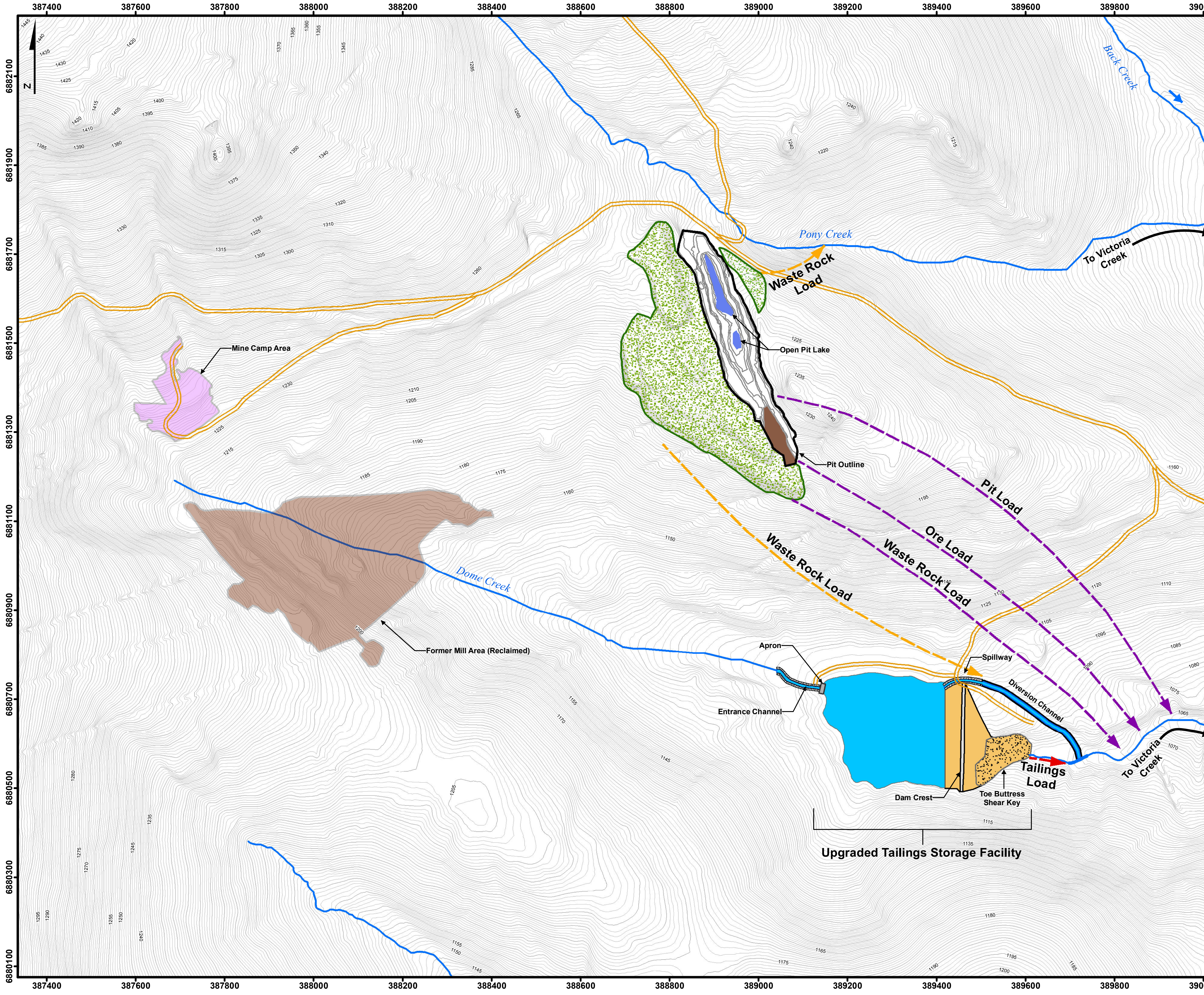
Option 1A:

- Year-round seepage from tailings storage area;
- Seasonal, shallow seepage from portions of waste rock on surface;
- Year-round, deep groundwater seepage from the low-grade ore within the pit;
- Year-round, deep groundwater seepage from portions of waste rock on surface; and
- Year-round, deep groundwater seepage from the pit lake.

Option 1B:

- Year-round seepage from tailings storage area;
- Year-round, deep groundwater seepage from the low-grade ore within the pit; and
- Year-round, deep groundwater seepage from the waste rock backfilled pit.

For Option 1 (1A and 1B), schematics depicting the key components of the water quality model are presented in Figure 5.4-4 and Figure 5.4-5, respectively.



CLIENT:: Yukon Government

Legend

- Roads
- Watercourse
- Former Mill Area (Reclaimed)
- Mine Camp Area
- Dam Area
- Pit Outline
- Reclaimed Ore Area
- Reclaimed Waste Rock Dump
- Upgraded Tailings Impoundment (Water Cover)
- Shallow Groundwater Seepage
- Tailings Seepage
- Deep Groundwater Seepage

Topography

- Index (5m)
- Interm (1m)

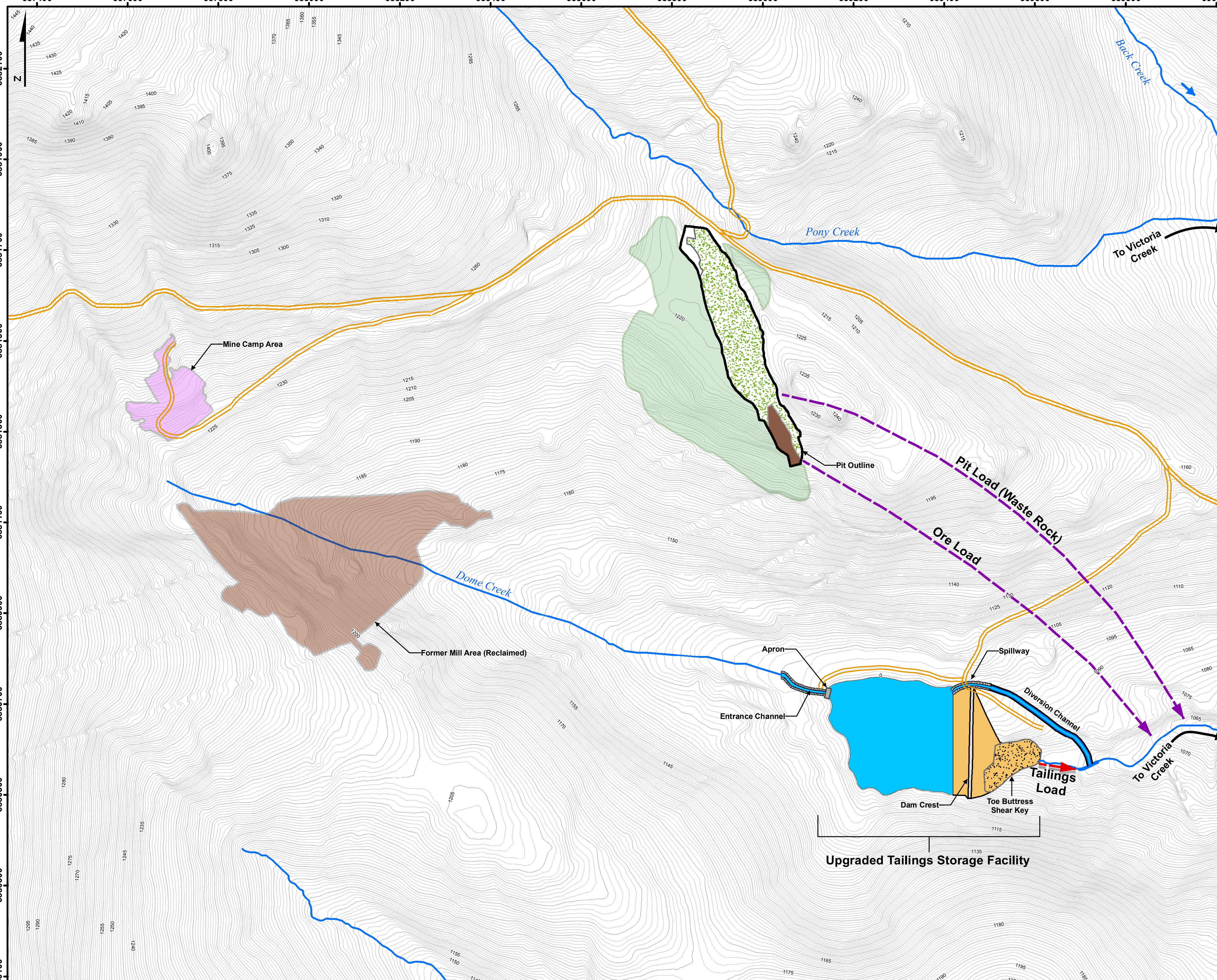
Meters: 0 150 300 600

Data courtesy of AECOM

Figure for illustrative purposes only

SCALE:	1:8,000
DATE:	OCT 22nd, 2010
PROJECTION:	NAD_1983_UTM_Zone_8N
PROJECT MANAGER:	J.S.
PROJECT:	**Mount Nansen Options for Closure**
TITLE:	**Closure Option 1A:Schematic of Source Loadings for Water Quality Model**
PROJECT No: J907-4	FIGURE No: 5.4-4

LORAX ENVIRONMENTAL
2289 Burrard St.
Vancouver, BC, V6J 3H9
Phone: (604) 688-7173
Website: www.lorax.ca



CLIENT:: Yukon Government

Legend

- Roads
- Watercourse
- Former Mill Area (Reclaimed)
- Mine Camp Area
- Dam Area
- Former Waste Rock Dump Area (Reclaimed)
- Pit_Outline
- Reclaimed Ore Area
- Reclaimed Pit Backfill (Waste Rock)
- Upgraded Tailings Impoundment (Water Cover)
- Tailings Seepage
- Deep Groundwater Seepage

Topography

- Index (5m)
- Interm (1m)

Meters: 0, 150, 300, 600

Data courtesy of AECOM

Figure for illustrative purposes only

SCALE:	1:8,000
DATE:	OCT 22nd, 2010
PROJECTION:	NAD_1983_UTM_Zone_8N
PROJECT MANAGER:	J.S.

PROJECT:

Mount Nansen Options for Closure

TITLE:

Closure Option 1B: Schematic of Source Loadings for Water Quality Model

PROJECT No:	FIGURE No:
J907-4	5.4-5

LORAX ENVIRONMENTAL

2289 Burrard St.
Vancouver, BC, V6J 3H9

Phone: (604) 688-7173
Website: www.lorax.ca

5.4.5.2 Key Assumptions

The following are the key assumptions that have been incorporated into the water balance and water quality model for Option 1A and 1B:

- The mill area has been fully reclaimed and as such the water quality upstream of the mill area was assigned to represent the upstream or background water quality in Dome Creek (*i.e.*, the model predictions exclude mine-related loadings emanating from the mill area);
- For un-impacted catchment areas, a runoff coefficient of 0.8 was assumed for spring freshet (April and May) and a runoff coefficient of 0.6 for the remaining open water season months;
- No attenuation (*i.e*., removal of dissolved metals from solution) is assumed to take place along either the shallow or deep groundwater flow paths from the pit and waste rock areas.
- To support the modeling, a synthetic historical precipitation record was generated for Mount Nansen based on climate data from Carmacks and Mount Nansen between 2000 to 2006 (Appendix D and Appendix F);
- Based on the synthetic precipitation record, dry, wet and average annual precipitation conditions were selected for modeling;
- Annual lake evaporation was estimated based on data from the Pelly Ranch Environment Canada Meteorological gauging station: 369 mm/year (Appendix D and Appendix F);
- For Dome Creek, zero flow was assumed during the winter months (November through March) as attempts to measure winter flow indicates frozen conditions through to the substrate; and
- For Victoria Creek, site monitoring indicates the presence of winter flow. For the model, monthly flow in Victoria Creek was estimated based on the monthly flow distribution in the Nordenskiold River.
- The water cover is modeled as a reservoir with inflows from onset precipitation and runoff from the surrounding catchment area. Outflows include discharge of excess water via the spillway, evaporation from the pond surface area, and vertical infiltration through the tailings and tailings dam;

- Vertical infiltration through the tailings and tailings dams was based on two-dimensional modeling work carried out by AECOM (Appendix C-1) and set to ~1.2 L/s;
- The overall long term seepage rate discharging from the toe of the upgraded dam to the receiving environment was assumed to be similar to the historical low-flow seepage pumping rate for the existing seepage collection pond and was assumed to be constant throughout the year at 3.5 L/s;
- The pit is left as is for Option 1A and the discharge rate from the pit to the receiving environment (*i.e.,* Dome Creek) used in the model was conservatively set to the maximum discharge rate estimated using Darcy's Law for a range of hydraulic conductivities: ~0.14 L/s (Appendix E);
- For seepage from waste rock, a key assumption is that there is no net surface runoff. Snowmelt and onset precipitation either evaporates or infiltrates into the waste rock dumps;
- Monthly net-infiltration rates for the waste rock dumps were based on the results of a one-dimensional unsaturated flow model developed by Golder (Appendix C-3) and monthly net-infiltration rates were applied uniformly to the entire waste rock surface area;
- Depending on the specific configuration of the dumps, water that infiltrates into the dumps either reports to the receiving environment as variable shallow groundwater seepage or continuous deep groundwater seepage;
- Diffusion rates of arsenic, manganese and sulfate from the tailings porewater to the water cover were estimated to be 8.6, 7.4 and 2,967 grams per day (g/day), respectively; and
- Diffusion of dissolved constituents from the tailings porewater to the water cover is assumed to occur year-round, except between December through March when frozen conditions are present.
- For Option 1B, all the waste rock is relocated into the pit resulting in a reduction in the waste rock footprint from 114,550 m^2 to 36,000 m^2;
- Net-infiltration through the backfilled waste rock in Option 1B was based on the results of a one-dimensional unsaturated flow model (Appendix C-3). The modeling provided computed fluxes including evaporation, runoff, surface infiltration, and infiltration through the top and bottom of the waste;

- Two independent approaches were used to estimate the annual flux through the pit that is partially backfilled. Both estimates yielded fluxes that were very low and well below 0.5 L/s (~0.14 L/s). Accordingly, the assumed groundwater discharge rate from the pit to Dome Creek was assumed to be 0.14 L/s for Option 1B.

5.4.5.3 Performance and Uncertainty

<u>Performance</u>

Water quality predictions for each of the model runs were used to assess the performance of Option 1A and 1B through comparison to existing water quality in the downstream receiving environment in Victoria Creek; CCME Guidelines for the Protection of Aquatic Life are also included as a point of reference.

A summary of the Best Estimate water quality predictions (average year) for sulfate, arsenic, cadmium and zinc in Victoria Creek for Option 1A and 1B are presented in Table 5.4-8 and Table 5.4-9.

Table 5.4-8:
Summary of Predicted Concentrations (mg/L) in Victoria Creek for Option 1A - Best Estimate Source Terms and Average Precipitation Conditions

		Existing Water Quality[b]		**Predicted Water Quality**	
Parameter	*CCME Guideline*	*Median*	*Winter Maximum[c]*	*Median*	*Maximum*
Arsenic	0.005	0.0016	0.0075	0.0020	0.0055
Cadmium	0.00034[a]	0.00003	0.0003	0.00012	0.00051
Zinc	0.03	0.009	0.02	0.018	0.062
Sulfate		30	61	36	106

Notes:
a. Draft CCME Guideline for Cadmium (Environment Canada 2008) at Hardness = 150 mg/L as $CaCO_3$.
b. Existing water quality data for Victoria Creek at Road (2007 to 2010).
c. Maximum winter concentration from the existing water quality data set for Victoria Creek (November to February, 2007 to 2010).

Table 5.4-9:
Summary of Predicted Concentrations (mg/L) in Victoria Creek for Option 1B - Best Estimate Source Terms and Average Precipitation Conditions

		Existing Water Quality[b]		**Predicted Water Quality**	
Parameter	*CCME Guideline*	*Median*	*Winter Maximum[c]*	*Median*	*Maximum*
Arsenic	0.005	0.0016	0.0075	0.0021	0.0059
Cadmium	0.00034[a]	0.00003	0.0003	0.00006	0.00028
Zinc	0.03	0.009	0.02	0.010	0.035
Sulfate		30	61	35	98

Notes: as per Table 5.4-7

Analysis of the water quality database has shown that existing metal levels in Victoria Creek are governed predominantly by particulate fractions, and show elevated levels in conjunction with TSS (Appendix F). However, there are no consistent seasonal trends in the data, which implies TSS events are governed by variables other than freshet flows, including storm events and upstream placer mining activities. Accordingly, maximum winter concentrations were used for the comparison as they most accurately reflect the range of current water quality conditions during the more sensitive winter low flow period when higher concentrations are predicted to occur. Note however that winter water quality data are limited to only a few samples from 2007 to 2010.

The most salient points (for Best Estimate/Average Flow Scenario) of the water quality predictions for Option 1A are as follows:

- For all modeled parameters, peak concentrations are predicted to occur during the winter low flow period due to ongoing loadings from the site during periods of minimal flow and available dilution. These results are a direct function of the conservative assumptions that the seepage rate from the tailings and discharge rate from the deep groundwater system will remain constant throughout the year despite varying flows in Victoria Creek.
- *Sulfate*
    - In general, the predicted concentrations for sulfate (median = 36 mg/L) are similar to existing sulfate concentrations (median = 30 mg/L) in Victoria Creek, except for winter low flow periods (Table 5.4-8). During this period, the predicted maximum concentration of 106 mg/L is notably higher than the maximum observed winter sulfate concentration (61 mg/L).
    - The primary source of the higher predicted sulfate concentrations in the winter low flow period is the invariant discharge of tailings seepage to the receiving environment at a rate of 3.5 L/s. In reality, it would be anticipated that the seepage discharge would decrease over the winter period, and as such, the winter predictions are considered to be conservative.
- *Arsenic*
    - Predicted concentrations of arsenic (median = 0.002 mg/L) are comparable to existing arsenic concentrations in Victoria Creek (median = 0.0016 mg/L) and are well below the CCME guideline of 0.005 mg/L (Table 5.4-8).
    - Maximum concentrations of arsenic are predicted to occur during winter low flow (peaking at 0.0055 mg/L). This value marginally exceeds the CCME

guideline, although is within the range of the existing maximum winter concentrations (maximum = 0.0075 mg/L).

- The predicted loading associated with tailings seepage is the dominant source of arsenic to the receiving environment.

- *Cadmium*
  - Predicted cadmium concentrations are higher than the existing values currently observed in Victoria Creek.
  - The predicted median cadmium concentration (0.00012 mg/L) is approximately 4 times higher than the existing median concentration in Victoria Creek data (0.00003 mg/L) but well below the CCME guideline (Table 5.4-8).
  - Maximum concentrations of cadmium are predicted to occur in winter (January to March) at concentrations above the draft CCME guideline.
  - The predicted maximum cadmium concentration of 0.00055 mg/L is approximately twice the existing maximum winter concentration 0.0003 mg/L.
  - The predicted loading from seepage from the waste rock dumps is the dominant source of cadmium to the receiving environment.
- *Zinc*
  - The predicted median zinc concentration (0.018 mg/L) is approximately twice the existing median concentration (0.009 mg/L) but below the CCME guideline of 0.03 mg/L.
  - Maximum concentrations of zinc are predicted to occur in winter at concentrations above the CCME guideline.
  - The predicted maximum zinc concentration (0.062 mg/L) is 3 times the existing winter maximum concentration (0.02 mg/L).
  - The predicted loading from seepage from the waste rock dumps is the dominant source of zinc to the receiving environment.

For both cadmium and zinc, the over estimation of concentrations in Victoria Creek is primarily due to the conservative assumptions for seepage from the waste rock dumps to the receiving environment. Observations on site and elsewhere (*e.g.,* Faro) suggest that south facing slopes do not produce significant seepage due to evaporation. Despite numerous attempts to collect seepage, seeps have not been found from south facing dumps southwest of the Mt. Nansen pit. As a result, seepage rates from these areas are likely overestimated. Further, seepage from portions of the dumps is assumed to infiltrate into the bedrock aquifer and discharge to Victoria Creek via Dome Creek at a constant rate through the year. This assumption likely overestimates flows in the winter and may underestimate flows during the active flow period. A further aspect contributing to model conservatism is that the model does not take into account any attenuation of dissolved constituents along the flow path to the receiving environment. Some degree of cadmium and zinc attenuation in the subsurface environment can be expected through adsporption/precipitation processes. Attenuation of cadmium and zinc appears to be currently occurring in the vicinity of the mill area in upper Dome Creek and below the tailings impoundment in lower Dome Creek. The persistence and long-term performance of these mechanisms are however uncertain and therefore not included in the model.

Key highlights of the model results for Option 1B are:

- Similar to Option 1A, for all modeled parameters, peak concentrations are predicted to occur during the winter low flow period due to continuous loadings from the site during periods of minimal flow and available dilution.
- *Sulfate*
    - In general, the predicted concentrations of sulfate for Option 1B (median = 35 mg/L; maximum = 98 mg/L) are marginally lower than those for Option 1A (median = 36 mg/L, maximum = 106 mg/L) (Table 5.4-9). The lower sulfate concentrations predicted for Option 1B are due to the reduction in loading from the backfilled waste rock.
    - Similar to Option 1A, the primary source of predicted sulfate concentrations in the winter low flow period is the year round discharge of tailings seepage to the receiving environment at constant rate of 3.5 L/s.
- *Arsenic*
    - Predicted concentrations of arsenic for Option 1B (median = 0.0021 mg/L, maximum = 0.0059 mg/L) are comparable to those for Option 1A (median = 0.002 mg/L, maximum = 0.0055 mg/L (Table 5.4-9).
    - The predicted loading from tailings seepage is the dominant source of arsenic to the receiving environment hence little change would be expected between 1A and 1B.

- *Cadmium*
  - The predicted cadmium concentrations for Option 1B (median = 0.00006 mg/L, maximum = 0.00028 mg/L) are lower than those predicted for Option 1A (median = 0.00012 mg/L, maximum = 0.00051 mg/L) and well below the CCME guideline.
  - Comparison of the predicted cadmium concentrations for Option 1B in Victoria Creek to those for Option 1 indicates an improvement in performance (Table 5.4-9).
  - The improvement in water quality relates to a decrease in loading from waste rock. Although still the dominant source of cadmium to the receiving environment, the waste rock contributes significantly less loading primarily due to the overall reduction of the waste rock footprint.
- *Zinc*
  - The predicted zinc concentrations for Option 1B (median = 0.010 mg/L, maximum = 0.035 mg/L) are lower than those predicted for Option 1A (median = 0.018 mg/L, maximum = 0.062 mg/L) and generally below the CCME guideline, except during winter low flow conditions (Table 5.4-9).
  - Comparison of the predicted zinc concentrations for Option 1B in Victoria Creek to those for Option 1 indicates an improvement in performance.
  - Similar to cadmium, the water quality improvements associated with zinc can be attributed to a decrease in the loading from waste rock primarily due to the overall reduction of the waste rock footprint.

Overall, the Best Estimate Average Precipitation model results for Option 1B are comparable to Option 1A and indicate that Victoria Creek water quality would not be degraded for sulfate and arsenic. For cadmium and zinc, the predicted water quality for Option 1B indicates an overall improvement compared to those predicted for Option 1A. The predicted decrease in cadmium and zinc concentrations in the receiving environment under Option 1B relative to Option 1A are due to the reduction in loading from waste rock due to the reduction in the waste rock footprint after backfilling to the open pit.

<u>Uncertainty</u>

As with all predictive models, there are uncertainties related to the various inputs and assumptions that form the basis of the model. Some of these uncertainties are general in nature and apply to all of the options such as monthly flow rates, annual precipitation, evaporation and background or upstream water quality. Others are unique to the specific closure options such as source term chemistry and source discharge or flow rates. Where there is more understanding and/or historical data to support the model assumptions, there is less uncertainty associated with the predicted results. The following provides a summary of the key uncertainties associated with the modeling results for Option 1A and 1B.

- For the tailings area, Options 1A and 1B have less overall uncertainty associated with the water quality predictions in comparison to the other options primarily due to the long-term flow and water quality records for the seepage collection pond. Specifically, the performance of the existing tailings facility with regards to seepage rates and water quality is predicted to provide a defensible proxy for the performance of Option 1 over the long term. This provides a reasonable amount of confidence in the predictions.
- A significant amount of conservatism has been incorporated into the model to account for various uncertainties. One key component of this conservatism is the assumption of constant seepage rate to Victoria Creek from both the tailings area and the deep groundwater pathways conveying contaminants from the pit and surrounding waste rock areas. This conservatism is reflected in the higher predicted winter concentrations which generally exceed historical winter maximum concentrations. In reality, the tailings seepage and deep groundwater flows will exhibit some seasonal variability with a reduction in flows during the winter months.
- With respect to the tailings area water balance for Option 1A and 1B, one of the key considerations is whether there is sufficient water supply in the catchment upstream of the tailings area to maintain a water cover of 0.7 m, particularly during the open water, non-frozen period. A two-part assessment of the available water supply was carried out for Option 1 as part of the water balance modeling work (Appendix F). The first assessment was carried out assuming a runoff coefficient of 0.8 for spring runoff (April and May) and a runoff coefficient of 0.6 for the remaining open water season months as per AECOM (2010) (Appendix D). It is unclear if these proposed coefficients adequately represent runoff conditions at the site for all locations and conditions.
- A sensitivity analysis was performed for Option 1 assuming a lower runoff coefficient of 0.4 for all the open water season months. Results of this assessment indicate that inflows to the tailings area are generally sufficient to maintain a water cover during the open water season. During dry conditions, a minimal drop in water cover would occur, although not significant enough to impact the ability of the water cover to maintain the tailings in a saturated state.

5.4.6 Costs

The estimated capital costs for implementing Options 1A and 1B are presented in Table 5.4-10 and Table 5.4-11. The estimated costs include a 30 percent contingency but do not included costs for design engineering, routine inspections and operations or maintenance as these are expected to be similar for all options considered and therefore do not materially affect the cost comparison. These estimates are considered to be Class D estimates (or ASTM E2516-06 Class 5), with an accuracy of -25 +40 percent.

The capital cost estimates do not include *Common Closure Element* costs which are described in Section 5.2 and Appendix C-2. The estimated capital cost for Option 1A is approximately $8.9 M. Option 1B has an estimated capital cost of roughly $12.5 M. More details related to cost assumptions and breakdown of individual components are found in Appendix C-1 and C-2.

Table 5.4-10:
Summary of Estimate Capital Costs for Option 1A

Work Item Description	Units	Quantity	Unit Cost	Total Cost
Mobilization and Demobilization	L.S.	1	$ 250,000	**$ 250,000**
Construction of Toe Berm				
Crush, transport and place rockfill	m^3	40,000	$ 35	$ 1,400,000
Geosynthetic filter placement	m^2	5,400	$ 20	$ 108,000
Sub Total				**$ 1,508,000**
Ground Improvement				
Thermosyphons	L.S.	1	$ 600,000	$ 600,000
Drainage, insulation, site prep. etc.	L.S.	1	$ 900,000	$ 900,000
Sub Total				**$ 1,500,000**
Tailings Management Area (TMA)				
Regrading	m^2	71,000	$ 5	$ 355,000
Sand diffusion barrier cover (0.3 m)	m^3	18,000	$ 15	$ 270,000
Soil cover beach	m^3	20,000	$ 15	$ 300,000
Beach armouring	m^3	3,300	$ 50	$ 165,000
Replace coarse tails with fine tails	m^3	68,000	$ 12	$ 816,000
Final site preparation, revegetation				$ 34,000
Sub Total				**$ 1,940,000**
Spillway				
Excavation	m^3	2,000	$ 10	$ 20,000
Concrete Overflow	L.S.	1	$ 150,000	$ 150,000
Geotextile	m^2	3,000	$ 10	$ 30,000
Armouring	m^3	1,000	$ 50	$ 50,000
South-Side Berm - fill	m^3	500	$ 10	$ 5,000
South-Side Berm - erosion protection	L.S.	1	$ 15,000	$ 15,000
Sub Total				**$ 270,000**
Dome Creek Diversion into TMA				
Excavation	m^3	750	$ 10	$ 7,500
Geotextile	m^2	675	$ 10	$ 6,750
Armouring	m^3	340	$ 50	$ 17,000
Water Level Controls	L.S.	1	$ 50,000	$ 50,000
Dome Creek Channel and Apron	L.S.	1	$ 50,000	$ 50,000
Sub Total				**$ 131,250**
Dam Raise	L.S.	1	$ 25,000	**$ 25,000**
Diversion/Interceptor Ditch Upstream of Spillway				
Fill in interceptor ditch	m^3	3,400	$ 10	$ 34,000
Fill in Interceptor diversion channel	m^3	5,400	$ 10	$ 54,000
Sub Total				**$ 88,000**
Reslope, regrade and revegetate Waste Rock Storage area				**$ 142,000**
Road construction - base	m^3	900	$ 50	**$ 45,000**
Diversion channel d/s of spillway	L.S.	1	$ 500,000	**$ 500,000**
Monitoring Insrumentation	L.S.	1	$ 200,000	**$ 200,000**
Scale/flatten pit walls	L.S.	1	$ 200,000	**$ 200,000**
Pit safety (signage and berm)	L.S.	1	$ 24,000	**$ 24,000**
Sub Total				**$ 6,823,250**
30% Contingency				**$ 2,046,975**
TOTAL ESTIMATED COST - OPTION 1A				**$ 8,870,225**

Table 5.4-11: Summary of Estimate Capital Costs for Option 1B

Work Item Description	Units	Quantity	Unit Cost	Total Cost
Mobilization and Demobilization	L.S.	1	$ 250,000	**$ 250,000**
Construction of Toe Berm				
Crush, transport and place rockfill	m^3	40,000	$ 35	$ 1,400,000
Geosynthetic filter placement	m^2	5,400	$ 20	$ 108,000
Sub Total				**$ 1,508,000**
Ground Improvement				
Thermosyphons	L.S.	1	$ 600,000	$ 600,000
Drainage, insulation, site prep. etc.	L.S.	1	$ 900,000	$ 900,000
Sub Total				**$ 1,500,000**
Tailings Management Area (TMA)				
Regrading	m^2	71,000	$ 5	$ 355,000
Sand diffusion barrier cover (0.3 m)	m^3	18,000	$ 15	$ 270,000
Soil cover beach	m^3	20,000	$ 15	$ 300,000
Beach armouring	m^3	3,300	$ 50	$ 165,000
Replace coarse tails with fine tails	m^3	68,000	$ 12	$ 816,000
Final site preparation, revegetation				$ 34,000
Sub Total				**$ 1,940,000**
Spillway				
Excavation	m^3	2,000	$ 10	$ 20,000
Concrete Overflow	L.S.	1	$ 150,000	$ 150,000
Geotextile	m^2	3,000	$ 10	$ 30,000
Armouring	m^3	1,000	$ 50	$ 50,000
South-Side Berm - fill	m^3	500	$ 10	$ 5,000
South-Side Berm - erosion protection	L.S.	1	$ 15,000	$ 15,000
Sub Total				**$ 270,000**
Dome Creek Diversion into TMA				
Excavation	m^3	750	$ 10	$ 7,500
Geotextile	m^2	675	$ 10	$ 6,750
Armouring	m^3	340	$ 50	$ 17,000
Water Level Controls	L.S.	1	$ 50,000	$ 50,000
Dome Creek Channel and Apron	L.S.	1	$ 50,000	$ 50,000
Sub Total				**$ 131,250**
Dam Raise	L.S.	1	$ 25,000	**$ 25,000**
Diversion/Interceptor Ditch Upstream of Spillway				
Fill in interceptor ditch	m^3	3,400	$ 10	$ 34,000
Fill in Interceptor diversion channel	m^3	5,400	$ 10	$ 54,000
Sub Total				**$ 88,000**
Backfill Pit with Waste Rock				
Load, haul, backfill pit with waste rock	m^3	510,000	$ 5	$ 2,550,000
Regrade and revegetate pit fill, safety measures				$ 53,000
Plug Pony Creek Adit	L.S.	1	$ 250,000	$ 250,000
Sub Total				**$ 2,853,000**
Regrade and revegetate Waste Rock Storage area				**$ 123,000**
Road construction - base	m^3	900	$ 50	**$ 45,000**
Diversion channel d/s of spillway	L.S.	1	$ 500,000	**$ 500,000**
Monitoring Insrumentation	L.S.	1	$ 200,000	**$ 200,000**
Scale/flatten pit walls	L.S.	1	$ 200,000	**$ 200,000**
Sub Total				**$ 9,633,250**
30% Contingency				**$ 2,889,975**
TOTAL ESTIMATED COST - OPTION 1B				**$ 12,523,225**

5.5 Options 2A and 2B: Tailings Dam Upgrade with Saturated Soil Cover

5.5.1 Overview

Option 2 (A and B) includes many of the key elements of Option 1, both of which entail remediation of the existing tailings facility through upgrading of the dam structure and maintaining the tailings in a saturated condition. The major difference between these options is that Option 2 includes the placement of a soil cover as opposed to a water cover (Figure 5.5-1). As with Option 1, Option 2A maintains the waste rock piles in place (Figure 5.5-2) while Option 2B includes waste rock relocation to the open pit (Figure 5.5-3).

The objectives of Option 2 are the same as Option 1, with the additional objective of restoring the tailings area to a more natural condition that will allow the establishment of vegetation. In this regard, the objectives include:

1) Ensure the long-term geotechnical stability of the existing tailings dam;
2) Minimize the potential for tailings oxidation and ML/ARD through the maintenance of saturation at the soil cover / tailings interface and within the tailings deposits;
3) Restore the tailings area to a condition more compatible with the original land use through the provision of a medium conducive to the establishment of wetland vegetation; and
4) Restore area of open pit to a condition more compatible with the original land use via waste rock backfill (Option 2B only).

As part of Option 2, the tailings will first be graded to allow placement of a minimum 1 m thick soil cover over the tailings. The soil cover will not be installed as a flat surface; rather the cover will be constructed with topographic irregularities (swales) to be representative of a more natural surface that will allow for efficient flow and infiltration of water. With the removal of the water cover, the soil cover results in improved physical stability of the tailings and the tailings dam due to the absence of wave or ice-induced erosion. The cover design will result in varied wetland vegetation. The maintenance of saturated conditions within the soil cover will be maintained through the diversion of Dome Creek into the TSF. Maximum water level will be controlled by the elevation of the spillway from the TSF, while minimum water levels will be dominantly controlled by variations in inflows from Dome Creek. During periods of high inflow, near complete inundation of the soil cover can be expected. During dry periods, decreased water levels will expose large areas of the soil cover. As part of Option 2B, waste rock will be managed as that described for Option 1B (*e.g.*, waste rock to open pit and reclaimed)

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Mt. Nansen Closure Alternatives Characterization

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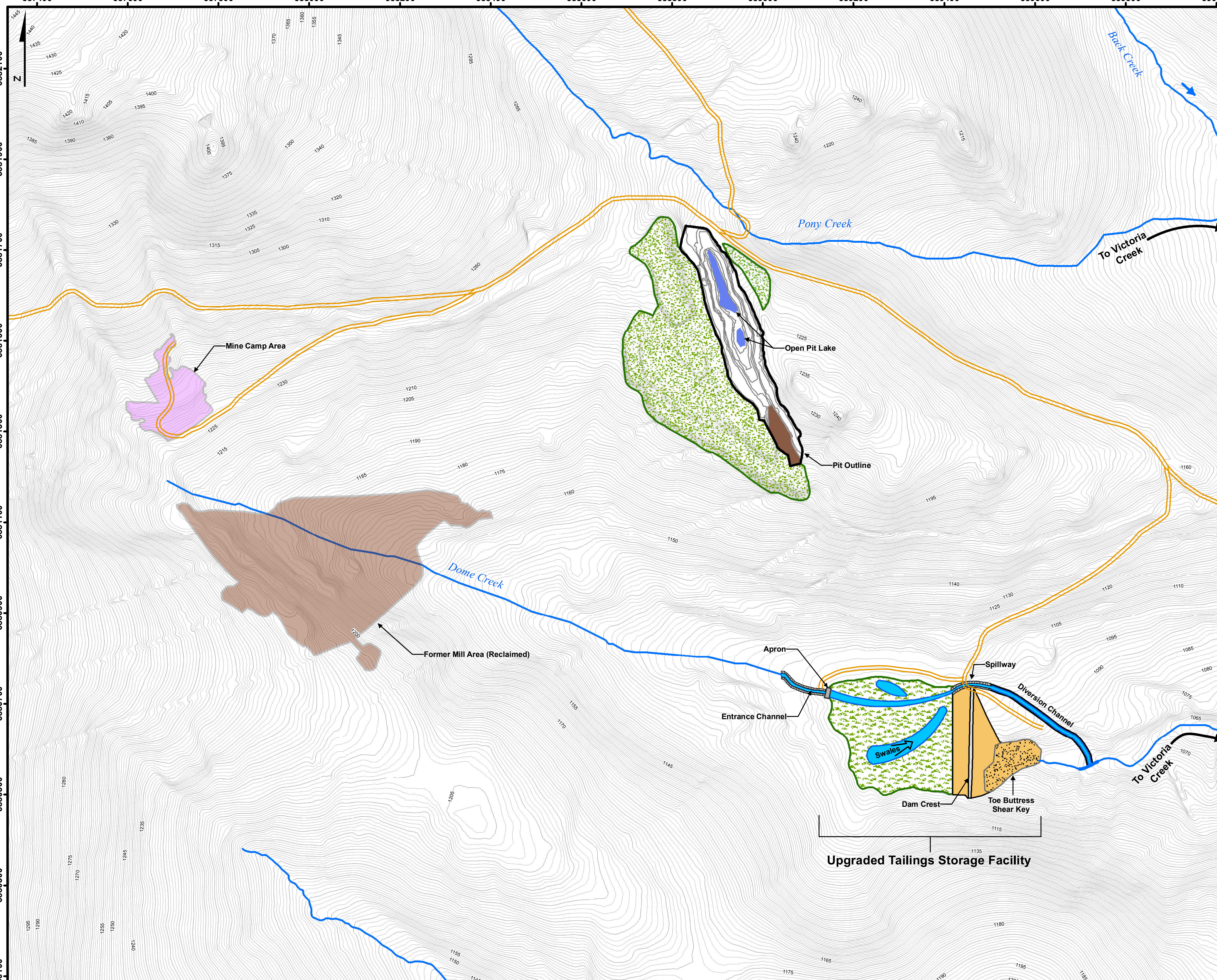
Figure 5.5-1

Option 2
Site Plan & Profile
Drawing 02

AECOM



CLIENT:: Yukon Government

Legend

- Roads
- Watercourse
- Former Mill Area (Reclaimed)
- Mine Camp Area
- Dam Area
- Pit Outline
- Reclaimed Ore Area
- Reclaimed Waste Rock Dump
- Upgraded Tailings Impoundment (Saturated Soil Cover)

Topography

- Index (5m)
- Interm (1m)

Meters: 0 150 300 600

Data Courtesy of AECOM

Figure for illustrative purposes only

SCALE:	1:8,000
DATE:	OCT 22nd, 2010
PROJECTION:	NAD_1983_UTM_Zone_8N
PROJECT MANAGER:	J.S.

PROJECT: **Mount Nansen Options for Closure**

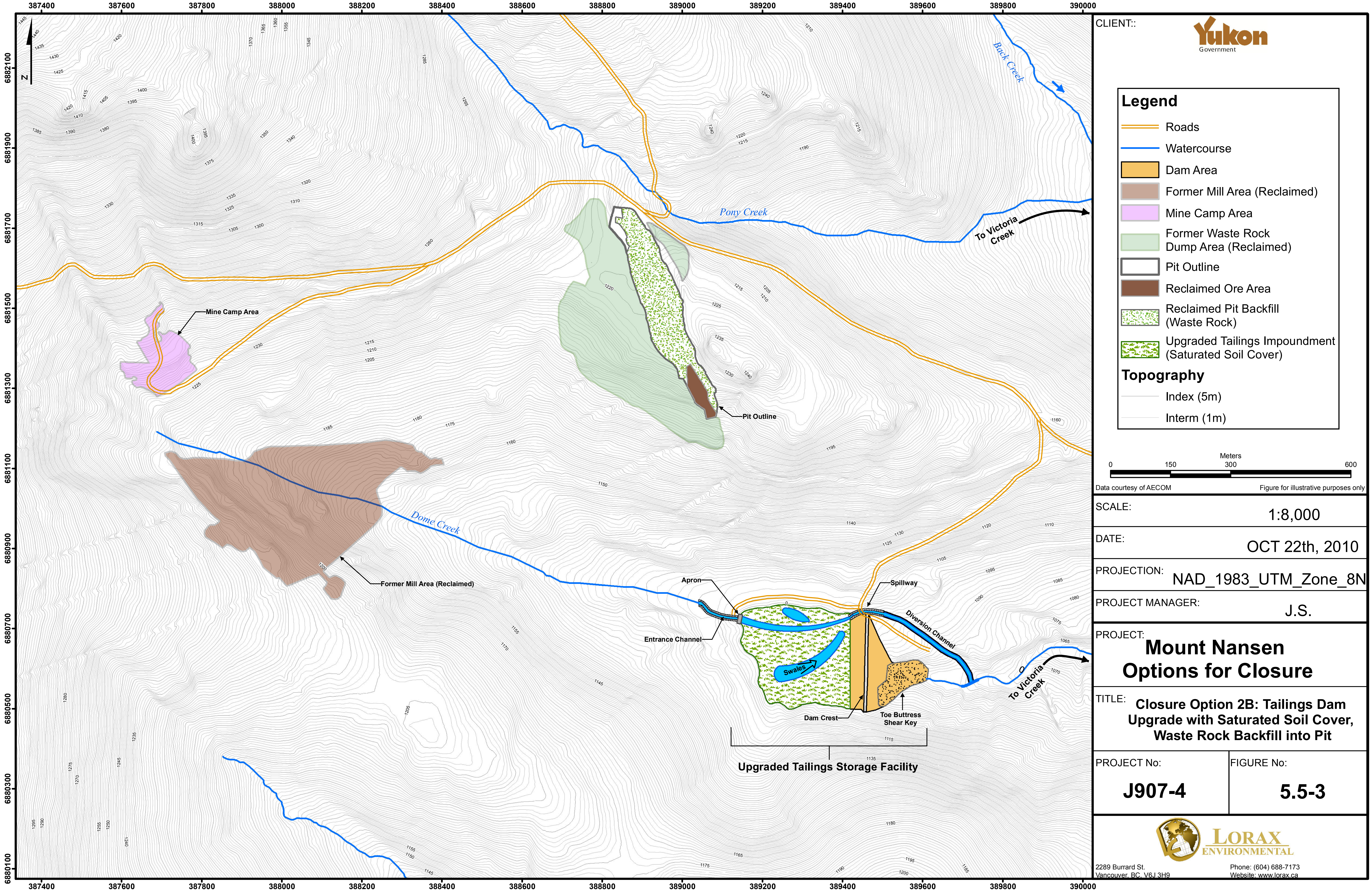
TITLE: **Closure Option 2A: Tailings Dam Upgrade with Saturated Soil Cover, Waste Rock in Place**

PROJECT No:	FIGURE No:
J907-4	**5.5-2**

LORAX ENVIRONMENTAL

2289 Burrard St.
Vancouver, BC, V6J 3H9

Phone: (604) 688-7173
Website: www.lorax.ca



Data courtesy of AECOM

Figure for illustrative purposes only

CLIENT:: Yukon Government

SCALE: 1:8,000

DATE: OCT 22th, 2010

PROJECTION: NAD_1983_UTM_Zone_8N

PROJECT MANAGER: J.S.

PROJECT: **Mount Nansen Options for Closure**

TITLE: **Closure Option 2B: Tailings Dam Upgrade with Saturated Soil Cover, Waste Rock Backfill into Pit**

PROJECT No: **J907-4**

FIGURE No: **5.5-3**

LORAX ENVIRONMENTAL
2289 Burrard St.
Vancouver, BC, V6J 3H9
Phone: (604) 688-7173
Website: www.lorax.ca

A summary of key elements associated with Options 2A and 2B is provided in Table 5.5-1. In the sections that follow, more detailed discussions are provided with respect to the design, performance and uncertainty relating to geotechnical measures, water management, geochemistry, water quality and cost.

Table 5.5-1:
Key closure elements associated with Option 2

Option	Closure Element	Description
2A and 2B	Placement of a saturated soil cover over the tailings.	A 1.0 m thick saturated soil cover will be placed on top of the tailings. The soil cover will also serve to physically stabilize the tailings and minimize water/wind erosion.
2A and 2B	Remediation of existing tailings dam.	Upgrades to the existing tailings dam are required to ensure acceptable factors of safety for various loading conditions. Proposed measures are designed to ensure protection against dam failure resulting from overtopping, internal erosion (piping), slope instability, and liquefaction under seismic loading conditions.
2A and 2B	Diversion of Dome Creek into TSF.	In order to maintain saturated conditions within the tailings deposits, diversion of Dome Creek into the tailings pond will be required. This will require armouring of the Dome Creek outlet channel into the TSF.
2A and 2B	Upgrading of TSF spillway.	In order to meet flood-flow requirements, upgrading of the spillway from the tailings pond will be required. The spillway will be used to discharge water from the TSF and control the pond water elevation
2A and 2B	Upgrading of water diversion channel at TSF.	Additional armouring and upgrading of the diversion channel downstream of the emergency spillway may be required
2A and 2B	Tailings Dam Crest	The beach against the upstream face of the dam will be constructed with locally available sand. A layer of non acid generating waster rock will be placed over top to prevent wind and water erosion at the dam crest.
2A and 2B	TSF Seepage control	Two measures are proposed to decrease seepage through the tailings dam: 1) coarse tailings located against the face of the dam will be excavated and replaced with fine tailings; or 2) a liner will be installed between the tailings and dam face. Such measures are required to reduce seepage while maintaining tailings saturation.
2A	Waste rock	Waste rock will be left in place. Physical stability of existing waste rock piles will be assessed, re-graded, and re-vegetated as necessary.
2B	Waste rock and Open Pit	Waste rock will be backfilled into open pit to remove void and create landscape more compatible with original land use.

5.5.2 Geotechnical

5.5.2.1 Overview

The overview of geotechnical considerations provided in Section 5.4.2.1 for Option 1 is applicable for Option 2A and 2B with the exception of the detail related to saturated soil cover design; all other components related to dam upgrades, waste rock stability and pit wall stability are identical and are not repeated herein. Geotechnical considerations for the soil cover for Option 2 are summarized below and are provided in more detail in Appendix C-1.

Soil Cover

As previously described, a saturated soil cover will be placed directly on top of tailings. The soil cover requires the placement of a minimum 1 m thick soil cover over the tailings and maintenance of an intermittent and discontinuous water cover approximately 0.15 m above the soil cover elevation to maintain the soil cover in a saturated condition. The surface of the cover would be constructed to be uneven, so that there would be areas where the cover is above the controlled water level while in other areas the soil would be below the typical water level. This would be conducive to establishing a vegetated wetland habitat on the cover. The intermittent water cover provides visual evidence that the cover is saturated, and serves as a temporary reservoir under dry conditions. Drainage swales with an invert elevation below the invert of the spillway would be used to direct excess flows to the outlet, while also ensuring that surface water is distributed throughout the tailings management area under lower flow conditions. One advantage of the saturated soil cover approach is that it is possible to establish vegetation on the top of the cover in some areas.

The total "soil" volume required for the cover has been estimated to be approximately 36,000 m^3. This quantity of suitable material is not available at the mine site. The predominant soil types in the immediate vicinity of the mine consist of poorly graded glaciofluvial sand and gravel but a potentially suitable, well-graded material was identified near Victoria Creek. The material is a well-graded gravelly sand containing 16% silt and 6% clay. The silt and clay fractions of the Victoria Creek borrow material are great enough that the material exhibits some plastic behaviour when manipulated. This material is considered to have a lower hydraulic conductivity than the Aeolian and glaciofluvial sands which are more common around the mine site. This material may be suitable as a cover material as it has some desirable characteristics not found in other local materials.

5.5.2.2 Key Assumptions

The key assumptions employed in the geotechnical evaluation of Option 2A and 2B are similar to those described for Option 1 and are as follows:

- The existing dam has an appropriate classification of *High* consequence;
- Future thawing or degradation of the permafrost can be halted through the use of thermosyphons to maintain frozen ground conditions;
- If thawing cannot be arrested and/or freezing impracticable with thermosyphons, other ground improvement measures will be available;
- Coarse tailings currently against the dam face can be removed and then replaced with finer tailings to limit seepage through the dam; and
- A suitable quantity of suitable soil cover material is readily available.

5.5.2.3 Performance and Uncertainty

The same performance and uncertainties described in Section 5.4.2.3 for Option 1 are applicable for Option 2A and 2B. In addition, the presence of an irregular cover, designed to promote vegetation growth as well as maintain saturated conditions will likely require significant maintenance in the early years following cover placement. Regrading of the tailings material will be necessary and differential settlement following regarding and cover placement may result in a drainage surface that does not perform satisfactorily. The time and amount of maintenance required to stabilize the cover and ensure hydrological characteristics of the covered impoundment perform acceptably is a significant uncertainty of Option 2.

5.5.3 Water Management

5.5.3.1 Overview

The maintenance of saturated conditions within the soil cover will be maintained through the diversion of Dome Creek into the TSF. Maximum water level will be controlled by the elevation of the spillway from the TSF, while minimum water levels will be predominantly controlled by variations in inflows from Dome Creek. During periods of high inflow, near complete inundation of the soil cover can be expected. During dry periods, it is hypothesized that decreased water levels will expose large areas of the soil cover.

Though the impacts on Dome Creek are anticipated to be small (*i.e.*, newly covered area compared to Upper Dome Creek catchment area is small), evaporation rates from the soil cover are expected to exceed rates from the land surface pre-cover. The introduction of the high infiltration soil cover, a higher dam crest (change in storage capacity) and the Dome Creek diversion would continue to "dampen" the Dome Creek hydrograph downstream of the site. The effects of such changes on the flow regime of Dome Creek are anticipated to remain small. The addition of waste rock to the pit lake will have an influence on its water balance. Once filled, rates of evaporation from the cover would be lower than for an open water surface, and the presence of rock (decrease in storage) may influence local water levels. At this time, the effects of changing surface water catchments around the pit on groundwater levels, groundwater divide and flow is not known.

5.5.3.2 Key Assumptions

Assumptions and considerations presented here closely parallel those presented in Section 5.4.3 and are briefly summarized below.

Spillway design

A hydraulic analysis has been carried out to size and cost spillway – many of the key details are summarized for Option 1A and B in section 5.4.3. Peak flows rates for the 1000-yr, 10,000 yr, probable maximum flood and inflow design flood were determined to be 4.0, 4.8, 12.5 and 6.8 m^3/s respectively. These rates translate to event volumes of 89,000, 107,000, 281,500 and 153,000 m^3 and were used to optimize spillway design.

Diversion Channel Upgrading

Implementation of Options 2 will require the direction of flows from the tailings pond diversion catchment (Upper Dome Creek) into the proposed tailings pond. To accommodate this, the diversion ditch upstream of the spillway will be backfilled and graded to fit the natural slope contour and the Dome Creek channel will be diverted over the tailings.

Open Pit Lake and Pony Creek Adit (Option 2B)

As part of Option 2B, approximately 500,000 m^3 of waste rock will be backfilled to the open pit (Figure 5-4). As per Option 1, there is concern that water levels at the waste rock storage site may rise and connect to the Pony Creek adit (and Pony Creek). As a contingency, closure costs to seal the bulkhead in the adit have been included.

5.5.3.3 Performance and Uncertainty

There are many similarities in performance and uncertainty when Options 1 and 2 are directly compared. The primary performance issues, risks and uncertainties for Option 2 include dam failure, spillway failure and cover efficacy. In general, the risks associated with Option 2 are assumed to be less than Option 1 owing to the smaller water volumes (*e.g.,*<10,000 versus 70,000 m^3) required to maintain the respective cover systems and the assumed shorter run-out should a dam breach occur under Option 2. The considerations presented below parallel those presented in Section 5.4 for Option 1.

<u>Cover System for Option 2</u>

- The performance of the cover system is inextricably linked to the water management plan for the site (*i.e.,* the plan that governs the design, construction, maintenance and monitoring of infrastructure). Much like the performance of the tailings dam, routine and unforeseen maintenance costs will be incurred
- Performance of the cover is linked to the ability of coarse grained tailings to maintain saturation and on performance under a wide range of environmental conditions. Cover effectiveness has yet to be tested rigorously under a range of conditions.

<u>Water Diversion Structures and Channels</u>

- New water diversion structures will require regulatory approval, and frequency and cost for routine or unexpected maintenance going forward is uncertain.

5.5.4 Geochemistry

5.5.4.1 Overview

As part of the Option 2 analysis, source terms for the water quality prediction model were developed for the tailings in the impoundment, pit lake, and waste rock stored subaerially (2A and 2B) and saturated in the pit (2B). The development of these source terms, as well as a description of existing geochemical conditions, is discussed in detail in Appendix B. From a geochemical standpoint, Options 2A and 2B will exhibit the same geochemical performance as Options 1A and 1B. Specifically, under both Options 1 and 2, the tailings will be maintained in a saturated state to preclude sulfide oxidation and associated metal leaching under acidic conditions. Accordingly, the mass loading model assumes that the geochemical processes currently controlling metal mobility will persist under Option 2A.

As per Option 1B, Option 2B involves relocating waste rock to the pit where a portion will be stored below the water table, potential resulting in the release of metals associated with phases that are unstable in suboxic settings (*e.g.*, Fe oxides). A significant portion of waste rock will also remain above the water table in an unsaturated state. Accordingly, the leaching properties of waste rock stored in the pit, and resulting drainage chemistry, will reflect a combination of geochemical processes occurring within both unsaturated and saturated settings.

5.5.4.2 Key Assumptions

The assumptions in support of the derivation of source terms for Options 2A and 2B are essentially the same as those presented under Options 1A and 1B in Section 5.4.4.2.

Option 2A:

- The geochemical mechanisms that currently dominate remobilization and attenuation within the tailings impoundment, waste rock piles, and pit lake, will continue to be the dominant mechanisms controlling metal mobility in the future.
- All components (pit lake, tailings, and waste rock) have reached pseudo-equilibrium and shifts in this equilibrium state will be minimal in the long term;
- The groundwater flow paths through the tailings will remain constant (*i.e.,* neither dam upgrades nor degradation of permafrost will significantly alter the groundwater flowpath through and under the impoundment);
- Tailings will remain saturated and will not produce acidic drainage;
- The unsaturated ore field bin, upon which ore source terms were based, is representative of long-term drainage from unsaturated ore; and
- Waste rock is non-acid generating.

All the assumptions made under Option 2A will apply to Option 2B with the exception of those relating to waste rock:

- Suboxic conditions will develop in the porewaters of saturated waste rock;
- Metals in the extensively oxidized waste rock are primarily associated with soluble and oxide phases which will be subject to dissolution under saturated/suboxic conditions;
- Source terms derived for saturated waste rock from data generated from the saturated waste rock field bin are representative of the suboxic conditions that are likely to develop within the pit;
- Waste rock stored in the pit and above the water table is assumed to exhibit drainage characteristics similar to that currently observed for subaerially exposed waste rock piles; and

- The chemistry of the drainage from the pit is dictated by a combination of geochemical processes occurring within both unsaturated and saturated portions of waste rock.

5.5.4.3 Performance and Uncertainty

The source terms developed for each mine component under Options 2A and 2B are provided in Table 5.5-2. As discussed for Option 1A, the degree of uncertainty associated with the source terms derived for Option 2A is less compared to other options given the availability of extensive historic data for the tailings impoundment that provide insight into both remobilization and attenuation mechanisms.

The areas of uncertainty for Option 2A are the same as those for Option 1A. The major uncertainty associated with Option 2A relates to whether the geochemical processes observed over the past 3 to10 years accurately represent a proxy for long-term conditions (see section 5.4.4.3 for more detail). There is also uncertainty relating to whether the drainage chemistry data for waste rock are representative of the all waste rock types. As described in Section 5.4.4.3, there is also significant uncertainty associated with the representativeness of the field bin data collected to date in support of long-term drainage predictions for the saturated waste rock and unsaturated ore.

Table 5.5-2:
Options 2A and 2B Geochemical Source Terms (mg/L)

Parameter	Conservative Best Estimate						Worst Case					
	Tailings Impoundment		*Pit*		Waste Rock Pile (2A)	Ore	*Tailings Impoundment*		*Pit*		Waste Rock Pile (2A)	Ore
	Seepage	Diffusive Flux (mg/m^2/day)	Saturated Soil (2A)	Waste Rock (2B)			Seepage	Diffusive Flux (mg/m^2/day)	Saturated Soil (2A)	Waste Rock (2B)		
Ca	241	385	368	368	431	24	470	346	346	431	241	385
Mg	33	124	93	93	297	5	163	91	91	297	33	124
As	0.04	0.02	0.1	0.007	0.03	0.3	0.08	1	0.02	0.04	0.04	0.02
Cd	0.0009	0.02	0.03	0.03	0.09	0.002	0.03	0.2	0.2	0.2	0.0009	0.02
Cu	0.009	0.03	0.04	0.04	0.02	0.02	0.09	0.2	0.2	0.04	0.009	0.03
Fe	13	0.5	2	0.01	0.03	40	3.0	5	0.06	0.05	13	0.5
Mn	8	3	143	5	49	10	7	181	29	97	8	3
Zn	0.02	2	5	5	10	0.1	3	34	34	31	0.02	2
Sulfate	663	1230	2040	1530	2265	1380	1690	2940	2940	2680	663	1230
Ammonia	6	0.2	1	0.03	0.03	12	0.4	2	0.1	0.09	6	0.2
CN (Tot)	0.7	-	-	-	-	0.5	-	-	-	-	0.7	-
WAD CN	0.03	-	-	-	-	0.2	-	-	-	-	0.03	-
Cyanate	2	-	-	-	-	18	-	-	-	-	2	-
Nitrate	3	2	0.3	2	0.3	10	4	1	10	0.9	3	2
Nitrite	0.3	0.06	0.1	0.02	0.08	0.6	0.3	0.4	0.4	0.1	0.3	0.06

Notes:
Under the Waste Rock 2B column shaded cells represent terms dominated by unsaturated chemistry, non-shaded cells represent terms dominated by saturated chemistry

5.5.5 Surface Water Quality

5.5.5.1 Overview

A water balance and water quality model was developed in Goldsim to support the assessment of closure Option 2A and 2B. Key inputs to the model included precipitation and water quality chemistry from the various source terms (*e.g.*, tailings seepage, waste rock, ore, background Victoria Creek, *etc*.). For each option, a total of six different model scenarios were run, including combinations of two different source term chemistry estimates (Conservative Best Estimate and Worst Case) and three precipitation conditions (dry, average and wet year). The Conservative Best Estimate and Worst Case predictions reflect the range in source concentrations used in the model (Appendix B). For each scenario, the model was run on a monthly time step for a calendar year (12 months).

The overarching objective of the water balance and water quality modeling was to provide a tool to directly compare the environmental merits and performance of each closure option. To this end, and in order to best illustrate the differences between the closure options with regards to water quality, mill area contaminant loadings were excluded from the assessment. Currently, mill area loadings are a dominant control on downstream water quality and inclusion would obscure the differences in final water quality under the proposed closure scenarios. For these reasons - in concert with the fact that the mill area is a common closure element to all options and will be remediated (Section 5.2) - mill area loadings were ignored in order to differentiate resultant water quality effects from each of the closure options.

In order to illustrate the predicted performance of the various options, emphasis was placed on arsenic, sulfate, cadmium and zinc, since these constituents are the primary parameters of concern. Water quality predictions for the above parameters are considered long-term or steady-state estimates. Details of the water balance and water quality model, including model configuration, assumptions and results, are provided in Appendix F. For the summary presented herein, only the Conservative Best Estimate results from the model are presented; all data are described and presented in Appendix F.

For Option 2A and 2B, the model integrates the mine-related loadings and flows in the receiving environment. The mine site related sources that may contribute contaminant loadings to the receiving environment for Option 2A and 2B are summarized below.

Option 2A:

- Year-round seepage from tailings storage area;
- Seasonal, shallow seepage from portions of waste rock on surface;

- Year-round, deep groundwater seepage from the low-grade ore within the pit;
- Year-round, deep groundwater seepage from portions of waste rock on surface; and
- Year-round, deep groundwater seepage from the pit lake.

Option 2B:

- Year-round seepage from tailings storage area;
- Year-round, deep groundwater seepage from the low-grade ore within the pit; and
- Year-round, deep groundwater seepage from the waste rock backfilled pit.

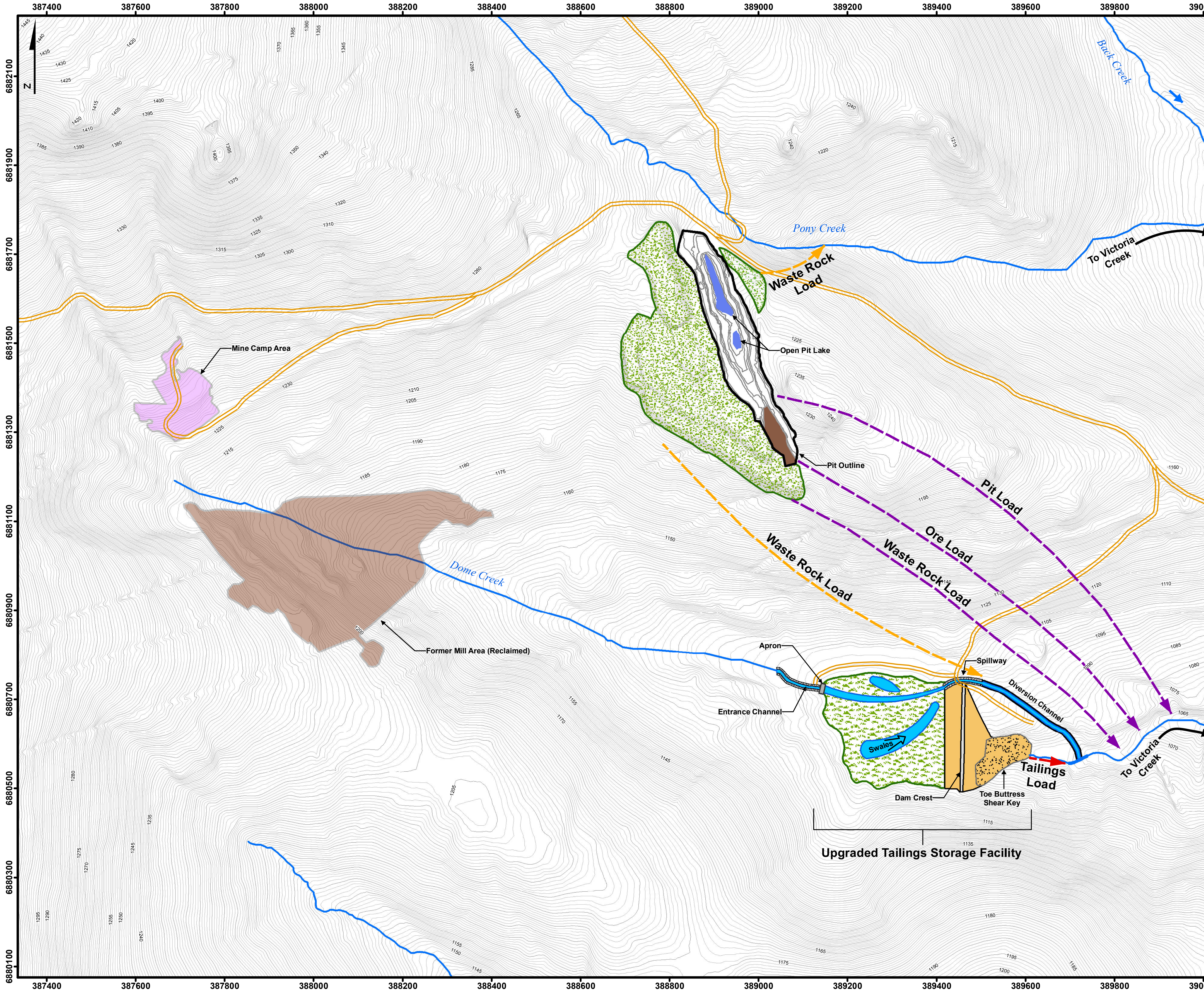
For Option 2 (2A and 2B), schematics depicting the key components of the water quality assessment are presented in Figure 5.5-4 and Figure 5.5-5, respectively.

5.5.5.2 Key Assumptions

The key assumptions incorporated into the water balance and water quality model for Option 2A are the same as those outlined in Section 5.4.5.2 for Option 1A with the exception of those related to the tailings area, and specifically the tailings cover.

The following are the key assumptions that have been incorporated into the water balance and water quality model for Option 1A and 1B:

- The mill area has been fully reclaimed and as such the water quality upstream of the mill area was assigned to represent the upstream or background water quality in Dome Creek (*i.e.*, the model predictions exclude mine-related loadings emanating from the mill area);
- For un-impacted catchment areas, a runoff coefficient of 0.8 was assumed for spring freshet (April and May) and a runoff coefficient of 0.6 for the remaining open water season months;
- No attenuation (*i.e.*, removal of dissolved metals from solution) is assumed to take place along either the shallow or deep groundwater flow paths from the pit and waste rock areas.
- To support the modeling, a synthetic historical precipitation record was generated for Mount Nansen based on climate data from Carmacks and Mount Nansen between 2000 to 2006 (Appendix D and Appendix F);
- Based on the synthetic precipitation record, dry, wet and average annual precipitation conditions were selected for modeling;



Data Courtesy of AECOM

Figure for illustrative purposes only

CLIENT:: Yukon Government

SCALE: 1:8,000

DATE: OCT 22nd, 2010

PROJECTION: NAD_1983_UTM_Zone_8N

PROJECT MANAGER: J.S.

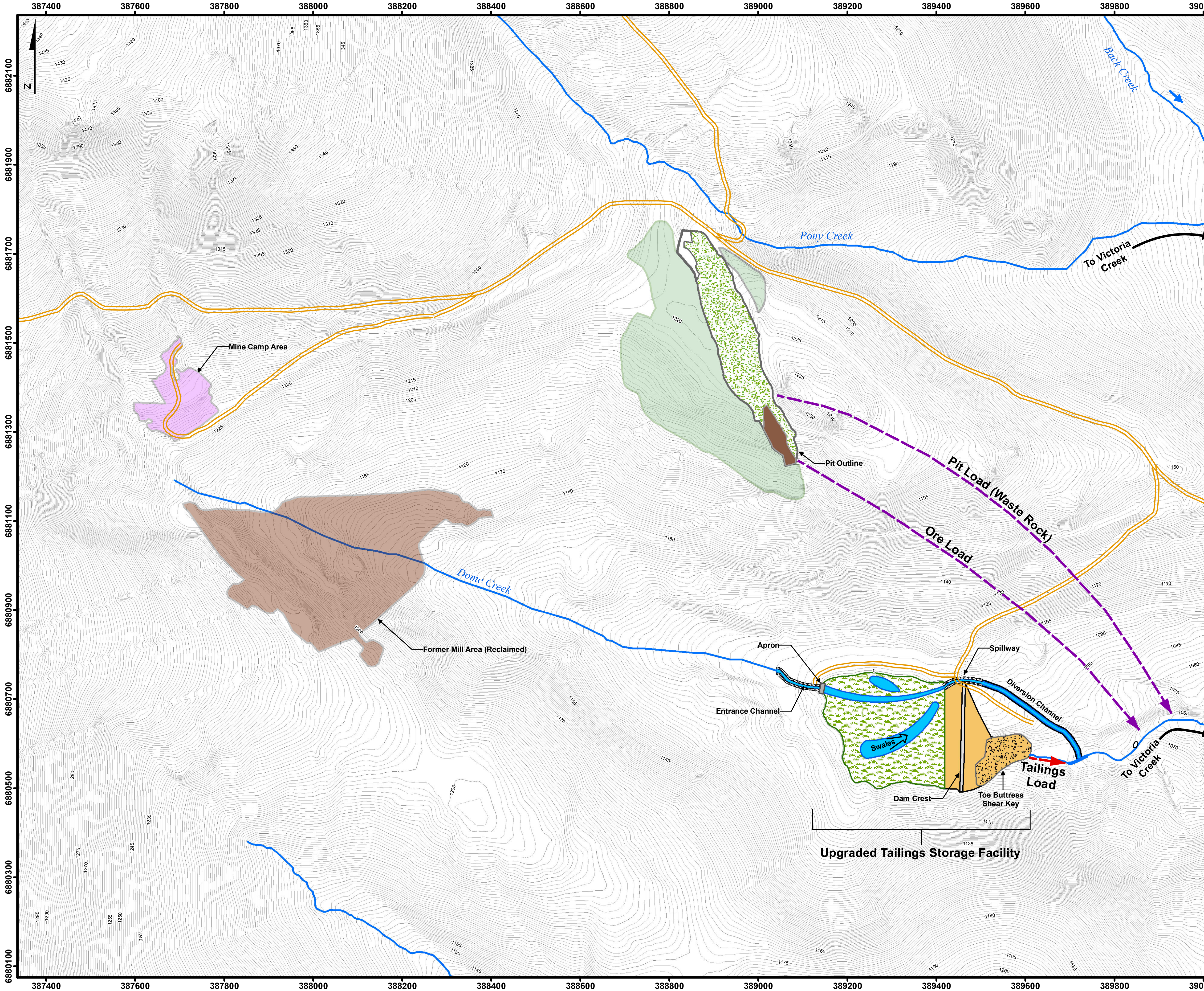
PROJECT: **Mount Nansen Options for Closure**

TITLE: **Closure Option 2A: Schematic of Source Loadings for Water Quality Model**

PROJECT No: **J907-4**

FIGURE No: **5.5-4**

LORAX ENVIRONMENTAL
2289 Burrard St.
Vancouver, BC, V6J 3H9
Phone: (604) 688-7173
Website: www.lorax.ca



CLIENT::

Yukon Government

Legend

- Roads
- Watercourse
- Dam Area
- Former Mill Area (Reclaimed)
- Mine Camp Area
- Former Waste Rock Dump Area (Reclaimed)
- Pit Outline
- Reclaimed Ore Area
- Reclaimed Pit Backfill (Waste Rock)
- Upgraded Tailings Impoundment (Saturated Soil Cover)
- Deep Groundwater Seepage
- Tailings Seepage

Topography

- Index (5m)
- Interm (1m)

Meters

0 150 300 600

Data courtesy of AECOM

Figure for illustrative purposes only

SCALE: 1:8,000

DATE: OCT 22th, 2010

PROJECTION: NAD_1983_UTM_Zone_8N

PROJECT MANAGER: J.S.

PROJECT:

Mount Nansen Options for Closure

TITLE:

Closure Option 2B: Schematic of Source Loadings for Water Quality Model

PROJECT No: **J907-4**

FIGURE No: **5.5-5**

LORAX ENVIRONMENTAL

2289 Burrard St.
Vancouver, BC, V6J 3H9

Phone: (604) 688-7173
Website: www.lorax.ca

- Annual lake evaporation was estimated based on data from the Pelly Ranch Environment Canada Meteorological gauging station: 369 mm/year (Appendix D and Appendix F);
- For Dome Creek, zero flow was assumed during the winter months (November through March) as attempts to measure winter flow indicates frozen conditions through to the substrate; and
- For Victoria Creek, site monitoring indicates the presence of winter flow. For the model, monthly flow in Victoria Creek was estimated based on the monthly flow distribution in the Nordenskiold River.
- The tailings cover area is modeled as a shallow reservoir with a maximum water depth of 0.25 m.
- Inflows to the tailings cover area include onset precipitation and runoff from the surrounding catchment area. Outflows include discharge of excess water via the spillway, evaporation from the pond surface area, and infiltration through the tailings and tailings dam.
- Infiltration rate through the tailings and tailings dams was based on two-dimensional modeling work carried out by AECOM (Appendix C-1) and set to 1.7 L/s.
- The overall long term seepage rate discharging from the toe of the upgraded dam to the receiving environment was assumed to be similar to the historical low-flow seepage pumping rate for the existing seepage collection pond and was assumed to be constant throughout the year at 3.5 L/s;
- For Option 2B, all the waste rock is relocated into the pit resulting in a reduction in the waste rock footprint from 114,550 m^2 to 36,000 m^2;
- Net-infiltration through the backfilled waste rock in Option 2B was based on the results of a one-dimensional unsaturated flow model (Appendix C-3). The modeling provided computed fluxes including evaporation, runoff, surface infiltration, and infiltration through the top and bottom of the waste;
- Two independent approaches were used to estimate the annual flux through the pit that is partially backfilled. Both estimates yielded fluxes that were very low and well below 0.5 L/s (~0.14 L/s). Accordingly, the assumed groundwater discharge rate from the pit to Dome Creek was assumed to be 0.14 L/s for Option 2B.

5.5.5.3 Performance and Uncertainty

<u>Performance</u>

Water quality predictions for each of the model runs were used to assess the performance of Option 2A and 2B through comparison to existing water quality in the downstream receiving environment in Victoria Creek; CCME Guidelines for the Protection of Aquatic Life are also included as a point of reference.

A summary of the Best Estimate water quality predictions (average year) for sulfate, arsenic, cadmium and zinc in Victoria Creek for Option 2A and 2B are presented in Table 5.5-3 and Table 5.5-4.

Table 5.5-3:
Summary of Predicted Concentrations (mg/L) in Victoria Creek for Option 2A - Best Estimate Source Terms and Average Precipitation Conditions

		Existing Water Quality[b]		Predicted Water Quality	
Parameter	*CCME Guideline*	*Median*	*Winter Maximum*[c]	*Median*	*Maximum*
Arsenic	0.005	0.0016	0.0075	0.0019	0.0055
Cadmium	0.00034[a]	0.00003	0.0003	0.00012	0.00051
Zinc	0.03	0.009	0.02	0.018	0.062
Sulfate		30	61	36	106

Notes:
a. Draft CCME Guideline for Cadmium (Environment Canada 2008) at Hardness = 150 mg/L as $CaCO_3$.
b. Existing water quality data for Victoria Creek at Road (2007 to 2010).
c. Maximum winter concentration from the existing water quality data set for Victoria Creek (November to February, 2007 to 2010).

Table 5.5-4:
Summary of Predicted Concentrations (mg/L) in Victoria Creek for Option 2B - Best Estimate Source Terms and Average Precipitation Conditions

		Existing Water Quality[b]		Predicted Water Quality	
Parameter	*CCME Guideline*	*Median*	*Winter Maximum*[c]	*Median*	*Maximum*
Arsenic	0.005	0.0016	0.0075	0.0019	0.0059
Cadmium	0.00034[a]	0.00003	0.0003	0.00006	0.00028
Zinc	0.03	0.009	0.02	0.010	0.035
Sulfate		30	61	35	98

Notes: as per Table 5.5-3

The most salient points (for Best Estimate/Average Flow Scenario) of the water quality predictions for Option 2A are as follows:

- For all modeled parameters, peak concentrations are predicted to occur during the winter low flow period due to ongoing loadings from the site during periods of minimal flow and available dilution. These results are a direct function of the conservative assumptions that the seepage rate from the tailings and discharge rate from the deep groundwater system will remain constant throughout the year despite varying flows in Victoria Creek.
- *Sulfate*
  - In general, the predicted concentrations for sulfate (median = 36 mg/L) are similar to existing sulfate concentrations (median = 30 mg/L) in Victoria Creek, except for winter low flow periods (Table 5.5-3). During this period, the predicted maximum concentration of 106 mg/L is notably higher than the maximum observed winter sulfate concentration (61 mg/L).
  - The primary source of the higher predicted sulfate concentrations in the winter low flow period is the invariant discharge of tailings seepage to the receiving environment at a rate of 3.5 L/s. In reality, it would be anticipated that the seepage discharge would decrease over the winter period, and as such, the winter predictions are considered to be conservative estimates.
- *Arsenic*
  - Predicted concentrations of arsenic (median = 0.0019 mg/L) are comparable to existing arsenic concentrations in Victoria Creek (median = 0.0016 mg/L) and are well below the CCME guideline of 0.005 mg/L (Table 5.5-3).
  - Maximum concentrations of arsenic are predicted to occur during winter low flow (peaking at 0.0055 mg/L). This value marginally exceeds the CCME guideline, although is within the range of the existing maximum winter concentrations (maximum = 0.0075 mg/L).
  - The predicted loading associated with tailings seepage is the dominant source of arsenic to the receiving environment.
- *Cadmium*
  - Predicted cadmium concentrations are higher than the existing values currently observed in Victoria Creek.
  - The predicted median cadmium concentration (0.00012 mg/L) is approximately 4 times higher than the existing median concentration in

Victoria Creek data (0.00003 mg/L) but well below the CCME guideline (Table 5.5-3).

- Maximum concentrations of cadmium are predicted to occur in winter (January to March) at concentrations above the draft CCME guideline.
- The predicted maximum cadmium concentration of 0.00051 mg/L is approximately twice the existing maximum winter concentration 0.0003 mg/L.
- The predicted loading from seepage from the waste rock dumps is the dominant source of cadmium to the receiving environment.

- *Zinc*
    - The predicted median zinc concentration (0.018 mg/L) is approximately twice the existing median concentration (0.009 mg/L) but below the CCME guideline of 0.03 mg/L.
    - Maximum concentrations of zinc are predicted to occur in winter at concentrations above the CCME guideline.
    - The predicted maximum zinc concentration (0.062 mg/L) is 3 times the existing winter maximum concentration (0.02 mg/L).
    - The predicted loading from seepage from the waste rock dumps is the dominant source of zinc to the receiving environment.

As discussed previously in Section 5.4.5.3, the over estimation of cadmium and zinc concentrations in Victoria Creek is primarily due to the conservative assumptions for seepage from the waste rock dumps to the receiving environment and the fact that no attenuation along the flowpath is included in the model assumptions.

Key highlights of the model results for Option 2B are:

- Similar to Option 2A, for all modeled parameters, peak concentrations are predicted to occur during the winter low flow period due to continuous loadings from the site during periods of minimal flow and available dilution.
- *Sulfate*
    - In general, the predicted concentrations of sulfate for Option 1B (median = 35 mg/L; maximum = 98 mg/L) are marginally lower than those for Option 2A (median = 36 mg/L, maximum = 106 mg/L) (Table 5.5-4). The slightly lower sulfate concentrations predicted for Option 2B are due to the reduction in loading from the backfilled waste rock.

- Similar to Option 2A, the primary source of predicted sulfate concentrations in the winter low flow period is the year round discharge of tailings seepage to the receiving environment at constant rate of 3.5 L/s.

- *Arsenic*
  - Predicted concentrations of arsenic for Option 2B (median = 0.0019 mg/L, maximum = 0.0059 mg/L) are comparable to those for Option 2A (median = 0.0019 mg/L, maximum = 0.0055 mg/L (Table 5.5-4).
  - The predicted loading from tailings seepage is the dominant source of arsenic to the receiving environment hence little change would be expected between 2A and 2B.
- *Cadmium*
  - The predicted median cadmium concentrations for Option 2B (0.00006 mg/L, maximum = 0.00028 mg/L) are lower than those predicted for Option 2A (median = 0.00012 mg/L, maximum = 0.00051 mg/L) and well below the CCME guideline.
  - Comparison of the predicted cadmium concentrations for Option 2B in Victoria Creek to those for Option 1 indicates an improvement in performance (Table 5.5-4).
  - The improvement in water quality relates to a decrease in loading from waste rock. Although still the dominant source of cadmium to the receiving environment, the waste rock contributes significantly less loading primarily due to the overall reduction of the waste rock footprint.
- *Zinc*
  - The predicted zinc concentrations for Option 2B (median = 0.010 mg/L, maximum = 0.035 mg/L) are lower than those predicted for Option 2A (median = 0.018 mg/L, maximum = 0.062 mg/L) and generally below the CCME guideline, except during winter low flow conditions (Table 5.5-4).
  - Comparison of the predicted zinc concentrations for Option 2B in Victoria Creek to those for Option 1 indicates an improvement in performance.
  - Similar to cadmium, the water quality improvements associated with zinc can be attributed to a decrease in the loading from waste rock primarily due to the overall reduction of the waste rock footprint.

Overall, the Best Estimate Average Precipitation model results for Option 2B are comparable to Option 2A and indicate that Victoria Creek water quality would not be degraded for sulfate and arsenic. For cadmium and zinc, the predicted water quality for Option 1B indicates an overall improvement compared to those predicted for Option 2A. The predicted decrease in cadmium and zinc concentrations in the receiving environment under Option 2B relative to Option 2A are due to the reduction in loading from waste rock due to the reduction in the waste rock footprint after backfilling to the open pit.

Uncertainty

The key uncertainties associated with modeling results for Option 2 are similar to those outlined for Option 1. One of the key considerations is whether there is sufficient water supply in the catchment upstream of the tailings area to maintain the tailings in a saturated state, and specifically, if the proposed runoff coefficients are representative of runoff conditions at the site for all locations and conditions. Results of a sensitivity analysis (Appendix F) indicate that inflows to the tailings area are generally sufficient to maintain the assumed 0.25 m water cover during the open water season. During dry conditions, a minimal drop in water cover would occur, although not significant enough to impact the ability of the saturated soil cover to maintain the tailings in a saturated state.

5.5.6 Costs

The estimated capital costs for implementing Options 2A and 2B are presented in Table 5.5-5 and Table 5.5-6. The estimated costs include a 30 percent contingency but do not included costs for design engineering, routine inspections and operations or maintenance as these are expected to be similar for all options considered and therefore do not materially affect the cost comparison. These estimates are considered to be Class D estimates (or ASTM E2516-06 Class 5), with an accuracy of -25 +40 percent.

The capital cost estimates do not include *Common Closure Element* costs which are described in Section 5.2 and Appendix C-2. For Option 2A, the estimated capital cost is approximately $10.2 M. Option 2B has an estimated capital cost of approximately $13.9 M. More details related to cost assumptions and breakdown of individual components are found in Appendix C-1 and C-2.

Table 5.5-5:
Summary of Estimate Capital Costs for Option 2A

Work Item Description	Units	Quantity	Unit Cost	Total Cost
Mobilization and Demobilization	L.S.	1	$ 250,000	**$ 250,000**
Construction of Toe Berm				
Crush, transport and place rockfill	m^3	40,000	$ 35	$ 1,400,000
Geosynthetic filter placement	m^2	5,400	$ 20	$ 108,000
Sub Total				**$ 1,508,000**
Ground Improvement				
Thermosyphons	L.S.	1	$ 600,000	$ 600,000
Drainage, insulation, site prep. etc.	L.S.	1	$ 900,000	$ 900,000
Sub Total				**$ 1,500,000**
Tailings Management Area (TMA)				
Regrading	m^2	71,000	$ 5	$ 355,000
Soil Cover (1.0 m)	m^3	60,000	$ 15	$ 900,000
Vegetate cover	m^2	60,000	$ 3	$ 180,000
Drainage swales - geotextile	m^2	5,000	$ 10	$ 50,000
Drainage swales - armouring	m^3	1,500	$ 50	$ 75,000
Soil Cover - Beach	m^3	20,000	$ 15	$ 300,000
Beach armouring	m^3	3,300	$ 50	$ 165,000
Replace coarse tails with fine tails	m^3	68,000	$ 12	$ 816,000
Final site preparation, revegetation				$ 124,000
Sub Total				**$ 2,965,000**
Spillway				
Excavation	m^3	2,000	$ 10	$ 20,000
Concrete Overflow	L.S.	1	$ 150,000	$ 150,000
Geotextile	m^2	3,000	$ 10	$ 30,000
Armouring	m^3	1,000	$ 50	$ 50,000
South-Side Berm - fill	m^3	500	$ 10	$ 5,000
South-Side Berm - erosion protection	L.S.	1	$ 15,000	$ 15,000
Sub Total				**$ 270,000**
Dome Creek Diversion into TMA				
Excavation	m^3	750	$ 10	$ 7,500
Geotextile	m^2	675	$ 10	$ 6,750
Armouring	m^3	340	$ 50	$ 17,000
Water Level Controls	L.S.	1	$ 50,000	$ 50,000
Dome Creek Channel and Apron	L.S.	1	$ 50,000	$ 50,000
Sub Total				**$ 131,250**
Dam Raise	L.S.	1	$ 25,000	**$ 25,000**
Diversion/Interceptor Ditch Upstream of Spillway				
Fill in interceptor ditch	m^3	3,400	$ 10	$ 34,000
Fill in Interceptor diversion channel	m^3	5,400	$ 10	$ 54,000
Sub Total				**$ 88,000**
Reslope, regrade and revegetate Waste Rock Storage area				**$ 142,000**
Road construction - base	m^3	900	$ 50	**$ 45,000**
Diversion channel d/s of spillway	L.S.	1	$ 500,000	**$ 500,000**
Monitoring Insrumentation	L.S.	1	$ 200,000	**$ 200,000**
Scale/flatten pit walls	L.S.	1	$ 200,000	**$ 200,000**
Pit safety (signage and berm)	L.S.	1	$ 24,000	**$ 24,000**
Sub Total				**$ 7,848,250**
30% Contingency				**$ 2,354,475**
TOTAL ESTIMATED COST - OPTION 2A				**$ 10,202,725**

Table 5.5-6:
Summary of Estimate Capital Costs for Option 2B

Work Item Description	Units	Quantity	Unit Cost	Total Cost
Mobilization and Demobilization	L.S.	1	$ 250,000	**$ 250,000**
Construction of Toe Berm				
Crush, transport and place rockfill	m^3	40,000	$ 35	$ 1,400,000
Geosynthetic filter placement	m^2	5,400	$ 20	$ 108,000
Sub Total				**$ 1,508,000**
Ground Improvement				
Thermosyphons	L.S.	1	$ 600,000	$ 600,000
Drainage, insulation, site prep. etc.	L.S.	1	$ 900,000	$ 900,000
Sub Total				**$ 1,500,000**
Tailings Management Area (TMA)				
Regrading	m^2	71,000	$ 5	$ 355,000
Soil Cover (1.0 m)	m^3	60,000	$ 15	$ 900,000
Vegetate cover	m^2	60,000	$ 3	$ 180,000
Drainage swales - geotextile	m^2	5,000	$ 10	$ 50,000
Drainage swales - armouring	m^3	1,500	$ 50	$ 75,000
Soil Cover - Beach	m^3	20,000	$ 15	$ 300,000
Beach armouring	m^3	3,300	$ 50	$ 165,000
Replace coarse tails with fine tails	m^3	68,000	$ 12	$ 816,000
Final site preparation, revegetation				$ 124,000
Sub Total				**$ 2,965,000**
Spillway				
Excavation	m^3	2,000	$ 10	$ 20,000
Concrete Overflow	L.S.	1	$ 150,000	$ 150,000
Geotextile	m^2	3,000	$ 10	$ 30,000
Armouring	m^3	1,000	$ 50	$ 50,000
South-Side Berm - fill	m^3	500	$ 10	$ 5,000
South-Side Berm - erosion protection	L.S.	1	$ 15,000	$ 15,000
Sub Total				**$ 270,000**
Dome Creek Diversion into TMA				
Excavation	m^3	750	$ 10	$ 7,500
Geotextile	m^2	675	$ 10	$ 6,750
Armouring	m^3	340	$ 50	$ 17,000
Water Level Controls	L.S.	1	$ 50,000	$ 50,000
Dome Creek Channel and Apron	L.S.	1	$ 50,000	$ 50,000
Sub Total				**$ 131,250**
Dam Raise	L.S.	1	$ 25,000	**$ 25,000**
Diversion/Interceptor Ditch Upstream of Spillway				
Fill in interceptor ditch	m^3	3,400	$ 10	$ 34,000
Fill in Interceptor diversion channel	m^3	5,400	$ 10	$ 54,000
Sub Total				**$ 88,000**
Backfill Pit with Waste Rock				
Load, haul, backfill pit with waste rock	m^3	510,000	$ 5	$ 2,550,000
Regrade and revegetate pit fill, safety measures				$ 53,000
Plug Pony Creek Adit	L.S.	1	$ 250,000	$ 250,000
Sub Total				**$ 2,853,000**
Regrade and revegetate Waste Rock Storage area				**$ 123,000**
Road construction - base	m^3	900	$ 50	**$ 45,000**
Diversion channel d/s of spillway	L.S.	1	$ 500,000	**$ 500,000**
Monitoring Insrumentation	L.S.	1	$ 200,000	**$ 200,000**
Scale/flatten pit walls	L.S.	1	$ 200,000	**$ 200,000**
Sub Total				**$ 10,658,250**
30% Contingency				**$ 3,197,475**
TOTAL ESTIMATED COST - OPTION 2B				**$ 13,855,725**

5.6 Option 3 – Pit Backfill with Wet Cover on Tailings, Dam Removal and Valley Restoration

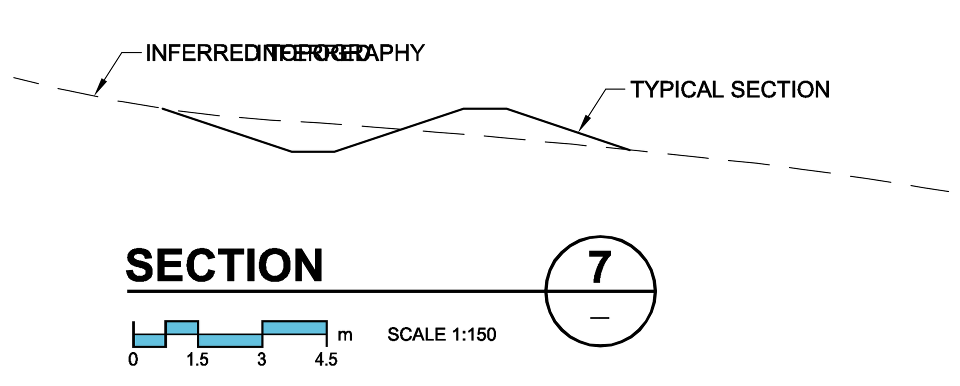
5.6.1 Overview

Option 3 involves the re-location of ~300,000 m^3 of tailings and underlying contaminated soil from their existing location in the TSF to the open pit. These materials will be maintained in a saturated state to the extent possible via placement of a high infiltration cover over the tailings (Figure 5.6-1). By removing the tailings deposits and any underlying contaminated soils, this option also allows for the restoration of the Dome Creek valley in the area of the TSF (Figure 5.6-2). The primary objectives of Option 3 are to:

1) Restore the Dome Creek valley in the area of the TSF to a more natural condition compatible with original land use;
2) Minimize the potential for tailings oxidation and ML/ARD through the maintenance of saturated conditions within the tailings deposits (maximize cover infiltration) in the backfilled pit; and
3) Restore the area of open pit to a condition more compatible with the original land use via tailings backfill and associated cover reclamation.

As part of Option 3, tailings in the backfilled pit will be covered with at least 1 m of non-acid-generating waste rock. The physical characteristics of waste rock (coarse material) and associated grading will enhance infiltration into the tailings. The purpose of the cover is to allow infiltration into the tailings from precipitation and snow melt, while providing a barrier to evaporation (*e.g.* capillary break) from the tailings solids. In this manner, the system is designed to maximize the degree of saturation within the tailings. Maximizing tailings saturation is desirable from the perspective of minimizing the potential for acid rock drainage and associated metal leaching. The cover will also serve to physically stabilize the tailings and prevent wind/water erosion.

In order to minimize the potential for ARD, maintaining the tailings at 85% saturation is desirable. The tailings are heterogeneous and the coarse fraction are highly sensitive to desaturation. In this regard, the design for Option 3 requires that the coarse and fine tailings be well-mixed to achieve desired water holding properties. Option 3 does not include diversion of water from Pony Creek as a potential source of make-up water, but is viewed as an available contingency measure. Based on a preliminary assessment of tailings removal methods, blending and transporting the tailings may occur through dredging and transport via pipeline slurry. The effectiveness at which the tailings can be removed, blended, transported, and deposited into the open pit remains uncertain.



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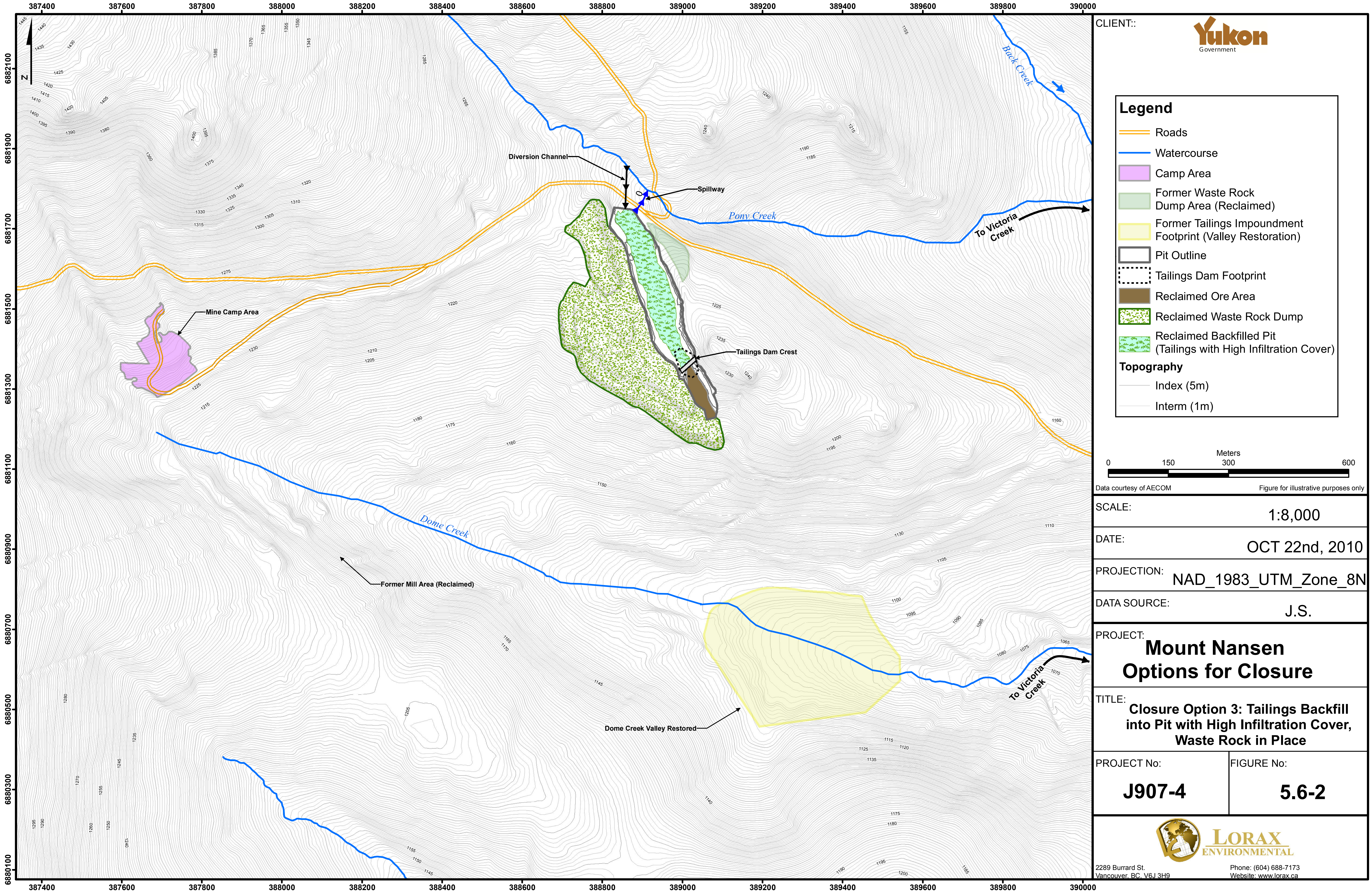
Mt. Nansen Closure Alternatives Characterization

Option 3
Plan, Profile & Sections - Brown-McDade Open Pit
Figure 5.6-1
Drawing - 03

AECOM



CLIENT::
Yukon Government
Legend
Roads
Watercourse
Camp Area
Former Waste Rock Dump Area (Reclaimed)
Former Tailings Impoundment Footprint (Valley Restoration)
Pit Outline
Tailings Dam Footprint
Reclaimed Ore Area
Reclaimed Waste Rock Dump
Reclaimed Backfilled Pit (Tailings with High Infiltration Cover)
Topography
Index (5m)
Interm (1m)
Meters
0 150 300 600
Data courtesy of AECOM
Figure for illustrative purposes only
Diversion Channel
Spillway
Pony Creek
Back Creek
To Victoria Creek
Mine Camp Area
Tailings Dam Crest
Dome Creek
Former Mill Area (Reclaimed)
Dome Creek Valley Restored
To Victoria Creek
N
SCALE: 1:8,000
DATE: OCT 22nd, 2010
PROJECTION: NAD_1983_UTM_Zone_8N
DATA SOURCE: J.S.
PROJECT: Mount Nansen Options for Closure
TITLE: Closure Option 3: Tailings Backfill into Pit with High Infiltration Cover, Waste Rock in Place
PROJECT No: J907-4
FIGURE No: 5.6-2
LORAX ENVIRONMENTAL
2289 Burrard St. Vancouver, BC, V6J 3H9
Phone: (604) 688-7173
Website: www.lorax.ca

A dam at the south end of the open pit, on the order of 8 to 10 m in height, will be required to contain the backfilled tailings (Figure 5.6-1). A liner will likely be required to minimize seepage losses through the dam. The liner would extend into the bedrock foundation to minimize the potential for foundation seepage. The dam would be constructed using locally available materials, such as inert waste rock and/or granular borrow. As such, the geotechnical liability associated with dam structures will remain on site. Specifically, the same requirements for routine inspections, dam safety reviews and maintenance would apply to a dam constructed to contain tailings in the open pit.

Under most flow conditions, there will be no surface water discharges from the pit owing to infiltration into the tailings and some evaporation from the waste rock surface. However, some provision will be required to allow surface water to exit the facility for extreme wet periods. This will involve construction of a bedrock spillway at the north end of the pit.

Restoration of the Dome Creek Valley to a setting compatible with the original land use will involve a series of sequenced engineering, environmental, and revegetation measures. Further assessment will be required to develop final remedial plans for the TSF. At a minimum, restoration of the TSF area will entail:

- Removal and deposition of fill soils to original natural ground and groundwater conditions;
- Replacement with natural, imported vegetative soil cover(s) with appropriate contouring and drainage improvement; and
- Revegetation using native plant species and selected fertilizers.

A summary of key elements associated with Option 3 is provided in Table 5-2. In the sections to follow, more detailed discussions are provided with respect the design, performance and uncertainty relating to geotechnical measures, water management, geochemistry, water quality and cost.

Table 5.6-1:
Key closure elements associated with Option 3

Option	Closure Element	Description
3	Tailings and Pit	Relocation of approximately 300,000 m^3 of tailings and contaminated soil from the TMA to the open pit. Tailings will be stored saturated to the extent possible through application of a high infiltration waste rock cover. Grain size characteristics of waste rock cover and associated grading will allow for maximum infiltration while minimizing losses due to evaporation. The cover will also serve to physically stabilize the tailings to prevent water/wind erosion.
3	In-Pit Dam	Construction of a dam at south margin of the pit will be required to impound the tailings. The dam will be subject to Canadian Dam Association guidelines with respect to construction, inspection and maintenance requirements.
3	Waste rock	Waste rock will be left in place, with the exception of approximately 21,000 m^3 for use in the tailings cover.
3	Tailings Storage Facility	Re-location of tailings will allow restoration of the Dome Creek valley in the area of the TSF to a condition compatible with the original land use.
3	Pony Creek Adit	Additional measures may be required to provide a more effective seal of the Pony Creek adit to minimize the hydraulic connection between the pit and Pony Creek.

5.6.2 Geotechnical

5.6.2.1 Overview

As previously described, approximately 300,000 m^3 of tailings would be relocated to the open pit and maintained in a saturated state in Option 3. The principle of the design is that by maintaining the tailings at 85% saturation or greater, the diffusion of oxygen into the tailings is limited, and therefore the potential for sulfide oxidation and acid generation. The cover serves some important functions as the available water is limited, and the efficient distribution of the available water to the surface of the tailings is critical to the success of Option 3. The objectives of the high infiltration cover design for Option 3 are to:

- promote infiltration of precipitation, and available surface water through the cover and into the tailings;
- limit evaporation; and
- control fugitive dust and limit erosion of the tailings and cover.

The analysis considered a high infiltration cover consisting of a 1 m thick layer of coarse waste rock to be suitable. The cover material should be inert so as not to contaminate ground or surface water. It would not be beneficial to establish vegetation on this cover as this may result in an increase in water losses through evapotranspiration. Further assessment of cover options and cover design should be addressed in the final design.

<u>Tailings Dam at Open Pit</u>

A dam at the south end of the open pit will be required to contain the tailings and their cover (Figure 5.6-1). It is assumed the height of the dam is expected to be in the order of 8 to 10 m. A liner may be required to minimize seepage losses through the dam; these losses may report as surface water at the south end of the pit. The liner would extend into the bedrock foundation to minimize the potential for foundation seepage.

The design of the dam will need to follow the 2007 Canadian Dam Association guidelines, including the spillway which would be designed for the IDF associated with a *High* consequence classification. As discussed, the dam would be constructed using locally available materials, primarily inert waste rock and/or granular borrow materials. The same requirements for routine inspections, dam safety reviews and maintenance as exist for the existing tailings dam would apply to a tailings dam constructed to contain tailings at the open pit.

<u>Tailings Properties</u>

The design for Option 3 requires that the coarse and fine tailings be mixed to form a homogeneous blend of materials with a consistent hydraulic conductivity. Numerical analysis by Golder (Appendix C-3) indicated that 85% saturation could be maintained in the tailings if an average hydraulic conductivity of $5x10^{-9}$ m/s or less could be achieved for the tailings. Laboratory testing of blended tailings demonstrated that the hydraulic conductivity of mixed tailings (blended in the laboratory) ranged from approximately $3x10^{-7}$ to $1.5x10^{-9}$ m/s. Laboratory blended tailings samples had a higher density (1850 kg/m^3) than the tailings in the current tailings management area (990 – 1785 kg/m^3) (Appendix C-3). Samples of higher density (under saturated conditions) will generally have a lower hydraulic conductivity than less dense material. Overall, it is not considered likely that the entire relocated tailings mass would have densities similar to those produced in the laboratory and the prescribed hydraulic conductivity may be difficult to achieve. This would also be true if the relocated tailings are not homogeneously blended.

Costing of Option 3 has assumed that blending and transporting the tailings would be acheived by dredging the tailings and transporting them in a slurry form (*i.e.,* by pipeline). Two dredging operations would be set up to collect materials from both fine and coarse tailings deposits simultaneously. The tailings would be mixed "in-line" by combining the flows from both dredgers into a single pipe. Under this scenario, segregation of the tailings upon placement into the pit would be a concern.

Differential settlement due to tailings consolidation will be expected under Option 3 and has important implications on spillway location and design.

Waste Rock Stability

The bulk of the existing waste rock piles will remain in place for closure Option 1A, although some waste rock will be used for cover material and in-pit dam construction. Some additional grading may be required to improve the stability of the piles following removal of the waste rock for the cover and dam construction. Currently the slopes of the waste rock piles are at the angle of repose, which yields a calculated factor of safety of unity (1), under static conditions above the water table. Long-term stability, considering various loading conditions, would require an increased factor of safety that would be determined during detailed design. For the purposes of the present assessment, waste rock regrading for Option 3 has been assumed and included in the cost assessment.

5.6.2.2 Key Assumptions

The key assumptions employed in the geotechnical evaluation of Option 3 are as follows:

- Tailings can be blended and transported to the pit for deposition as a homogeneous blend;
- Tailings can be deposited in the pit such that the bulk hydraulic conductivity of the tailings mass is consistent and less than approximately $5x10^{-9}$ m/s;
- A new in-pit dam can be successfully constructed with suitable inert material at the south-end of the pit to contain the tailings with minimal seepage occurring around the structure; and
- The Pony Creek Adit can be successfully sealed.

5.6.2.3 Performance and Uncertainty

The most notable performance and uncertainty related to Option 3 is the ability to create a blend of tailings that achieves the required hydraulic properties (*i.e.*, a homogeneous mixture with a hydraulic conductivity of less than of $5x10^{-9}$ m/s) and density characteristics. These would be difficult to ensure at the field scale of a dredging operation.

The other uncertainty relates to the effects of differential settlement on the cover integrity and performance through tailings consolidation. As such, additional maintenance and repairs of the final cover will likely be required and have been included in the cost assessment.

5.6.3 Water Management

5.6.3.1 Overview

A dam at the south end of the open pit will be required to contain the tailings and water cover (Figure 5.6-1) for Option 3. A liner would likely be required to minimize seepage losses through the dam since these losses would report as surface water at the south end of the pit. The liner would extend into the bedrock foundation to minimize the potential for foundation seepage.

The design of the dam is envisioned to respect the 2007 Canadian Dam Association guidelines, including the spillway which would be designed for the IDF associated with the location. The soil cover for Option 3 is similar to that of Option 2, except that it is likely that there will be extended periods where there is no surface water under this option. A layer of coarse waste rock could be placed over top of the soil cover to prevent wind erosion, and reduce evaporation.

With the reclamation of the valley, changes in the hydrology can be expected as conditions return to pre-mining condition.

5.6.3.2 Key Assumptions

<u>Spillway and Pony Creek Diversion</u>

Under normal operating conditions, a spillway would not be active because inflows are expected to be lower than the sum of losses to infiltration, seepage and evaporation. However, since the tailings are contained by a dam, it is necessary to provide some provision for the routing of excess surface water to prevent overtopping of the dam. Routing water north into Pony Creek is proposed for Option 3 and may require some excavation through bedrock.

A contingency provision for a diversion channel from Pony Creek to the pit area is included in the event that tailings desaturation becomes a concern. Should the diversion be necessary a side hill diversion channel would be required as shown on Figure 5.6-1. A stop-log weir structure could accomplish this and would have the advantage of redirecting flow in the natural creek channel should water quality objectives not be met in the pond or if maintenance of the cover over the tailings is required.

Pony Creek Adit and Pony Creek

Under this scenario, it is assumed that it will be necessary to provide a more effective seal at the Pony Creek adit to reduce this potential pathway for groundwater loss. A cost estimate has been provided.

5.6.3.3 Performance and Uncertainty

The key performance and uncertainties related to water management issues for Option 3 are as follows:

- Foundation and abutment conditions at the dam location may pose challenges during construction. Furthermore, maintenance and repair of seals in sidewalls, foundation, and adit may affect performance over long-term.
- Seepage from tailings backfill into surrounding bedrock remains an uncertainty. A significant uncertainty at this time is the volume of seepage losses that can be expected around the perimeter of the tailings mass into fractured bedrock and the possible requirement for seepage control measures in this regard.

Cover system

- Reliability of water supply (Pony Creek diversion) to maintain saturated conditions of the tailings;
- Consequences of differential settlement with respect to cover integrity, surface drainage and spillway design; and
- Frequency and cost for routine or unexpected maintenance.

Water Diversion Structures and Diversion Channels

- New water diversion structures will require regulatory approval, and frequency and cost for routine or unexpected maintenance going forward is uncertain;
- There are challenges associated with maintaining side-hill channels (Pony Creek to open pit), as well as requirements to cross entrance and spillway channels under this option; and
- Potential consolidation will be an important consideration in establishing spillway control. It may be necessary to provide the ability to lower the spillway elevation if maintaining a constant water depth is desired after consolidation takes place.

Existing Tailings Management Area

- Once the tailings are removed from the existing TMA, it is expected that a reclamation process will be initiated. Some of these efforts will affect the hydrology and water balance of the area, as conditions return to a pre-mining "state" (*e.g.*, re-vegetation, contouring and drainage improvement).

5.6.4 Geochemistry

5.6.4.1 Overview

As part of Option 3, source terms for the water quality prediction model were developed for tailings stored in the pit, as well as for waste rock and ore stored subaerially. The development of these source terms are discussed in detail in Appendix B. Similar to Options 1 and 2, the primary objective of Option 3, from a geochemical perspective, is to maintain the tailings in a saturated state and minimize the potential for tailings oxidation and the development of acidic drainage. This will necessitate excavation, blending, transportation and, and placement of tailings in the pit which may lead to notable short-term water quality degradation. The removal of tailings from the tailings impoundment will also result in the removal and entrainment of organic deposits underlying the tailings. Under tension-saturated conditions and in the presence of organic matter, the tailings are likely to develop mildly to strongly suboxic conditions within the pit in the longer-term. As per the status quo and Options 1 and 2, suboxic conditions throughout the tailings will promote the mobilization of the redox sensitive tailings phases (Fe and Mn oxides) and associated metals (primarily As but may also include Zn, Cu, and Cd).

As outlined for Options 1 and 2, the attenuation mechanisms (*e.g.,* sulfide precipitation) currently operating within the tailings impoundment are assumed to apply to the long-term water quality predictions. The same assumptions do not apply to Option 3. Specifically, the pit environment may not be suitable for the development of sulfide precipitation processes which currently account for significant metal attenuation within the impoundment. Although this form of attenuation has not been accounted for in the model, given the long groundwater flow path between the pit and surface receptors, and the long travel time in groundwater, significant attenuation (*e.g.*, sorption to clay minerals) is likely along the groundwater flow path. The absence of attenuation assumed for Option 3 imparts conservatism into the water quality predictions.

For Option 3, waste rock will be stored subaerially and is expected to behave in a manner similar to the status quo condition.

5.6.4.2 Key Assumptions

Derivation of source terms for Option 3 includes the following assumptions:

- The tailings remain at or above 85% saturation and will not produce acidic drainage;
- Under tension-saturated conditions and in the presence of organic matter the tailings will be mildly to strongly suboxic; redox mechanisms will be the dominant control on the release and attenuation of the metals of concern;
- The attenuation mechanisms currently observed in the tailings impoundment will not occur within the pit;
- Drainage chemistry data for the unsaturated ore field bin, upon which ore source terms were based, is representative of long-term drainage from unsaturated ore;
- Drainage currently observed within subaerially stored waste rock is representative of longer-term drainage; and
- Waste rock is non-acid generating.

5.6.4.3 Performance and Uncertainty

The geochemical source terms derived for Option 3 are shown in Table 5.6-2. The performance and uncertainties regarding waste rock and ore source terms are the same as those for Options 1A and 2A and are described in greater detail in section 5.4.4.3 and Appendix B. In summary, there is uncertainty relating to whether the data used in deriving subaerial waste rock source terms are representative of all waste rock. Also, there is uncertainty as to whether drainages from the unsaturated ore field bin are representative of long-term drainage conditions.

With the exception of Zn, total cyanide and WAD cyanide, the “Conservative Best Estimate” and “Worst Case” source terms for tailings are within an order of magnitude (Table 5.6-2). This narrow range in values generally reflects the conservative approach taken in the derivation of the Conservative Best Estimate source terms.

Table 5.6-2:
Option 3 Geochemical Source Terms, all values in mg/L

Parameter	Conservative Best Estimate			Worst Case		
	Tailings in Pit	Waste Rock Pile	Ore	Tailings in Pit	Waste Rock Pile	Ore
Ca	136	368	431	470	346	431
Mg	50	93	297	45	91	297
As	9	0.01	0.03	15	0.02	0.04
Cd	0.001	0.03	0.09	0.001	0.2	0.2
Cu	0.002	0.04	0.02	0.002	0.2	0.04
Fe	3	0.01	0.03	15	0.06	0.05
Mn	5	5	49	24	29	97
Zn	0.05	5	10	0.5	34	31
Sulfate	1700	1530	2265	2000	2940	2680
Ammonia	15	0.03	0.03	15	0.1	0.09
CN (Tot)	0.04	-	-	0.9	-	-
WAD CN	0.03	-	-	0.2	-	-
Cyanate	6	-	-	6	-	-
Nitrate	0.1	2	0.3	0.1	9.96	0.9
Nitrite	0.09	0.02	0.08	0.09	0.4	0.1

Relative to Options 1 and 2, there is significantly more uncertainty associated with the tailings source terms derived for Option 3. Although it is very likely that the tailings porewater will become suboxic, it is unclear as to whether Mn-reduction or Fe-reduction will dominate. In mine waste, significantly more metals are released when Fe-reduction dominates due to the predominance of metal-bearing Fe-oxides. Another unknown is the rate of Mn or Fe-reduction that may occur within the in-pit tailings. If the rate is fairly slow, then the flux of metals released to the environment will be lower in comparison to a higher dissolution rate scenario.

As outlined above, the potential for attenuation within the pit and along the groundwater flow paths is not clear. Potential attenuation mechanisms include: 1) adsorption/co-precipitation with to Fe oxides (Bowel, 1994); 2) sorption to clay minerals (Violante and Pigna, 2002; Manning and Goldberg, 1997); and 3) precipitation as secondary sulphide minerals in suboxic settings (Martin and Pedersen, 2002). The assumption that no attenuation of metals will occur under Option 3 is considered conservative, as some degree of metal removal can be expected along the groundwater flow path.

Lastly, *in-situ* groundwater and porewater sampling may be biased. Groundwater sampling from the tailings mass is biased toward the more porous tailings intervals (*e.g.*, silt and sand). It is possible that porewater in the clay, which encompasses a large proportion of the tailings, has a different chemical signature compared to its sand and silt counterparts and is not adequately represented.

Monitoring well MP09-10, the only well screened over a clay-rich tailings interval, exhibits distinctly elevated As, Cu, total and WAD cyanide concentrations that are characteristic of process waters. While process water has been flushed from the coarser tailings layers (Appendix B), process water exhibits longer retention within the lower permeability clay materials. In the long-term, process water will be flushed from the tailings entirely. However, in the short-term, (*i.e.*, during disturbance associated with relocation), drainage chemistry with a strong process water signature may be encountered and treatment may be required. Table 5.6-3 compares the source terms (long-term drainage predictions) to groundwater thought to be representative of process water trapped within the extensive clay lenses which may be released during transport. Most notably, copper is predicted to be two orders of magnitude greater in the short-term compared to long-term.

Table 5.6-3:
Option 3 Geochemical Source Terms compared to predicted short-term drainage, all values in mg/L

Parameter	Long-term		Short-term
	Best Estimate	*Worst Case*	
As	9.3	15	25
Cu	0.002	0.002	0.8
CN (Tot)	0.04	0.9	3
WAD CN	0.03	0.2	1

5.6.5 Surface Water Quality

5.6.5.1 Overview

A water balance and water quality model was developed in Goldsim to support the assessment of closure Option 3. Key inputs to the model included precipitation and water quality chemistry from the various source terms (*e.g.*, tailings seepage, waste rock, ore, background Victoria Creek, *etc*.) For this option, a total of six different model scenarios were run, including combinations of two different source term chemistry estimates (Conservative Best Estimate and Worst Case) and three precipitation conditions (dry, average and wet year). The Conservative Best Estimate and Worst Case predictions reflect the range in source concentrations used in the model (Appendix B). For each scenario, the model was run on a monthly time step for a calendar year (12 months).

The overarching objective of the water balance and water quality modeling was to provide a tool to directly compare the environmental merits and performance of each closure option. To this end, and in order to best illustrate the differences between the closure options with regards to water quality, mill area contaminant loadings were excluded from the assessment. Currently, mill area loadings are a dominant control on downstream water quality and inclusion would obscure the differences in final water quality under the proposed closure scenarios. For these reasons - in concert with the fact that the mill area is a common closure element to all options and will be remediated (Section 5.2) - mill area loadings were ignored in order to differentiate resultant water quality effects from each of the closure options.

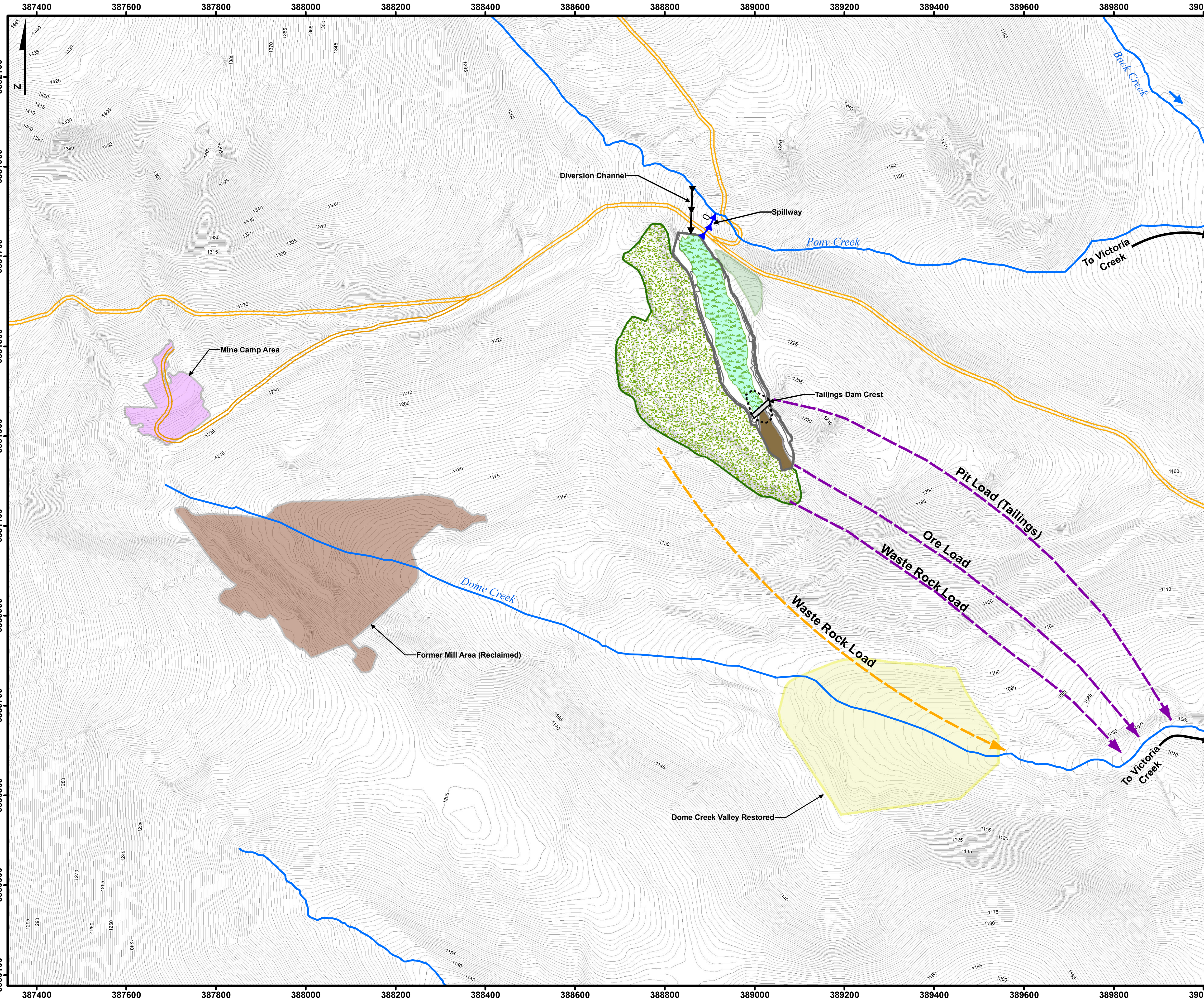
Following tailings relocation to the pit, restoration of the TSF was assumed to result in the restoration of ambient water quality to Dome Creek. This assumption was applied to Option 3 to illustrate the differences in long-term water quality between the other closure options.

In order to illustrate the predicted performance of the various options, emphasis was placed on arsenic, sulfate, cadmium and zinc, since these constituents are the primary parameters of concern. Water quality predictions for the above parameters are considered long-term or steady-state estimates. Details of the water balance and water quality model, including model configuration, assumptions and results, are provided in Appendix F. For the summary presented herein, only the Conservative Best Estimate results from the model are presented; all data are described and presented in Appendix F.

For Option 3, the model integrates the mine-related loadings and flows in the receiving environment. The mine site related sources that may contribute contaminant loadings to the receiving environment for Option 3 are summarized below.

- Year-round, deep groundwater seepage from the low-grade ore within the pit;
- Year-round, deep groundwater seepage from portions of waste rock on surface; and
- Year-round, deep groundwater seepage from tailings within the backfilled pit.

For Option 3, a schematic depicting the key components of the water quality model are presented in Figure 5.6-3.



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Legend

- Roads
- Watercourse
- Former Mill Area (Reclaimed)
- Mine Camp Area
- Former Waste Rock Dump Area (Reclaimed)
- Former Tailings Impoundment Footprint (Valley Restoration)
- Pit Outline
- Tailings Dam Footprint
- Reclaimed Ore Area
- Reclaimed Waste Rock Dump
- Reclaimed Backfilled Pit (Tailings with High Infiltration Cover)
- Shallow Groundwater Seepage
- Deep Groundwater Seepage

Topography

- Index (5m)
- Interm (1m)

Meters: 0 150 300 600

Data courtesy of AECOM

Figure for illustrative purposes only

SCALE: 1:8,000

DATE: OCT 22nd, 2010

PROJECTION: NAD_1983_UTM_Zone_8N

DATA SOURCE: J.S.

PROJECT: **Mount Nansen Options for Closure**

TITLE: **Closure Option 3: Schematic of Source Loadings for Water Quality Model**

PROJECT No: **J907-4**

FIGURE No: **5.6-3**

LORAX ENVIRONMENTAL
2289 Burrard St.
Vancouver, BC, V6J 3H9
Phone: (604) 688-7173
Website: www.lorax.ca

5.6.5.2 Key Assumptions

The following are the key assumptions relevant to the water balance and water quality model for Option 3:

- The mill area has been fully reclaimed and as such the water quality upstream of the mill area was assigned to represent the upstream or background water quality in Dome Creek (*i.e.*, the model predictions exclude mine-related loadings emanating from the mill area);
- The former TSF area is assumed to return to ambient water quality conditions in the long-term following Dome Creek restoration;
- For un-impacted catchment areas, a runoff coefficient of 0.8 was assumed for spring freshet (April and May) and a runoff coefficient of 0.6 for the remaining open water season months;
- No attenuation (*i.e.*, removal of dissolved metals from solution) is assumed to take place along either the shallow or deep groundwater flow paths from the pit and waste rock areas.
- To support the modeling, a synthetic historical precipitation record was generated for Mount Nansen based on climate data from Carmacks and Mount Nansen between 2000 to 2006 (Appendix D and Appendix F);
- Based on the synthetic precipitation record, dry, wet and average annual precipitation conditions were selected for modeling;
- Annual lake evaporation was estimated based on data from the Pelly Ranch Environment Canada Meteorological gauging station: 369 mm/year (Appendix D and Appendix F);
- For Dome Creek, zero flow was assumed during the winter months (November through March) as attempts to measure winter flow indicates frozen conditions through to the substrate; and
- For Victoria Creek, site monitoring indicates the presence of winter flow. For the model, monthly flow in Victoria Creek was estimated based on the monthly flow distribution in the Nordenskiold River.
- Tailings are relocated to the pit and the tailings area has been reclaimed and does not provide any contaminant loading to the receiving environment;
- Tailings are relocated to the pit and covered with waste rock to enhance infiltration;

- The relocated tailings are assumed to be homogeneous with a uniform hydraulic conductivity of 1 x 10^{-8} m/s, which is a conservative input for calculating fluxes;
- The annual fluxes of water through the top and bottom of the tailings were based on the results of a one-dimensional water balance model developed by Golder (Appendix C-3). This one-dimensional model does not consider surface inflows from other areas of the pit catchment and the only source of water considered was direct precipitation to the tailings footprint;
- A target saturation level of 85% is assumed to prevent tailings oxidation and the development of acidic conditions. The model assumes this target saturation level is achieved during all precipitation conditions. This also assumes that flow from the surrounding catchment provides any additional inflow required to maintain the tailings at 85% saturation (estimated at 420 m^3 annually for dry and average conditions);
- Based on one-dimensional modeling results, a flux of approximately 0.1 L/s through the bottom of the tailings was adopted for all precipitation conditions;
- The long term discharge rate from the pit to Dome Creek was set to 0.14 L/s;
- All waste rock remains on surface except for the relocation of the East Pile to the pit for use as cover material for the tailings;
- For seepage from waste rock, a key assumption is that there is no net surface runoff. Snowmelt and onset precipitation either evaporates or infiltrates into the waste rock dumps;
- Monthly net-infiltration rates for the waste rock dumps were based on the results of a one-dimensional, unsaturated, flow model developed by Golder (Appendix F). The monthly, net-infiltration rates were applied uniformly to the entire waste rock surface area;
- Depending on the specific configuration of the dumps, water that infiltrates into the dumps either reports to the receiving environment as variable, shallow groundwater seepage or continuous, deep groundwater seepage;

5.6.5.3 Performance and Uncertainty

<u>Performance</u>

Water quality predictions for each of the model runs were used to assess the performance of Option 3 through comparison to existing water quality in the downstream receiving environment in Victoria Creek; CCME Guidelines for the Protection of Aquatic Life are also included as a point of reference.

A summary of the Best Estimate water quality predictions (average year) for sulfate, arsenic, cadmium and zinc in Victoria Creek for Option 3 are presented in Table 5.6-4.

Table 5.6-4:
Summary of Predicted Concentrations (mg/L) in Victoria Creek for Option 3 - Best Estimate Source Terms and Average Precipitation Conditions

		Existing Water Quality[b]		Predicted Water Quality	
Parameter	*CCME Guideline*	*Median*	*Winter Maximum*[c]	*Median*	*Maximum*
Arsenic	0.005	0.0016	0.0075	0.005	0.043
Cadmium	0.00034[a]	0.00003	0.0003	0.00009	0.00038
Zinc	0.03	0.009	0.02	0.017	0.059
Sulfate		30	61	31	43

Notes:
a. Draft CCME Guideline for Cadmium (Environment Canada 2008) at Hardness = 150 mg/L as $CaCO_3$.
b. Existing water quality data for Victoria Creek at Road (2007 to 2010).
c. Maximum winter concentration from the existing water quality data set for Victoria Creek (November to February, 2007 to 2010).

Key highlights (for Best Estimate/Average Flow Scenario) of the assessment for Option 3 are:

- Similar to all options, peak concentrations for all parameters occur during the winter, low-flow period due to the ongoing discharge of mine-related loadings during periods of minimal flow and available dilution. This disproportionate load is emphasized by discharges from the deep groundwater system (pit and waste rock) which are assumed to remain constant throughout the year.
- *Sulfate*
    - In general, predicted concentrations of sulfate (median = 31 mg/L, maximum = 43 mg/L) are lower than those for Option 1 and 2 (maximum = 106 mg/L). The lower sulfate concentrations predicted for Option 3 reflect the removal of seepage from the tailings area which represents the primary source of sulfate to Victoria Creek.
- *Arsenic*
    - Predicted concentrations of arsenic for Option 3 (median = 0.005 mg/L, maximum = 0.043 mg/L) are higher than those for Options 1 and 2 (median = 0.002 mg/L, maximum = 0.0055 mg/L).

  - The predicted loading from saturated tailings stored in the pit is the dominant source of arsenic to the receiving environment.

- *Cadmium*

  - The predicted cadmium concentrations for Option 3 (median = 0.0001 mg/L, maximum = 0.00038 mg/L) are slightly lower than those predicted for Option 1A and 2A and are well below the CCME guideline.

  - The predicted loading from waste rock is the dominant source of cadmium to the receiving environment.

- *Zinc*

  - The predicted zinc concentrations for Option 3 (median = 0.017 mg/L, maximum = 0.059 mg/L) are similar than those predicted for Option 1A and 2A and are generally below the CCME guideline, except during winter low flow conditions.

  - Similar to cadmium, the predicted loading from waste rock is the dominant source of zinc to the receiving environment.

Overall, the Best Estimate Average Precipitation model results for Option 3 show comparable values for cadmium and zinc in comparison to Option 1A and 2A. For sulfate, the removal of the tailings from the Dome Creek valley results in a reduction in concentration in Victoria Creek compared to current conditions and those predicted for Option 1 and 2. This largely relates to a decrease in the water flux associated with in-pit tailings placement. For arsenic, the predicted concentrations for Option 3 are significantly higher than those predicted for Option 1 and 2. The increase in arsenic largely reflects the assumption that no attenuation will occur along the groundwater flow path from the pit to the receiving environment.

<u>Uncertainty</u>

The uncertainties associated with the modeling results for Option 3 are as follows:

- A significant amount of conservatism has been incorporated into the model to account for various uncertainties. One key component of this conservatism is the assumption of constant seepage rate from both the tailings area and the deep groundwater pathways conveying contaminants from the pit and surrounding waste rock areas. This conservatism is reflected in the higher predicted winter concentrations which generally exceed historical winter maximum concentrations. In reality, the tailings seepage and deep groundwater flows will exhibit some seasonal variability with a reduction in flows during the winter months.

- The sensitivity of the system to variations in precipitation conditions was evaluated for three precipitation conditions: average year, dry year and wet year. As expected, during dryer years, there is less dilution capacity in the receiving environment and therefore higher predicted concentrations. Conversely, during wet precipitation years, the additional flow in the receiving environment results in lower predicted concentrations.

- A critical uncertainty associated with Option 3 is related to the feasibility of attaining a desired level of tailings saturation (85%) in the pit. As discussed in the 2010 geotechnical analysis (Appendix C-1), there is a high level of uncertainty with regards to the feasibility of blending the tailings sufficiently to achieve a desired bulk hydraulic conductivity. The water balance and water quality model for Option 3 assumed that the tailings are well mixed with a uniform hydraulic conductivity. In reality, some degree of incomplete mixing will occur, resulting in spatial heterogeneity in the water holding properties of the tailings.

- The results of one-dimensional modeling indicate that a minimum annual addition of 420 m^3 of water is required to ensure tailings saturation levels are maintained at 85% or higher (*i.e.*, water that must come from outside the tailings footprint). The water quality modeling for this option assumed that the surrounding catchment of the pit area can provide the water to offset this deficit. To ensure sufficient water is available, a water balance assessment was carried for dry and average conditions. Assuming the surface area of the tailings placed in the pit is 21,000 m^2 and the entire pit catchment for Option 3 is 33,930 m^2, the residual pit catchment area is 12,930 m^2. Based on this assessment, this residual catchment area can provide an additional 2,328 m^3/year of potential inflow during a dry year and 3,663 m^3/year during an average year. Assuming a runoff coefficient of 0.4, these water volumes translate to 931 m^3 and 1,465 m^3 during dry and average conditions, respectively. Such volumes are sufficient to offset the assumed, modeled deficit, and therefore maintain tailings saturation.

- A relevant uncertainty is the potential for the attenuation of contaminants along groundwater flow paths from the pit. The Option 3 loading model for tailings placement in the open pit does not account for any attenuation of arsenic along the groundwater flow path between the pit and Dome Creek. In this context, attenuation refers to adsorption and precipitation processes that result in the removal of dissolved arsenic from solution. The presence of silt-clay facies in the underlying deposits in the area certainly suggests that the adsorption of arsenic to clay minerals may play a dominant role in arsenic removal. The magnitude of removal cannot be quantified.

However, given the long groundwater flow path (825 m) between the pit and surface receptors, and the likely travel time in groundwater (1 to 26 years), significant attenuation is likely. This will affect both the timing and magnitude of arsenic loadings to Dome Creek. The considerations presented here suggest that the predicted water quality for Option 3 (and 4), particularly for arsenic, are overly conservative and represent maximum possible concentrations. In reality, a similar level of arsenic attenuation may occur for an in-pit tailings scenario to that observed currently in the existing tailings storage area. The removal mechanisms described for arsenic also apply to other relevant trace elements, including zinc and cadmium.

- Groundwater discharge was conservatively estimated to be approximately 0.14 L and is calculated from first principles and site observations, including several years of pit lake elevation data (Appendix E). The estimated flux rate, while conservative, is sufficiently low such that water quality in Victoria Creek is relatively insensitive to seepage quality degradation from the pit (*e.g.,* from un-attenuated tailings seepage; Appendix F). Groundwater flux rates, while considered conservative, remain uncertain.

5.6.6 Costs

The estimated capital cost for implementing Option 3 is summarized in Table 5.6-5. The estimated cost includes a 30 percent contingency but does not include costs for design engineering, routine inspections and operations or maintenance as these are expected to be similar for all options considered and therefore do not materially affect the cost comparison. The estimate is considered to be Class D estimate (or ASTM E2516-06 Class 5), with an accuracy of -25 to +40 percent.

The capital cost estimates do not include *Common Closure Element* costs which are described in Section 5.2 and Appendix C-2. For Option 3, the estimated capital cost is approximately $16.3 M. More details related to cost assumptions and breakdown of individual components are found in Appendix C-1 and C-2.

Table 5.6-5:
Summary of Estimate Capital Costs for Option 3

Work Item Description		Units	Quantity	Unit Cost	Total Cost
Mobilization and Demobilization		L.S.	1	$ 500,000	**$ 500,000**
Transport and Place Tailings					
Set up dredges, pumps and lines		L.S.	1	$ 2,000,000	$ 2,000,000
Dredge tailings		m^3	300,000	$ 9	$ 2,700,000
Sub Total					**$ 4,700,000**
Restore Tailings Management Area (TMA)					
Relocate dam fill to borrow sources		m^3	80,000	$ 5	$ 400,000
Relocate dam fill to pit		m^3	80,000	$ 12	$ 960,000
Restoration of Dome Creek valley					$ 1,670,000
Sub Total					**$ 3,030,000**
Construct in-pit Tailings Dam					
Fill material		m^3	10,000	$ 35	$ 350,000
Tailings dam liner		m^2	1,000	$ 150	$ 150,000
Foundation preparation		L.S.	1	$ 500,000	$ 500,000
Monitoring instrumentation		L.S.	1	$ 200,000	$ 200,000
Sub Total					**$ 1,200,000**
High infiltration cover over tailings (1m)		m^3	21,000	$ 15	**$ 315,000**
Spillway					
Excavation		m^3	500	$ 20	$ 10,000
Geotextile		m^2	500	$ 10	$ 5,000
Armouring		m^3	250	$ 50	$ 12,500
Sub Total					**$ 27,500**
Regrade and repair cover		m^3	21,000	$ 5	**$ 105,000**
Reslope, regrade and revegetate Waste Rock Storage area					**$ 142,000**
Plug Pony Creek Adit		L.S.	1	$ 250,000	**$ 250,000**
Scale/flatten pit walls		L.S.	1	$ 200,000	**$ 200,000**
Revegetate pit fill, pit safety (signage and berm)		L.S.	1	$ 49,000	**$ 49,000**
Monitoring Insrumentation		L.S.	1	$ 200,000	**$ 200,000**
Water Treatment - Capital		L.S.	1	$ 1,650,000	**$ 1,650,000**
Water Treatment - Maintenance		per year	5	$ 35,000	**$ 175,000**
Sub Total					**$ 12,543,500**
30% Contingency					**$ 3,763,050**
TOTAL ESTIMATED COST - OPTION 3					**$ 16,306,550**

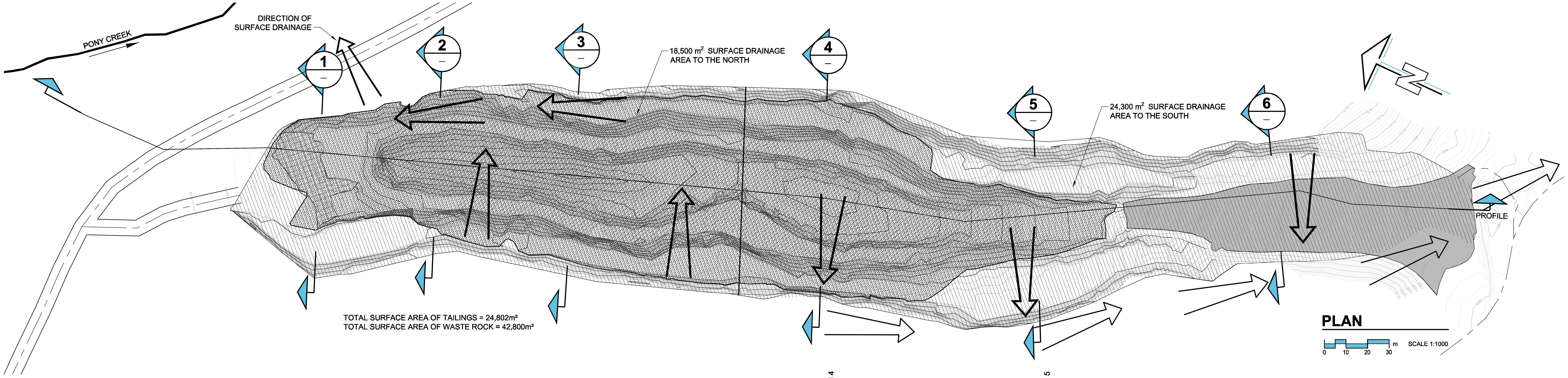
5.7 Option 4 – Pit Backfill with Dry Cover on Tailings, Dam Removal and Valley Restoration

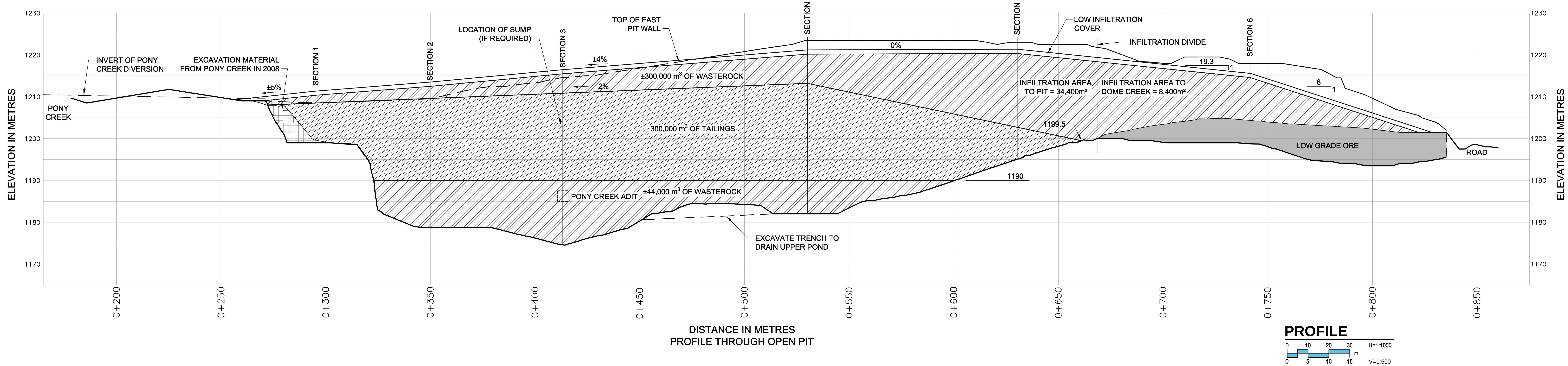
5.7.1 Overview

Similar to Option 3, Option 4 involves the re-location of ~300,000 m^3 of tailings and underlying contaminated soil from their existing location to the open pit. In contrast to Option 3, Option 4 is designed to maintain the tailings in a dry condition to the extent possible via storage of the tailings above the water table and placement of a low infiltration (water shedding) cover (Figure 5.7-1). This option also entails the backfilling of ~344,000 m^3 of waste rock into the pit. Restoration of the Dome Creek valley in the area of the TSF is also a common element to both Options 3 and 4 (Figure 5.7-2). The primary objectives of Option 4 are to:

1) Remove the geotechnical liability associated with maintaining a tailings dam in the Dome Creek valley;
2) Restore the Dome Creek valley in the area of the TSF to a more natural condition compatible with the original land use;
3) Minimize the potential for tailings oxidation and ML/ARD through the maintenance of dry conditions within the tailings deposits (minimize infiltration); and
4) Restore area of open pit to a condition more compatible with the original land use via tailings and waste rock backfill.

As part of Option 4, several design measures will be implemented to minimize water contact with the tailings. Firstly, the tailings will be stored above the local water table through the placement of ~44,000 m^3 of coarse waste rock into the pit bottom prior to tailings placement (Figure 5.7-1). The tailings would then be placed in one continuous layer (up to 25 m thick) over the waste rock. A further 300,000 m^3 of waste rock would then be placed on top of the tailings and graded to direct surface runoff away from the backfilled pit. A low infiltration cover designed to minimize infiltration would then be placed on top of the waste rock. Preliminary assessments indicate a vegetated, store-release-divert type cover would be a viable option (Appendix C-4), consisting of 0.3 m of topsoil (vegetated), 1 m of the well graded Victoria Creek borrow material to act as a barrier to infiltration, and 1 m coarse waste rock to act as a capillary break. The encapsulation of the tailings will provide an effective means to physically stabilize the tailings and prevent water/wind erosion.

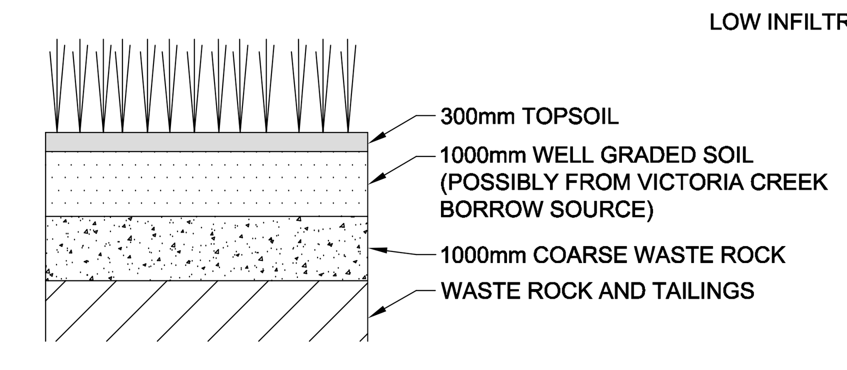




LOW INFILTRATION

LOW INFILTRATION

DRAFT



COVER

SCALE 1:200

AECOM

Government of Yukon

Mt. Nansen Closure Alternatives Characterization

Option 4

Plan, Profile & Sections - Brown-McDade Open Pit

Figure 5.7-1

Drawing - 04

D SIZE 22" x 34" (558.8mm x 863.6mm)
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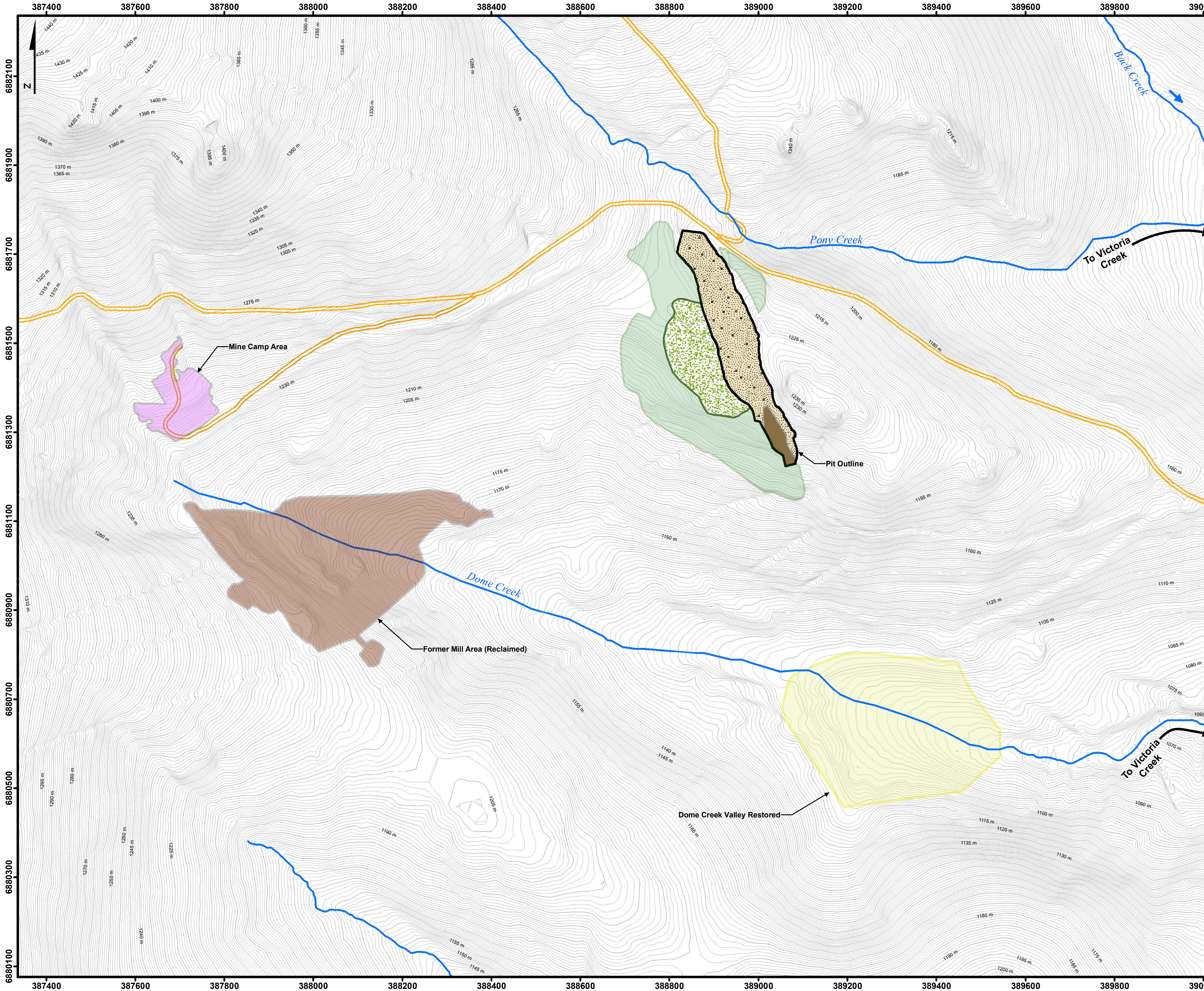


CLIENT:: Yukon Government

Legend

- Roads
- Watercourse
- Former Mill Area (Reclaimed)
- Mine Camp Area
- Former Waste Rock Dump Area (Reclaimed)
- Former Tailings Impoundment Footprint (Valley Restoration)
- Pit Outline
- Reclaimed Ore Area
- Reclaimed Waste Rock Dump
- Reclaimed Backfilled Pit (Tailings + Waste Rock with Low Infiltration Cover)

Topography

- Index (5m)
- Interm (1m)

Meters: 0, 150, 300, 600

Data courtesy of AECOMM

Figure for illustrative purposes only

SCALE:	1:8,000
DATE:	OCT 22nd, 2010
PROJECTION:	NAD_1983_UTM_Zone_8N
PROJECT MANAGER:	J.S.
PROJECT:	**Mount Nansen Options for Closure**
TITLE:	**Closure Option 4: Tailings and Waste Rock Backfill into Pit with Low Infiltration Cover**
PROJECT No: J907-4	FIGURE No: 5.7-2

LORAX ENVIRONMENTAL
2289 Burrard St.
Vancouver, BC, V6J 3H9
Phone: (604) 688-7173
Website: www.lorax.ca

The relocation of tailings for Option 4 would be similar to that for Option 3 except that the coarse and fine tailings would not require blending. This contrast to Option 3 will influence tailings transport methods. Preliminary evaluation of tailings transport indicates that tailings relocation by mechanical removal presents a more viable option for Option 4 (as opposed to dredging and transport via pipeline slurry in Option 3).

Preliminary geotechnical assessments indicate that if the tailings are placed with a gradual slope towards to the south end of the pit, a waste rock dam at the southern margin of the pit will not be required to maintain stability of the tailings. This would remove the geotechnical liability associated with the inspection and maintenance of dam structures as outlined by the Canadian Dam Association. This differs from Option 3 which will require an in-pit tailings dam to impound the tailings.

Under most flow conditions, there will be no surface water discharges from the pit area owing to the water storage afforded by the cover system and evapotranspiration from the vegetated surface. Runoff can be expected during wet periods associated with freshet and storm events. In this regard, grading will route runoff flows to Pony Creek for the northern half of the pit area, and to Dome Creek for runoff generated in the southern half of the backfilled pit (Figure 5.7-1).

A summary of key elements associated with Option 4 is provided in Table 5.7-1. In the sections to follow, more detailed discussions are provided with respect the design, performance and uncertainty relating to geotechnical measures, water management, geochemistry, water quality and cost.

Table 5.7-1:
Key closure elements associated with Option 4

Option	Closure Element	Description
4	Tailings and Pit	Relocation of approximately 300,000 m^3 of tailings and contaminated soil to the open pit. Tailings will be stored in a dry condition to the extent possible through storage of tailings above the water table and placement of a cover designed to minimize infiltration. The cover will also serve to physically stabilize the tailings to prevent water/wind erosion.
4	In-Pit Dam	Preliminary assessment indicates that an in-pit dam structure will not be required.
4	Waste rock	Re-location of ~344,000 m^3 of waste rock to open pit. Approximately 156,000 m^3 of waste rock will be left in place and regarded and revegetated as necessary.
4	Tailings Storage Facility	Re-location of tailings will allow restoration of the Dome Creek valley in the area of the TSF to a condition compatible with the original land use.
4	Pony Creek Adit	Additional measures may be required to provide a more effective seal of the adit to minimize the hydraulic connection between the pit and Pony Creek.

5.7.2 Geotechnical

5.7.2.1 Overview

Option 4 requires that the tailings be relocated to the pit above the water table. A mass of waste rock (~44,000 m^3) will serve to separate the tailings from the water table. The relocation of the tailings in Option 4 will not require specific blending requirements. The gradation of the waste rock used for the base as well as intermediate layers will be determined during detailed design. Preliminary inspections of the waste rock piles indicates a wide range of gradations are available although processing is likely required. It will be important to consider the appropriate filter layers at the interface between the waste rock layers and fine grained tailings.

A waste rock plug at the south end of the pit may or may not be required for containment of the tailings. Preliminary assessments have shown that if the tailings are placed with a gradual slope, the plug would not be required to maintain stability of the tailings. In either case the pit backfill will be designed with an adequate factor of safety for all loading cases.

Upon completion of tailings relocation, consolidation and resulting settlement is expected to occur. The time required for consolidation settlement to occur depends on the length of either vertical or horizontal drainage paths; the shorter the drainage path, the more rapidly the tailings will consolidate. Geotechnical properties of the tailings were determined based on laboratory testing results and published information. If the tailings are placed in one continuous layer (up to 25 m thick), the estimated time to reach 90% consolidation (end of primary consolidation) is estimated to be in the order of 20 years. The anticipated total vertical settlement from consolidation is expected to be in the order of 0.8 to 1.5 m. This settlement will not be uniform across the tailings surface due to differences in density, the presence of frozen material and varying thickness. It should be recognized that considerably more settlement could occur if the tailings are placed in a frozen state with large void spaces; it may also take considerably longer for thaw induced settlement to occur.

A low infiltration cover is proposed for Option 4 with the objective of the cover design to reduce infiltration of precipitation and snow melt water into the tailings material. For this prefeasibility assessment, five cover options were considered and are described in detail in Appendix C-4. The assessment concluded that a vegetated store-release-divert type cover would be a viable option with the following preliminary design specifications:

- 0.3 m of topsoil, with vegetation established in it.
- 1 m of the well graded Victoria Creek soil to act as a barrier to infiltration
- 1 m coarse waste rock – to act as a capillary break

Because of the anticipated differential consolidation settlement, the soil cover design will need to consider the uneven settlement of the tailings with time and final regrading of the cover may have to be delayed by several years. In this same vein, there are a number of operational and maintenance items to be considered for closure Option 4:

- Some maintenance is anticipated for the cover for several years following construction. It is anticipated that the tailings will be placed without any compaction, and therefore overall and differential settlements would be anticipated. The settlements may affect the performance of the cover if the cover is not able to drain or shed surface water effectively.
- Treatment of the porewater (expelled during consolidation of the tailings) may be required for some period of time. The period of time that treatment would be required for would be dependent on tailings seepage water quality, attenuation by saturated waste rock, and dilution.

- Access to the site should be maintained to accommodate maintenance, and monitoring programs as required. This access may not be required in the long term if satisfactory performance is achieved. Over the long-term, occasional inspections may be conducted by helicopter if necessary.

Assuming that the cover performs satisfactorily, and that the environmental criteria are met, this option would require minimal long term monitoring and maintenance.

5.7.2.2 Key Assumptions

The key assumptions employed in the geotechnical evaluation of Option 4 are as follows:

- Waste rock of suitable quality can be placed at the bottom of the pit and can successfully isolate the tailings from the water table (Note that locally available inert, Aeolian sand may be used as a contingency to backfill the pit bottom);
- Suitable waste rock material is available to be used as filter layers within the tailings deposit in the pit;
- A low infiltration cover will perform as designed and successfully limit infiltration recharge to the tailings backfill.

5.7.2.3 Performance and Uncertainty

The most notable uncertainties related to geotechnical considerations for Option 4 are as follows:

- No requirement for a waste rock plug or dam to contain the tailings and waste rock. If the waste rock is required to act as a containment structure, the waste rock plug may have to be considered as a dam, and would be subject to the requirements outlined in the Canadian Dam Association Guidelines;
- The time taken and magnitude of consolidation settlement of relocated tailings is uncertain and is in part dependent on transportation and placement methods;
- The long-term integrity of the low infiltration cover and the ability to limit recharge to the tailings. Differential consolidation of the tailings will likely result in low depression areas that could result in ponding and excess infiltration. Maintenance of the cover during the consolidation period will likely be required in the form of regrading.

5.7.3 Water Management

5.7.3.1 Overview

As part of Option 4, several design measures will be implemented to minimize water contact with the tailings. Under most flow conditions, there will be no surface water discharges from the pit area owing to the water storage afforded by the cover system and evaporative losses from the vegetated surface. Runoff can be expected during wet periods associated with freshet and storm events. Under such circumstances, grading will route runoff flows to Pony Creek for the northern half of the pit area, and to Dome Creek for runoff generated in the southern half of the pit (Figure 5.7-1).

In this scenario, it will be necessary to seal the Pony Creek Adit as it may become submerged once water levels in the pit stabilize. Any water from the tailings will report to the waste rock reservoir where its release will be governed by the regional groundwater flow in the surrounding rock. A trench could be excavated between the two existing ponds in the open pit to allow for a pumping well to be installed in the lowest section of the pit at a later date should pumping and treatment be required.

5.7.3.2 Key Assumptions

<u>Tailings Consolidation Draindown</u>

As the tailings consolidate, contaminated porewater will report to the underlying waste rock reservoir. The volume of water released will be directly related to the volume change of the tailings mass. Depending on the assumed compression index for the tailings (0.08 *vs.* 0.15), preliminary calculations indicate that this volume is in the order of 3,000 to 21,000 m^3. This volume would increase substantially if the tailings were transported to the pit by dredging or slurry.

5.7.3.3 Performance and Uncertainty

The most notable uncertainties related to water management considerations for Option 4 are as follows:

<u>Open pit</u>

- There is less concern with radial outward flow of groundwater from the pit under Option 4 as compared to Option 3. However, the ability to maintain tailings in a dry state and to minimize groundwater flow through the tailings mass is uncertain;

- As previously described, the ability of the cover to limit seepage in consideration of differential settlement, freeze-thaw cycling and long-term degradation remains uncertain;
- Consequences of differential settlement with respect to surface drainage and spillway design; and
- The frequency and cost for routine or unexpected pit maintenance.

5.7.4 Geochemistry

5.7.4.1 Overview

As part of Option 4, source terms for the water quality prediction model were developed for tailings and waste rock backfilled in the pit, and waste rock and ore stored subaerially. The development of these source terms are discussed in detail in Appendix B. Similar to all other options, the objective of Option 4 is to minimize the development of acidic drainage. In contrast to all other options, the tailings in Option 4 will be stored as dry as possible above the water table. Hence it is assumed that some degree of sulfide oxidation will occur. However, emplacement of a low infiltration cover will minimize flow through the tailings and hence minimize the overall transport (*i.e.,* load) of metals from the backfilled pit to aquatic receptors.

Following tailings relocation to the pit, restoration of the TSF was assumed to result in the restoration of ambient water quality to Dome Creek. This assumption was applied to Option 4 to illustrate the differences in long-term water quality between the other closure options.

As with Options 1B and 2B, Option 4 involves the relocation of some waste rock to the pit where a portion will be stored below the water table, potentially resulting in the remobilization of metals that are unstable in suboxic environments (*e.g.*, Fe oxides). A portion of waste rock will also remain above the water table and subaerially exposed. Therefore, the chemistry of the drainage from the pit will be dictated by a combination of geochemical processes occurring within both unsaturated and saturated waste rock settings. A small portion of the waste rock may also be left in its current location and subaerially exposed.

5.7.4.2 Key Assumptions

The assumptions made in the derivation of source terms for Option 4 include the following:

- Sulfide oxidation will occur within the tailings and acidic conditions in tailing porewaters will develop over the long term;
- Given their similar geological origins and solid-phase chemistry, the acid rock drainage originating from Mt. Nansen tailings will be similar to that observed at the Arctic Gold and Silver site;
- There will be no attenuation of metals along the flowpath from the backfilled pit to Victoria Creek;
- Waste rock is non-acid generating;
- The drainage currently observed within the subaerially stored waste rock is representative of longer-term drainage quality;
- Suboxic conditions will develop in the saturated waste rock porewater (*e.g.,* pit bottom backfill);
- Metals associated with extensively oxidized waste rock are primarily associated with soluble and oxide phases which will be subject to dissolution under saturated/suboxic conditions;
- Source terms for the saturated waste rock were developed using data generated from the saturated waste rock field bin. This assumes that the field bin has reached an equilibrium state that will be representative of the suboxic conditions that are likely to develop within the pit environment;
- The waste rock stored in the pit and above the water table is assumed to exhibit drainage characteristics similar to the current subaerially exposed waste rock piles;
- The chemistry of drainage from waste rock in the pit is dictated by a combination of geochemical processes occurring within both unsaturated and saturated waste rock; and
- Drainage chemistry data for the unsaturated ore field bin, upon which ore source terms were based, is representative of long-term drainage from unsaturated ore.

5.7.4.3 Performance and Uncertainty

The geochemical source terms derived for Option 4 are shown in Table 5.7-2. Given the assumed acidic nature of tailings porewaters, drainage originating from the tailings in Option 4 exhibits concentrations of Cd, Cu, and Zn that are orders of magnitude greater than those provided for other options. Arsenic and sulfate concentrations are also elevated for Option 4. Therefore, the performance of this option is highly dependent on the success of the cover to reduce infiltration through the tailings mass.

Option 4 presents the greatest amount of uncertainty with regards to the tailings source terms due to difficulties in extrapolating static and short-term kinetic tests far into the future. The Arctic Gold and Silver Tailings analogue site provides some degree of confidence, particularly due to the similarities between the two sites, both geochemically and geographically. However, this certainty is limited by the lack of long-term data from the Arctic Site (drainage chemistry is represented by a single seepage quality sample). Evaluating temporal tends, such as seasonality of drainage chemistry or verification of chemical equilibrium in site drainages, is therefore not possible.

Table 5.7-2:
Option 4 Geochemical Source Terms (mg/L)

Parameter	Conservative Best Estimate				Worst Case			
	Pit		Waste Rock Pile	Ore	Pit		Waste Rock Pile	Ore
	Tailings	*Waste Rock*			*Tailings*	*Waste Rock*		
Ca	250	498	368	431	250	487	346	431
Mg	60	220	93	297	60	151	91	297
As	28	0.1	0.007	0.03	28	1	0.02	0.04
Cd	0.2	0.03	0.03	0.09	0.2	0.05	0.2	0.2
Cu	1	0.007	0.04	0.02	1	0.05	0.2	0.04
Fe	574	2	0.01	0.03	574	5	0.06	0.05
Mn	29	143	5	49	29	181	29	97
Zn	26	4	5	10	26	8	34	31
Sulfate	2500	2040	1530	2265	2500	2180	2940	2680
Ammonia	7	1	0.03	0.03	7	2	0.1	0.09
CN (Tot)	0.07	-	-	-	0.07	-	-	-
WAD CN	0.03	-	-	-	0.03	-	-	-
Cyanate	2	-	-	-	2	-	-	-
Nitrate	3	0.3	2	0.3	3	1	10	0.9
Nitrite	0.3	0.1	0.02	0.08	0.3	0.4	0.4	0.1

Humidity cell tests were also used to constrain source terms for this acidic scenario. While these tests provide valuable information on the leaching behavior of metals from tailings under acidic conditions, they only represent primary release rates with no consideration given to the influence of field conditions that govern the actual metal concentrations in drainage. For this reason, laboratory-based kinetic tests are typically conducted in concert with field-based tests that better represent site-specific conditions. The unsaturated tailings field bin installed in 2009 for this purpose has not yet evolved to acidic conditions, and therefore cannot be used to constrain the drainage chemistry predictions.

The performance and uncertainties regarding the unsaturated waste rock and ore source terms are the same as those described for Options 1A, 2A, and 3 and are described in greater detail in section 5.4.4.3. In summary, there is uncertainty as to whether the data used in deriving unsaturated waste rock source terms are truly representative of the waste rock component as a whole. Further, there is uncertainty with regards to the assumption that drainages from the unsaturated ore and the waste rock + organics field bins are representative of long-term drainage conditions.

5.7.5 Surface Water Quality

5.7.5.1 Overview

A water balance and water quality model was developed in Goldsim to support the assessment of closure Option 4. Key inputs to the model include precipitation and water quality chemistry from the various source terms (*e.g.*, tailings seepage, waste rock, ore, background Victoria Creek, *etc*.) For this option, a total of six different model scenarios were run, including combinations of two different source term chemistry estimates (Conservative Best Estimate and Worst Case) and three precipitation conditions (dry, average and wet year). The Conservative Best Estimate and Worst Case predictions reflect the range in source concentrations used in the model (Appendix B). For each scenario, the model was run on a monthly time step for a calendar year (12 months).

The overarching objective of the water balance and water quality modeling was to provide a tool to directly compare the environmental merits and performance of each closure option. To this end, and in order to best illustrate the differences between the closure options with regards to water quality, mill area contaminant loadings were excluded from the assessment. Currently, mill area loadings are a dominant control on downstream water quality and inclusion would obscure the differences in final water quality under the proposed closure scenarios. For these reasons - in concert with the fact that the mill area is a common closure element to all options and will be remediated

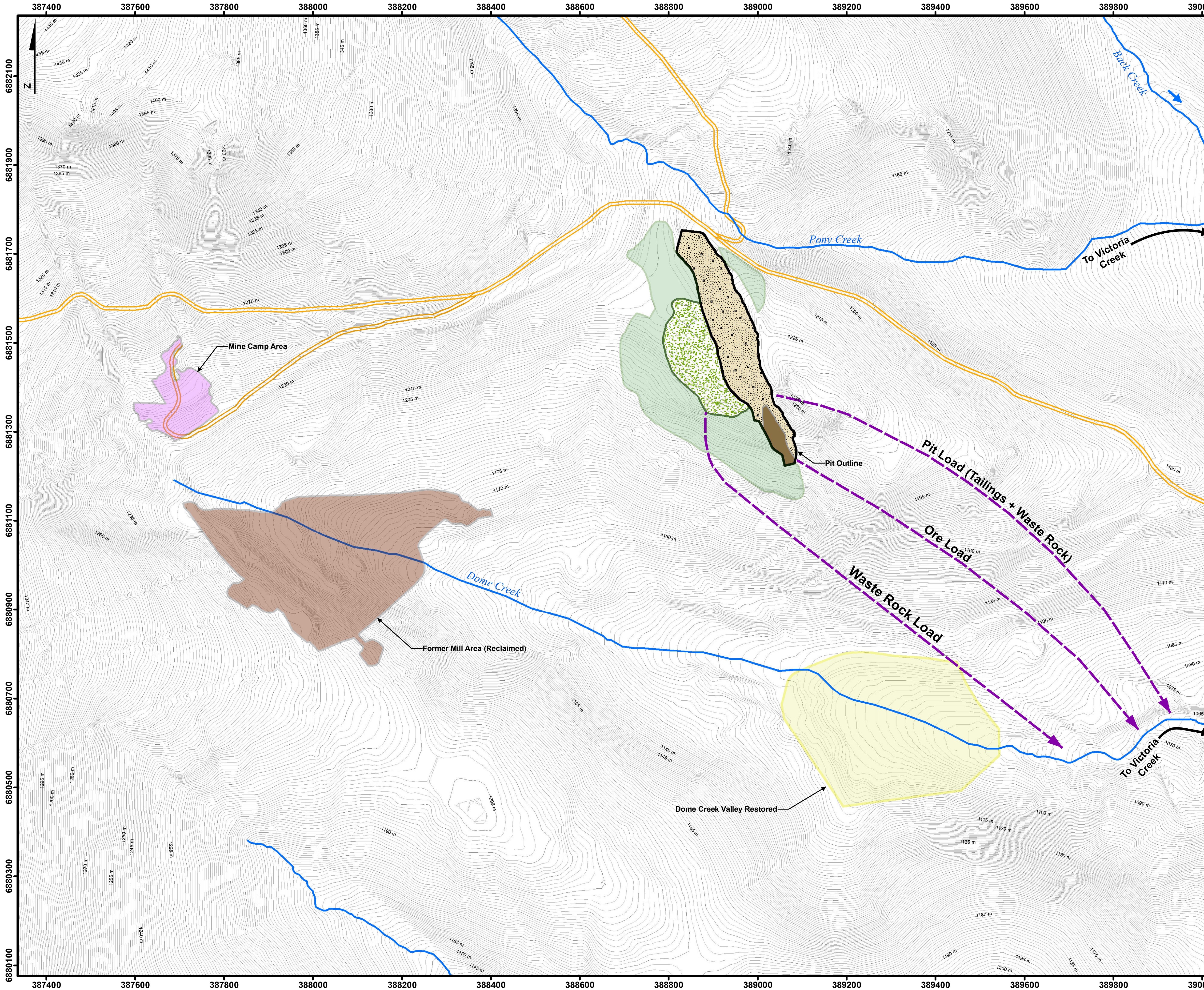
(Section 5.2) - mill area loadings were ignored in order to differentiate resultant water quality effects from each of the closure options.

In order to illustrate the predicted performance of the various options, emphasis was placed on arsenic, sulfate, cadmium and zinc, since these constituents are the primary parameters of concern. Water quality predictions for the above parameters are considered long-term or steady-state estimates. Details of the water balance and water quality model, including model configuration, assumptions and results, are provided in Appendix F. For the summary presented herein, only the Conservative Best Estimate results from the model are presented; all data are described and presented in Appendix F.

For Option 4, the model integrates the mine-related loadings and flows in the receiving environment. The mine site related sources that may contribute contaminant loadings to the receiving environment for Option 4 are summarized below.

- Year-round deep groundwater seepage from the low-grade ore within the pit; and
- Year-round deep groundwater seepage from the backfilled pit.

For Option 4, a schematic depicting the key components of the water quality model are presented in Figure 5.7-3.



CLIENT:: Yukon Government

Legend

- Roads
- Watercourse
- Former Mill Area (Reclaimed)
- Mine Camp Area
- Former Waste Rock Dump Area (Reclaimed)
- Former Tailings Impoundment Footprint (Valley Restoration)
- Pit Outline
- Reclaimed Ore Area
- Reclaimed Waste Rock Dump
- Reclaimed Backfilled Pit (Tailings + Waste Rock with Low Infiltration Cover)
- Deep Groundwater Seepage

Topography

- Index (5m)
- Interm (1m)

Meters: 0 150 300 600

Data courtesy of AECOMM

Figure for illustrative purposes only

SCALE:	1:8,000
DATE:	OCT 22nd, 2010
PROJECTION:	NAD_1983_UTM_Zone_8N
PROJECT MANAGER:	J.S.

PROJECT:

Mount Nansen Options for Closure

TITLE:

Closure Option 4: Schematic of Source Loadings for Water Quality Model

PROJECT No:	FIGURE No:
J907-4	5.7-3

LORAX ENVIRONMENTAL

2289 Burrard St.
Vancouver, BC, V6J 3H9

Phone: (604) 688-7173
Website: www.lorax.ca

5.7.5.2 Key Assumptions

The following are the key assumptions relevant to the water balance and water quality model for Option 4:

- The mill area has been fully reclaimed and as such the water quality upstream of the mill area was assigned to represent the upstream or background water quality in Dome Creek (*i.e.*, the model predictions exclude mine-related loadings emanating from the mill area);
- The former TSF area is assumed to return to ambient water quality conditions in the long-term following Dome Creek restoration;
- For un-impacted catchment areas, a runoff coefficient of 0.8 was assumed for spring freshet (April and May) and a runoff coefficient of 0.6 for the remaining open water season months;
- No attenuation (*i.e.*, removal of dissolved metals from solution) is assumed to take place along either the shallow or deep groundwater flow paths from the pit and waste rock areas.
- To support the modeling, a synthetic historical precipitation record was generated for Mount Nansen based on climate data from Carmacks and Mount Nansen between 2000 to 2006 (Appendix D and Appendix F);
- Based on the synthetic precipitation record, dry, wet and average annual precipitation conditions were selected for modeling;
- Annual lake evaporation was estimated based on data from the Pelly Ranch Environment Canada Meteorological gauging station: 369 mm/year (Appendix D and Appendix F);
- For Dome Creek, zero flow was assumed during the winter months (November through March) as attempts to measure winter flow indicates frozen conditions through to the substrate; and
- For Victoria Creek, site monitoring indicates the presence of winter flow. For the model, monthly flow in Victoria Creek was estimated based on the monthly flow distribution in the Nordenskiold River.
- Tailings are relocated to the pit and the tailings area is reclaimed. The restored tailings area of Dome Creek valley does not provide any contaminant loadings to the receiving environment.

- Sulfide oxidation will occur within the tailings and acidic conditions in tailings porewaters will develop over the long term. Given their similar geological origins and solid-phase chemistry, it is assumed that the acid rock drainage originating from Mt. Nansen tailings will be similar to that observed at the Arctic Gold and Silver site;
- Tailings are underlain by a waste rock drainage layer (44,000 m^3) and covered with 300,000 m^3 of waste rock and a vegetated low-infiltration divert-store-release cover.
- Golder (2010; Appendix C-4) carried out infiltration modeling of the proposed divert-store-release soil cover which indicated that fluxes through the bottom of the capillary break would be less than 1% of annual precipitation (Appendix F). This modeled infiltration rate is low compared to the typical infiltration rates for these types of covers which typically range from 2% to 15%. To account for these observations, a long-term infiltration rate of 15% of average annual precipitation was selected for modeling purposes.
- In addition to the actual footprint of the relocated tailings (24,800 m^2), the pit catchment also includes an additional covered area of 9,600 m^2. For modeling purposes, it was assumed that the water from this additional area eventually infiltrates through the tailings.
- A long-term infiltration rate through the tailings of ~0.05 L/s was assumed.
- In addition to the vertical flow, there is a component of horizontal flow through the waste rock underlying the tailings and is assumed to be the difference between the total pit discharge rate and the vertical infiltration rate through the tailings or 0.09 L/s.
- Groundwater discharge from the pit was conservatively estimated to be approximately 0.14 L and is calculated from first principles and site observations, including several years of pit lake elevation data (Appendix E). The estimated flux rate, while conservative, is sufficiently low such that water quality in Victoria Creek is relatively insensitive to seepage quality degradation from the pit (*e.g.,* from un-attenuated tailings seepage; Appendix F). Groundwater flux rates, while considered conservative, remain uncertain.
- The low-grade ore remains in place but is incorporated under the pit cover.
- For seepage from waste rock, a key assumption is that there is no net surface runoff. Snowmelt and onset precipitation either evaporates or infiltrates into the waste rock dumps.
- Monthly net-infiltration rates for the waste rock dumps were based on the results of a one-dimensional unsaturated flow model developed by Golder (Appendix F). The

monthly net-infiltration rates were applied uniformly to the entire waste rock surface area; and

- Depending on the specific configuration of the dumps, water that infiltrates into the dumps either reports to the receiving environment as variable shallow groundwater seepage or continuous deep groundwater seepage.

5.7.5.3 Performance and Uncertainty

<u>Performance</u>

Water quality predictions for each of the model runs were used to assess the performance of Option 4 through comparison to existing water quality in the downstream receiving environment in Victoria Creek; CCME Guidelines for the Protection of Aquatic Life are also included as a point of reference.

A summary of the Best Estimate water quality predictions (average year) for sulfate, arsenic, cadmium and zinc in Victoria Creek for Option 4 are presented in Table 5.7-3.

Table 5.7-3:
Summary of Predicted Concentrations (mg/L) in Victoria Creek for Option 4 - Best Estimate Source Terms and Average Precipitation Conditions

		Existing Water Quality[b]		**Predicted Water Quality**	
Parameter	*CCME Guideline*	*Median*	*Winter Maximum[c]*	*Median*	*Maximum*
Arsenic	0.005	0.0016	0.0075	0.0052	0.046
Cadmium	0.00034[a]	0.00003	0.0003	0.00008	0.00053
Zinc	0.03	0.009	0.02	0.014	0.082
Sulfate		30	61	29	40

Notes:
a. Draft CCME Guideline for Cadmium (Environment Canada 2008) at Hardness = 150 mg/L as $CaCO_3$.
b. Existing water quality data for Victoria Creek at Road (2007 to 2010).
c. Maximum winter concentration from the existing water quality data set for Victoria Creek (November to February, 2007 to 2010).

Key highlights (for Best Estimate/Average Flow Scenario) of the assessment for Option 3 are:

- Similar to all options, peak concentrations for all parameters occur during the winter, low-flow period due to the ongoing discharge of mine-related loadings during periods of minimal flow and available dilution. This disproportionate load is emphasized by discharges from the deep groundwater system (pit and waste rock) which are assumed to remain constant throughout the year.

- *Sulfate*
    - In general, the predicted concentrations of sulfate (median = 29 mg/L, maximum = 40 mg/L) are lower than those for Options 1 and 2 but comparable to Option 3 (median = 31 mg/L, maximum = 43 mg/L). The lower sulfate concentrations predicted for Option 4 reflect the removal of seepage from the tailings area.
- *Arsenic*
    - Predicted concentrations of arsenic for Option 4 (median = 0.0052 mg/L, maximum = 0.046 mg/L) are higher than those for Option 1 and 2 (median = ~0.002 mg/L, maximum = 0.0055 mg/L) but similar to Option 3.
    - The predicted loading from tailings stored in the pit is the dominant source of arsenic to the receiving environment, and assumes no attenuation along the groundwater flow path.
- *Cadmium*
    - The predicted cadmium concentrations for Option 4 (median = 0.00008 mg/L, maximum = 0.00053 mg/L) are similar to those predicted for the other options and well below the draft CCME guideline.
    - The predicted loading from the tailings stored in the pit is the dominant source of cadmium to the receiving environment.
- *Zinc*
    - The predicted zinc concentrations for Option 4 (median = 0.014 mg/L, maximum = 0.082 mg/L) are similar than those predicted for the other options and generally below the CCME guideline, except during winter, low-flow conditions.
    - Similar to cadmium, the predicted loading from the tailings in the pit is the dominant source of zinc to the receiving environment.

Overall, the Best Estimate Average Precipitation model results for Option 4 are comparable to Option 1A with respect to cadmium and zinc. For sulfate, the removal of the tailings from the Dome Creek valley results in a reduction in concentrations compared to current conditions owing to removal of the seepage loading from the current impoundment. For arsenic, the predicted concentrations for Option 4 are similar to Option 3, and are significantly higher than those predicted for Option 1, Option 2, and current conditions. The higher arsenic predictions for Options 3 and 4 can be linked to a higher tailings source term and the assumption of zero attenuation along groundwater flow paths. The results for Option 4 also demonstrate that despite the assumption that acidic conditions develop within in-pit tailings, such conditions do not have a marked effect on increasing the loading to Victoria Creek when compared to Option 3. This can be related to the low water flux through the tailings (*e.g.,* tailings / waste rock cover) which offsets the higher source term concentrations in the loading calculations.

<u>Uncertainty</u>

The uncertainties associated with the modeling results for Option 4 are as follows:

- Low-infiltration cover modeling indicates that fluxes through the bottom of the capillary break would be less than 1% of the total annual precipitation. This modeled infiltration rate is low compared to the typical infiltration rates for these types of covers which typically range from 2% to 15% (Appendix F). For the loading model, an infiltration rate of 15% of average annual precipitation was conservatively assumed to account for cover degradation and the anticipated decrease in performance in the long-term. This uncertainty relates to a range in possible infiltration rates. Implications of a lower infiltration would be a reduction in the loading of constituents from the tailings mass to Victoria Creek.
- The uncertainty with regards to potential for the attenuation of arsenic and other parameters along the groundwater flow path has relevance to Option 4.

5.7.6 Costs

The estimated capital cost for implementing Option 4 is summarized in Table 5.7-4. The estimated cost includes a 30 percent contingency but does not include costs for design engineering, routine inspections and operations or maintenance as these are expected to be similar for all options considered and therefore do not materially affect the cost comparison. The estimate is considered to be Class D estimate (or ASTM E2516-06 Class 5), with an accuracy of -25 to +40 percent.

The capital cost estimates do not include *Common Closure Element* costs which are described in Section 5.2 and Appendix C-2. For Option 4, the estimated capital cost is approximately $17.86 M. More details related to cost assumptions and breakdown of individual components are found in Appendix C-1 and C-2.

Table 5.7-4:
Summary of Estimate Capital Costs for Option 4

Work Item Description		Units	Quantity	Unit Cost	Total Cost
Mobilization and Demobilization		L.S.	1	$ 400,000	**$ 400,000**
Transport and Place Tailings		m^3	300,000	$ 15	**$ 4,500,000**
Restore Tailings Management Area (TMA)					
Relocate dam fill to borrow sources		m^3	80,000	$ 5	$ 400,000
Relocate dam fill to pit		m^3	80,000	$ 12	$ 960,000
Restoration of Dome Creek valley					$ 1,670,000
Sub Total					**$ 3,030,000**
Waste Rock Placement (bottom and top)		m^3	344,000	$ 5	**$ 1,720,000**
Low Infiltration Soil Cover		m^3	43,000	$ 33	**$ 1,419,000**
Regrade and repair cover		m^3	43,000	$ 5	**$ 215,000**
Regrade and revegetate Waste Rock Storage area					**$ 123,000**
Plug Pony Creek Adit		L.S.	1	$ 250,000	**$ 250,000**
Revegetate pit fill, pit safety (signage and berm)		L.S.	1	$ 46,000	**$ 46,000**
Monitoring Insrumentation		L.S.	1	$ 200,000	**$ 200,000**
Water Treatment - Capital		L.S.	1	$ 1,650,000	**$ 1,650,000**
Water Treatment - Maintenance		per year	5	$ 35,000	**$ 175,000**
Sub Total					**$ 13,728,000**
30% Contingency					**$ 4,118,400**
TOTAL ESTIMATED COST - OPTION 4					**$ 17,846,400**

6. Summary of Closure Options Evaluation

6. Summary of Closure Options Evaluation

This chapter provides a summary comparison of the key aspects of the closure options presented for Mt. Nansen. An overview of the geotechnical and cost considerations is presented in Section 6.1. Geochemical and water quality aspects of the closure options are summarized and compared in Section 6.2. A summary of the most salient components of each closure option described is presented in Table 6.1-1.

6.1 Geotechnical and Water Management Considerations

Geotechnical and water management considerations for each closure option are summarized in Table 6.1-1. Options 1 and 2 require a combination of dam buttressing and ground improvement techniques in order to improve the factors of safety for the dam, primarily for the post-earthquake conditions owing to the presence of liquefiable soils in thawed ground beneath the dam. The ground improvement techniques will involve some form of a shear key. A fundamental requirement of the shear key is that it be keyed into frozen soil and that the permafrost is protected against thawing to guard against the slip surface running below the bottom of the key. Because the shear key must be keyed into frozen ground, protection against thawing of the permafrost is a critical component of the shear key design and some form of long-term maintenance of the permafrost is required. The ability for thermosyphons to maintain the frozen ground in perpetuity, under potentially changing (*e.g.* warming) climatic conditions, is the primary uncertainty and residual risk related to Options 1 and 2.

The water balance modeling for Options 1 and 2 indicate little residual risk with respect potential acid generation occurring in the tailings resulting from the formation of unsaturated conditions in the tailings mass.

Under Options 3 and 4, the complete removal of the tailings dam and relocation of the tailings to the pit obviates the geotechnical concerns related to long-term stability of the existing tailings dam. A much smaller in-pit “dam” would be required in Option 3 to safely contain the relocated tailings. While this dam would fall under CDA guidelines and require regular inspection, foundation instabilities are not a concern under this option with dam foundations keyed into bedrock. Option 4 likely does not require an in-pit dam to contain the relocated tailings and waste rock and hence concerns related to dam stability are not applicable.

Table 6.1-1:
Summary Comparison of Key Components of Mt. Nansen Closure Options

Description	Option 1A	Option 2A	Option B (for Options 1 and 2)	Option 3	Option 4
	Dam upgrade with water cover; waste rock and pit in place	Dam upgrade with saturated soil cover; waste rock and pit in place	Same for 1B and 2B; pit backfill with waste rock	Tailings backfill in pit with high infiltration cover. Waste rock in place	Waste rock and tailings backfill in pit with low infiltration cover.
Closure Components					
Surface Water Diversions	Upgrade diversion into and out of TMF	Upgrade diversion into and out of TMF	*Not Applicable*	Construct diversion from Pony Creek to pit TMF and spillway back to Pony Creek (as contingency)	*Not Applicable*
Dams	Upgrade spillway and stabilize dam	Upgrade spillway and stabilize dam	*Not Applicable*	Construct TMF dam at south end of pit	*Not Applicable*
Tailings	Water cover with diffusion barrier	Saturated soil cover	*Not Applicable*	Relocate to pit bottom High infiltration cover	Relocate to pit above water table Low infiltration cover
Waste Rock	Regraded and revegetated	Regraded and revegetated	Relocate waste rock to pit	Regraded and revegetated	Relocated to pit bottom and above tailings Low infiltration cover
Open Pit	Protective berm*	Protective berm*	Backfilled with waste rock	Backfilled with tailings	Backfilled with tailings and waste rock
Monthly Water Quality Predictions at Victoria Creek**					
Sulfate (mg/L) - median (max)	36 (106)	36 (106)	35 (98)	31 (43)	29 (40)
Arsenic (mg/L) - median (max)	0.0020 (0.0055)	0.0019 (0.0055)	0.0021 (0.0059)	0.005 (0.043)	0.0052 (0.046)
Cadmium (mg/L) - median (max)	0.00012 (0.00051)	0.00012 (0.00051)	0.00006 (0.00028)	0.00009 (0.00038)	0.00008 (0.00053)
Zinc (mg/L) - median (max)	0.018 (0.062)	0.018 (0.062)	0.010 (0.035)	0.017 (0.059)	0.014 (0.082)
Estimate Closure Costs (Class D -25 to +40%)					
Capital Cost Estimate	$ 8,900,000.00	$ 10,200,000	$12,500,000 to $13,900,000	$ 16,300,000	$ 17,600,000
Common Element Cost Estimate (-25 to +75%)	$ 3,600,000.00	$ 3,600,000.00	$ 3,600,000.00	$ 3,600,000.00	$ 3,600,000.00
Total Capital Cost Estimate	***$ 12,500,000***	***$ 13,800,000***	***$16,100,000 to $17,500,000***	***$ 19,900,000***	***$ 21,200,000***
Annual Operations and Maintenance Cost Estimate	$ 285,000	$ 285,000	See Option 1A or 2A	$ 160,000	$ 125,000
Uncertainty and Residual Risk					
Dam Stability	Low to moderate with respect to maintaining frozen ground within shear key	Low to moderate with respect to maintaining frozen ground within shear key	Low to moderate with respect to maintaining frozen ground within shear key	Waste rock "Dam" will be subject to CDA requirements. Low uncertainty and risk related to long-term stability of dam and containment	Not Applicable
Tailings Water Balance and Cover Performance	Low uncertainty with regards to maintaining tailings saturation over long term.			High uncertainty with respect to achieving desired level of tailings saturation. Associated risk of localized acid generation in coarser blended materials	Moderate uncertainty with regards to water flux through low-infiltration cover. Consolidation, rooting, heaving revegetation could diminish integrity of impermeable cover over time.
Tailings Seepage Quantity	Low uncertainty given extensive historic data record for tailings seepage flows.			Moderate uncertainty related to long-term discharge rate from tailings-filled pit.	Moderate uncertainty related to long-term discharge rate from tailings-filled pit.
Waste Rock Seepage Quantity	Moderate uncertainty related to estimated volume of seepage from waste rock.		Moderate uncertainty related to long-term discharge rate from backfilled pit.	Moderate uncertainty related to estimated volume of seepage from waste rock.	Moderate uncertainty related to estimated volume of seepage from waste rock.
Pit Seepage Quantity	Rrelatively low uncertainty as this option is a continuation of status quo conditions. Water flux from pit based on conservatively high estimate of hydraulic conductivity.			Moderate uncertainty related to long-term discharge rate from tailings-filled pit.	Moderate uncertainty related to long-term discharge rate from tailings-filled pit.
Tailings Seepage Quality	Low uncertainty given extensive historic data record for tailings seepage water quality.		Low uncertainty given large historic data set.	Moderate uncertainty related to potential for localized acid generation, leaching rates, and attenuation mechanisms along groundwater flow paths.	High uncertainty for source terms related to a lack of acidic drainage data. Moderate uncertainty related to potential for attenuation along groundwater flow paths.
Waste Rock Seepage Quality			Moderate uncertainty (backfilled waste rock) due to a lack of data pertaining to saturated waste rock seepage	Relatively low uncertainty given the large historic dataset from which the source terms were derived.	Moderate uncertainty (backfilled waste rock) due to a lack of data pertaining to saturated waste rock seepage
Pit Lake Seepage Quality			*Not Applicable*	*Not Applicable*	*Not Applicable*
Potential for Long-term Water Treatment	Low - Good containment; opportunities for passive technologies	Low - Good containment; opportunities for passive technologies	Low - Good containment; opportunities for passive technologies	Moderate - Poor containment; may require active treatment and control	Moderate - Poor containment; may require active treatment and control

Notes:
*Protective berm or similar is required for physical safety (pit walls are considered stable).
**Long-term predictions. Modeled scenario includes "Best Estimate" source terms and average flow conditions.

Option 3 carries a significant degree of uncertainty with respect to water management and specifically, the maintenance of tension saturated tailings in perpetuity within the pit. Modeling of the hydraulic characteristics of the relocated tailings highlighted the importance of achieving a well blended tailings mixture within the pit in order to ensure that tailings remain saturated; the ability to achieve a homogenous blend during the remediation process is a high uncertainty. Accordingly there remains a residual risk for Option 3 that portions of the tailings becoming acid generating in the pit.

Water management in Option 4 relies on an effective low infiltration cover to limit water flux into the relocated tailings and the potential for transport of contaminants out of the tailings. The low infiltration cover proposed for Option 4 is dependent upon both store and release properties of the soil cover as well as the ability to effectively shed water off of the cover following precipitation and snowmelt periods. As such, success of the cover is linked to grade control and cover integrity. The relocation of tailings to the pit will invariably result in post-deposition, differential settlement of the tailings that could affect cover performance. The formation of depressions and the potential for ponded water on the cover could greatly increase infiltration rates beyond those assumed in water quality modeling. Moreover, the harsh climatic conditions are a significant challenge to store and release cover systems that rely upon well established vegetative covers to facilitate evapotranspiration during the ice-free period. Collectively, there is a moderate uncertainty with respect to cover performance for Option 4 and the ability to limit water fluxes through the cover and into the tailings.

6.2 Geochemistry and Water Quality

Water quality predictions for the various closure options are summarized in Table 6.1-1 with respect to the major parameters of concern (sulfate, arsenic, cadmium and zinc). In order to provide a basis for comparison, median and maximum predicted values for Victoria Creek are compared for the model scenario that incorporates average flow conditions and best-estimate, source term concentrations. Detailed discussion of the water quality predictions is provided in Appendix F.

Inspection of the water quality predictions illustrates that the options can be pooled into three major groupings based on similarities in the model output:

- Options 1A and 2A: These options show nearly identical water quality predictions, which reflect the common model inputs with respect to water balance, source term concentrations and attenuation mechanisms. Model results for Option 1A and 2A are comparable to existing water quality conditions in Victoria Creek and thus the can be used as a defensible analogue to existing conditions;

- Options 1B and 2B: Options 1B and 2B show identical water quality predictions. Such observations relate to the common model inputs associated with the tailings area water balance and source terms, as well as the shared water balance and source term inputs associated with back-filled waste rock;
- Options 3 and 4: Option 3 (high infiltration cover) and Option 4 (low infiltration cover) show very similar water quality predictions despite contrasting water balances and chemical environments of deposition. Specifically, despite the assumption that acidic conditions develop within the tailings as part of Option 4, such conditions do not have a marked effect on increasing contaminant loadings when compared to Option 3. This can be related to the effect of the low infiltration cover in reducing the water flux through the tailings, which offsets the higher source term concentrations in the loading calculations.

Among these option groupings, performance is dependent on the parameter of interest. For sulfate, median concentrations are similar between all options. Options 1A/B and 2A/B show comparable maximum sulfate predictions for Victoria Creek (maximum concentrations of 106 to 98 mg/L). In contrast, maximum sulfate predictions for Options 3 and 4 (maximum concentrations of 43 to 40 mg/L) are slightly more favourable. The lower predicted sulfate concentrations in Victoria Creek as part of Options 3 and 4 largely relate to a decrease in the water flux (and hence loading) associated with in-pit tailings placement in comparison to the higher seepage flux from the tailings facility.

Arsenic shows contrasting trends to sulfate, which relates to its mode of remobilization from the tailings (suboxic environments) and attenuation. For Options 1A/B and 2A/B, arsenic concentrations are low and consistent between options (median concentrations of ~0.002 mg/L; maximum concentrations of ~0.006 mg/L). By comparison, Options 3 and 4 show marked increases in predicted concentrations in Victoria Creek (median concentrations of ~0.005 mg/L; maximum concentrations of ~0.04 mg/L). The increase in arsenic loadings associated with in-pit tailings placement primarily reflects the higher arsenic source term concentration for the backfilled tailings coupled with the assumption that no attenuation of arsenic will occur along the groundwater flow paths from the pit to the receiving environment. This represents a highly conservative assumption, since some degree of arsenic attenuation can be expected in the subsurface environment through adsorption and/or precipitation mechanisms. In this manner, the water quality predictions for arsenic for Options 3 and 4 are considered to be conservative (high estimates).

For cadmium and zinc, the predicted water quality for Options 1B and 2B indicate a moderate improvement compared to Option 1A/2A (current conditions). The predicted reductions in cadmium and zinc concentrations associated with Option 1B/2B are primarily a result of waste rock footprint reduction after backfilling the open pit. Cadmium and zinc predictions associated with Options 3 and 4 show values similar in magnitude to those for Options 1A/2A, illustrating no significant change in performance with respect to existing conditions.

In order to best assess the merits of each option, the water quality predictions must be viewed with an understanding of the model uncertainties and assumptions. In overview, for those options that maintain the tailings in their current configuration (Options 1 and 2) there is a greater degree of confidence in the water quality predictions in comparison to those options involving tailings relocation to the pit (Options 3 and 4). Such conclusions relate to our understanding of the existing tailings facility. Specifically, the extensive flow and water quality records for seepage waters emanating from the current tailings facility provide a defensible proxy for future conditions. In particular, the attenuation mechanisms responsible for the removal of trace elements along sub-surface flow paths can be expected to persist in the long-term (multiple decades). In essence, the model results for Option 1A/2A are comparable to existing water quality conditions in Victoria Creek and thus can be used as a defensible analogue to the existing scenario. The model does predict somewhat higher winter values in comparison to the status quo. This is related in part to the assumption of a constant tailings seepage rate (throughout the year) in the model.

In contrast to Options 1 and 2, more uncertainty is associated with both the flow and chemical signatures for in-pit tailings placement options (Options 3 and 4). In particular, there is considerable uncertainty with regards to potential for attenuation along groundwater flow paths for seepage originating from in-pit tailings. In this regard, the assumption of zero attenuation imparts a considerable degree of conservatism into the model output for Options 3 and 4.

Key assumptions and uncertainties apply to the water balances for all options, which have direct implications to water quality predictions. For Options 1 and 2, a key assumption is that the tailings can be maintained in a saturated state to prevent the development of acidic conditions, thereby minimizing the potential for metal leaching. Based on sensitivity modeling of the water balance, there is a considerable degree of confidence that saturated conditions can be maintained. In contrast, a lower degree of confidence is associated with the water balances for Options 3 and 4. A critical uncertainty associated with Option 3 is the feasibility of attaining a desired level (85%) of tailings saturation. In particular, there is a high level of uncertainty with regards to the feasibility of blending the coarse and fine tailings sufficiently to achieve a desired bulk hydraulic conductivity. In reality, some degree of incomplete mixing will occur, resulting in spatial heterogeneity in the water holding properties of the tailings. In this instance, the uncertainty regarding the final *in situ* hydraulic conductivity of the mixed tailings translates to potentially unfavourable consequences. Specifically, poor blending increases the potential for localized zones of acid generation in the tailings and increased loadings from the pit.

For the water balance for Option 4, there is uncertainty regarding the water flux through the low-infiltration cover and into the tailings. To account for this uncertainty, a conservative infiltration rate of 15% of average annual precipitation was assumed. Implications of a lower infiltration rate would be a reduction in loadings from the tailings-filled pit. Accordingly, the loading from the backfilled tailings as part of Option 4 is considered to be conservative (high).

6.3 Summary

Closure options have been developed for the Mt. Nansen Mine to a pre-feasibility or conceptual level of design. Closure plan designs have taken into consideration geotechnical engineering, geochemistry, local climate, hydrology, and hydrogeology. A refinement of closure options has been provided based on these site-specific factors. An evaluation of each short-listed closure options has been conducted including geotechnical stability and long-term performance of water balance and surface water quality. Comparisons have been made between the closure option designs, but the options have not been formally ranked. An effort has been made to provide reviewers with an unbiased, integrated, comparative assessment upon which to select a preferred closure and reclamation design for the Mt. Nansen Mine.

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