SISSON MINES LTD.
SISSON PROJECT

ASSESSMENT OF TAILINGS MANAGEMENT ALTERNATIVES

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EXECUTIVE SUMMARY

An assessment of tailings management alternatives for the Sisson Project was undertaken in conformance with the guidance provided by Environment Canada (Environment Canada 2013) to provide information in support of amending Schedule 2 of the *Metal Mining Effluent Regulations*.

The pre-screening evaluation of tailings management technologies revealed that the preferred alternative is conventional slurry disposal.

A pre-screening evaluation of TSF locations was completed which revealed that the site alternatives 1b and 1c should be subject to the multiple accounts assessment (MAA).

The base case evaluation in the MAA clearly indicated that Site 1b is the preferred TSF location.

A sensitivity analysis was completed to determine what effect modifying the relative importance (weight) of the environmental, socio-economic, technical, and economic accounts would have on the overall merit scores. These alternate account weighting cases considered equal weighting of accounts and sub-accounts, and then represented a progression of increasing relative importance in the environmental and socio-economic accounts with decreasing relative importance in the technical and economic accounts. Under all alternate account weighting cases, the MAA continued to clearly indicate that Site 1b is the preferred TSF location.

Another sensitivity analysis varied the indicator score for the two indicators that had been scored based on proxy information – Traditional Use by Aboriginal Persons and Archaeological Potential. Under the two scenarios that were analyzed, the value of both indicators was lowered progressively for Site 1b, making it less desirable for these two assessment factors. Analysis of both indicator scoring sensitivity scenarios utilizing the Base Case Weighting and Weighting Sensitivity Case #5 (70-30-0-0) indicated a continuing preference for Site 1b.

The assessment of tailings management alternatives for the Sisson Project, completed in conformance with the Environment Canada guidance (Environment Canada 2013), resulted in the preferred tailings management alternative being conventional slurry disposal at the Site 1b TSF location.

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1 – INTRODUCTION

The Sisson Project (the “Project”) will be an open pit tungsten-molybdenum mine with associated ore processing facilities. The Project site is situated entirely on provincial Crown land at approximately N 46º 22’ by W 67º 03’ in east-central New Brunswick. The site is approximately 60 km directly northwest of the city of Fredericton, and approximately 10 km southwest of the community of Napadogan (Figure 1.1). An aerial view looking west over the area of the Sisson deposit is shown on Figure 1.2.

After submission of the Sisson Project EIA Report to governments in July 2013, Northcliff Resources Ltd. and Todd Minerals Ltd. entered into a limited partnership agreement to advance the development of the Sisson Project. As a result of this agreement, the Sisson Project is now being developed and advanced by Sisson Mines Ltd., on behalf, and as general partner, of the Sisson Project Limited Partnership. Thus, the project proponent is now Sisson Mines Ltd. (SML), and all earlier activities by Northcliff Resources Ltd. are represented herein as activities of Sisson Mines Ltd.

The Project will involve the development and use of a tailings storage facility (TSF) that is expected to cover some brooks that are productive fish habitat. Thus, if there is a need to deposit tailings or waste rock into “waters frequented by fish”, the Project will require an amendment to Schedule 2 of the federal *Metal Mining Effluent Regulations* (MMER) under the *Fisheries Act* before it is allowed to proceed. Such an amendment requires a thorough analysis of alternate tailings management technologies, TSF embankment designs, and TSF site locations according to the *Guidelines for the Assessment of Alternatives for Mine Waste Disposal* provided by Environment Canada (2013).

This report documents the assessment of tailings management alternatives for the Sisson Project undertaken according to these Guidelines in order to provide the information needed to support the MMER Schedule 2 amendment process. As such, this report is an elaboration and further refinement of the tailings management alternatives analysis presented in Section 3.3 of the EIA Report (Stantec 2013). The report describes how the various management alternatives were pre-screened for inclusion in the Multiple Accounts Analysis (MAA) required by Environment Canada, and the MAA itself which ranked the two final alternatives according to their relative merits based on defined environmental, socio-economic, technical and economic factors. It also describes the sensitivity analyses undertaken to test the MAA results and ultimately which tailings management alternative is preferred for the Sisson Project.

The tailings management alternatives analysis as presented in Section 3.3 of the EIA Report (Stantec 2013) was discussed by the SML-sponsored Sustainability Working Group (SWG) on November 20, 2012 and Aquatics Working Group (AWG) on December 6, 2012. The SWG was formed in May 2012 and is comprised of representatives of communities around the Project site and stakeholder groups (e.g., NB Trappers & Fur Harvesters Federation). The AWG was formed in December 2011 and consists of representatives of stakeholder groups with interests in the aquatic environment (e.g., Nashwaak Watershed Association, Canadian Rivers Institute, Atlantic Salmon Federation, NB Salmon Council). Neither group had substantive issues with that analysis or its results, though the SWG did recommend the inclusion of greenhouse gas emissions as an evaluation factor; that recommendation was adopted.

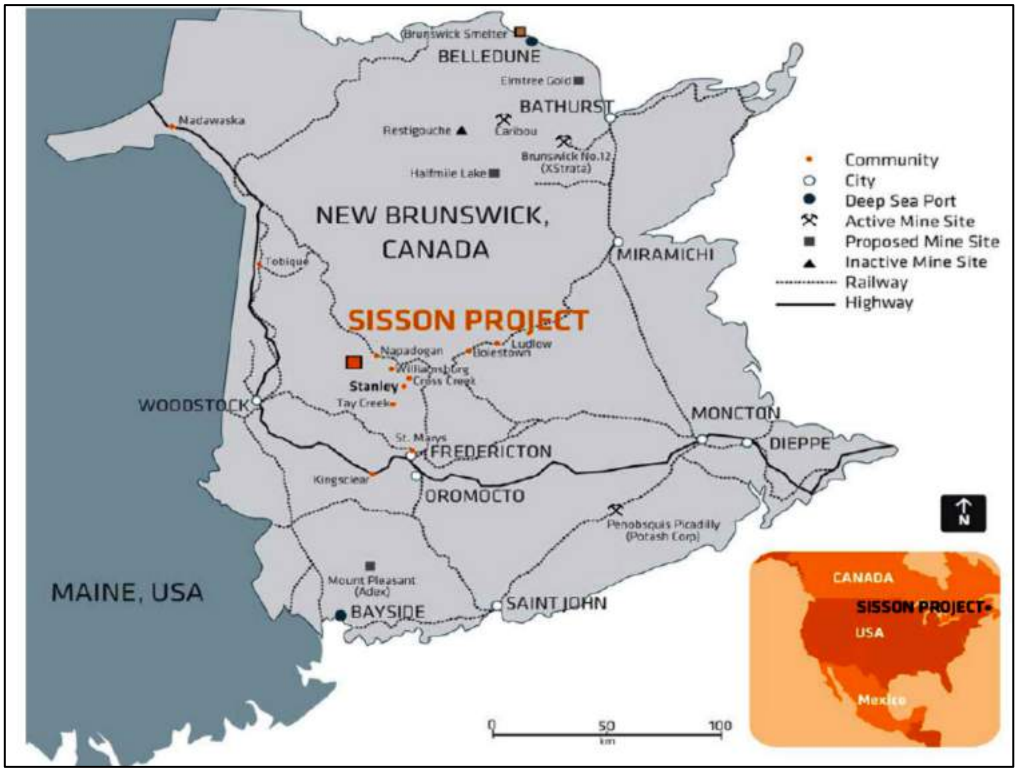

Figure 1.1 Sisson Project Location Map

Source: SML

Figure 1.2 Aerial View of Project Site, Looking West Over the Sisson Ore Body

SML had planned to have that alternatives analysis discussed at a First Nations Environmental Assessment Working Group (FNEAWG) meeting in December 2013. The FNEAWG was established by SML in April 2012 as a means of enabling direct, regular, ongoing communications among the Crown, First Nations and SML related to the Project and the EIA process, with a specific objective of facilitating Project understanding and assisting the Crown in fulfilling its duty to consult with First Nations; however, at the request of First Nations involved in the Sisson Project review, that and subsequent FNEAWG meetings were suspended pending First Nations review of SML responses to their information requests concerning the EIA Report. It should be noted that none of the comments or information requests received from First Nations about the EIA Report concerned the assessment of tailings management alternatives included in Section 3.3 of that report.

As much as possible, this report on the assessment of tailings management alternatives is written to accommodate non-technical readers; however, it does presume some familiarity with the mining industry and mining terminology.

2 – DESCRIPTION OF THE PROJECT

2.1 OVERVIEW

The following is a high-level overview of the Project. The reader is referred to Chapter 3 of the Sisson Project EIA Report (Stantec 2013) for further detail on the various components, phases, and activities planned as part of the Project.

The proposed Sisson Project is a conventional, open pit tungsten and molybdenum mine located near the community of Napadogan, New Brunswick (Figure 1.1). The mine will operate for an estimated 27 years at a nominal mining rate of 30,000 dry metric tonnes per day (t/d) of tungsten- and molybdenum-containing ore, processed in an ore processing plant to produce tungsten and molybdenum mineral products. The main activities associated with the Project include:

- Mining by conventional open pit methods.
- Stockpiling of organics and overburden for future reclamation use.
- On-site processing of ore in an ore processing plant to produce mineral concentrates and tailings, and further processing of tungsten concentrate to a higher-value crystalline tungsten product (ammonium paratungstate, or APT) and solid precipitate waste products.
- Development and operation of a tailings storage facility (TSF), and associated storage of tailings and waste rock.
- Diversion of clean surface water away from Project facilities (*e.g.,* open pit, TSF, etc.).
- Collection and storage in the TSF of all precipitation on the Project site and groundwater flows into the open pit (termed “mine contact water”) for re-use in the ore processing plant, and discharge of surplus water, with treatment as needed to meet permit conditions to be established by the Province of New Brunswick. These conditions are expected to include both discharge and in-stream water quality objectives; the discharge objectives are expected to meet or be lower than the effluent quality limits specified in the MMER.
- Transportation of the mineral products to off-site buyers.
- Decommissioning of facilities, and reclamation and closure of the site at the end of the Project life.

Project construction is expected to take about two years and provide up to 500 direct jobs at the peak of construction activities. Project operation will directly employ about 300 staff.

The concentrator will produce both non-potentially acid generating (NPAG) tailings (about 95% of the total) and potentially acid generating (PAG) tailings (the remaining 5%). The PAG tailings will be deposited subaqueously in the TSF and be encapsulated by NPAG tailings and water thus effectively mitigating the potential for acid generation. Approximately 282 Mt of tailings will be produced over the life of the Project.

During the course of the feasibility studies, it was determined that, as a practical mining matter, it is unlikely that NPAG and PAG waste rock can be separately mined; therefore, the conservative decision was made to store all waste rock subaqueously in the TSF (and in the open pit during the last phase of mining to be flooded during closure). This is best international mining industry practice, and is a widely recognized, conservative approach to minimizing the environmental risks of waste rock disposal. Not following industry best practice could be considered by some to be a “fatal flaw” in the Project design for this site. Approximately 287 Mt of waste rock (barren rock plus mid-grade ore) will be produced over the life of the Project, of which 209 Mt will be stored in the TSF. The storage plan is such that waste rock within the TSF will become submerged within two years of being deposited; the mid-grade ore stockpile will be flooded by the end of operations.

The only other available waste rock management option is surface storage, which would take up more land area and increase loss of wildlife habitat, involve ML/ARD and water quality management systems that would be more demanding technically and economically, and require more challenging and costly closure and reclamation work. Its disadvantages would not be substantially reduced if the rock were backfilled into the open pit at closure, because the storage site would have to be reclaimed, and the cost of handling the rock a second time would be considerable. Thus, the surface storage option has evident environmental, socio-economic, technical and economic disadvantages to the proposed subaqueous storage in the TSF, and a detailed pre-screening analysis of waste rock storage alternatives was not included in this alternatives assessment.

The decision was also made to construct the TSF embankments from NPAG quarried rock using the centre-line construction method. The design of the quarry at the northwest corner of the TSF is such that the initial phases of the quarry will be flooded within the TSF. At closure, a channel will be cut between the final “sink cut” of the quarry and the TSF, ensuring all subsequent drainage from the quarry flows into the TSF.

The layout of Project facilities, including the locations of the waste rock within the TSF and the quarry, at different stages of the mine life are shown on Figure 2.1 through Figure 2.6. These figures represent pre-production (Year -1) and production years 1, 5, 10, 20, and 27, where Year 27 represents the ultimate life-of-mine layout.

The solid waste products from the APT plant will be stored in dedicated lined cells within the TSF footprint which, following capping of the cells, will become encapsulated with tailings and submerged beneath the supernatant water during operations. These solid wastes will total approximately 680 kt over the life of the Project. A description of the wastes and storage plan is provided in Appendix A.

At closure, an engineered channel will be established through the hill on which the plant site is located so that excess water from the TSF (and quarry) will drain into the open pit. The pit will be allowed to fill (in about 12 years) to an elevation that ensures it is a groundwater sink; the elevation of the pit lake will be maintained by pumping the water for discharge, with treatment as required to meet provincial permit conditions. When the pit lake water quality is such that it can be directly discharged without treatment, pumping will cease and the lake elevation will be allowed to rise to discharge naturally through an engineered channel to the residual lower reach of Sisson Brook. For reclamation, wetland and other vegetation species will be established around a residual pond on the TSF surface to mimic habitat diversity in the Project area and to ensure that PAG materials in the TSF remain saturated to effectively minimize the potential for acid generation. The water management ponds around the TSF perimeter will continue to return water to the TSF until it is of sufficient quality that it can be allowed to discharge naturally to adjacent watercourses.

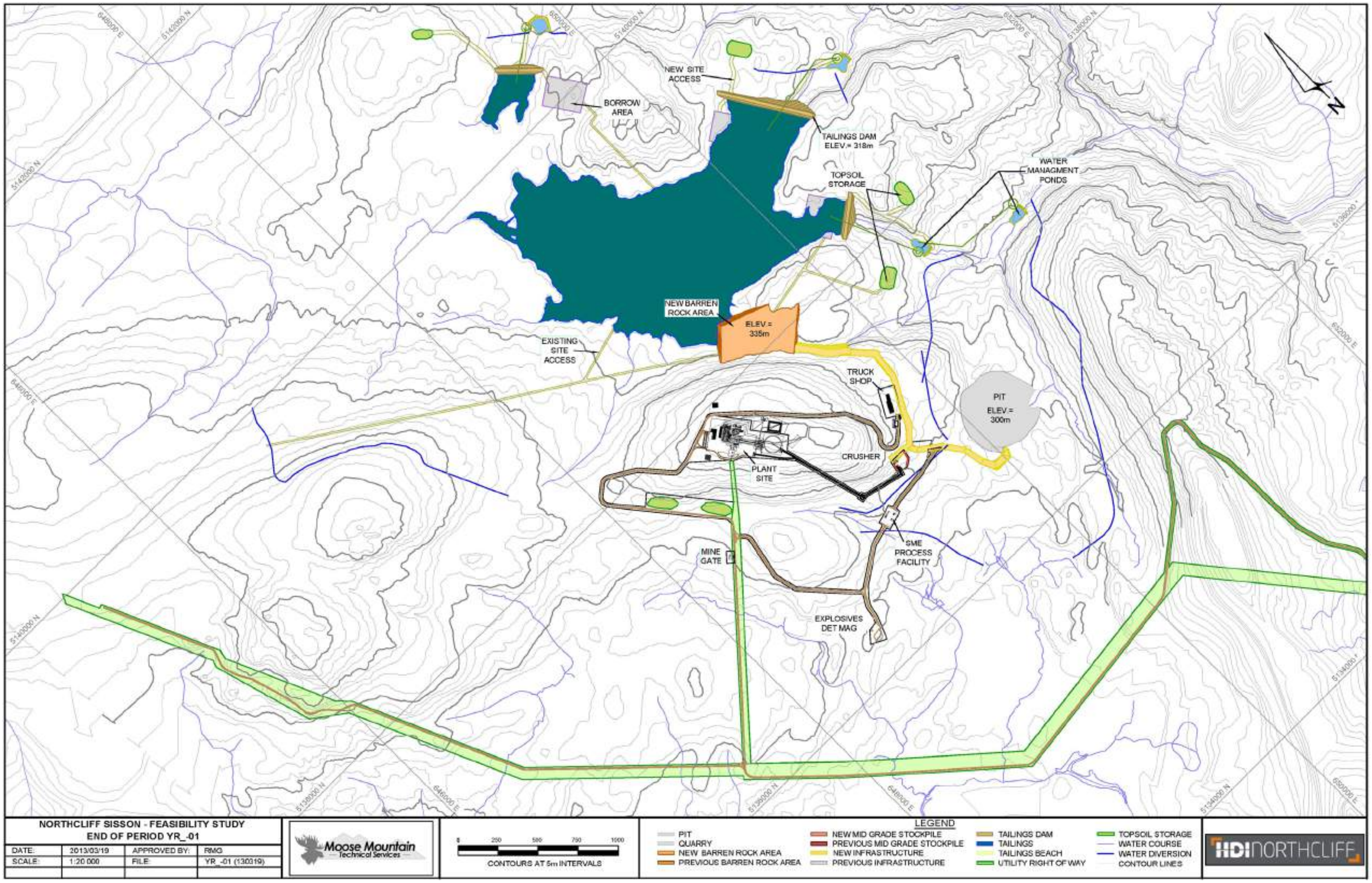

Figure 2.1 End of Period (EoP) Map, Pre-production Year -1 (Mill Start-up)

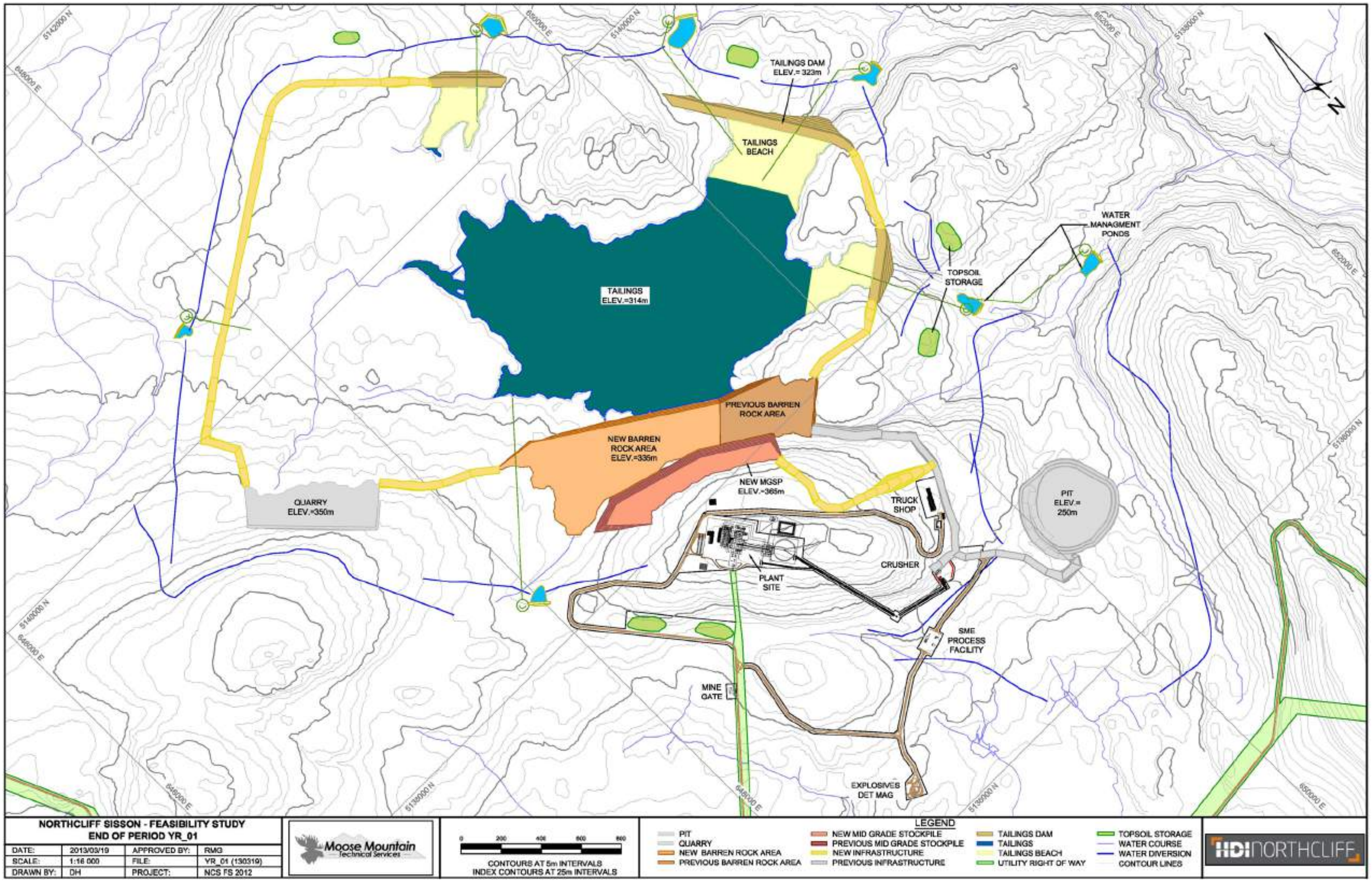

Figure 2.2 End of Period (EoP) Map, Production Year 1

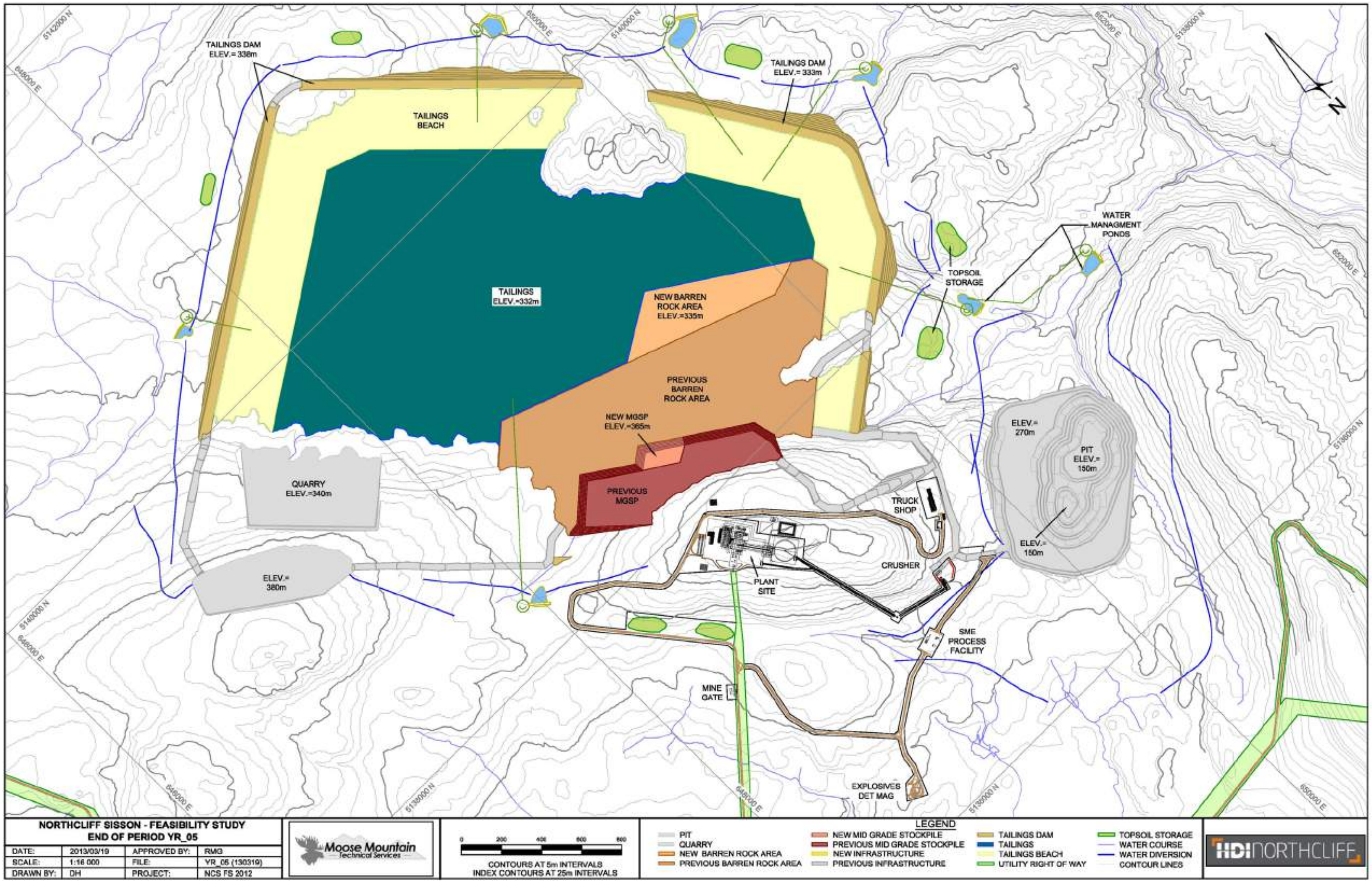

Figure 2.3 End of Period (EoP) Map, Production Year 5

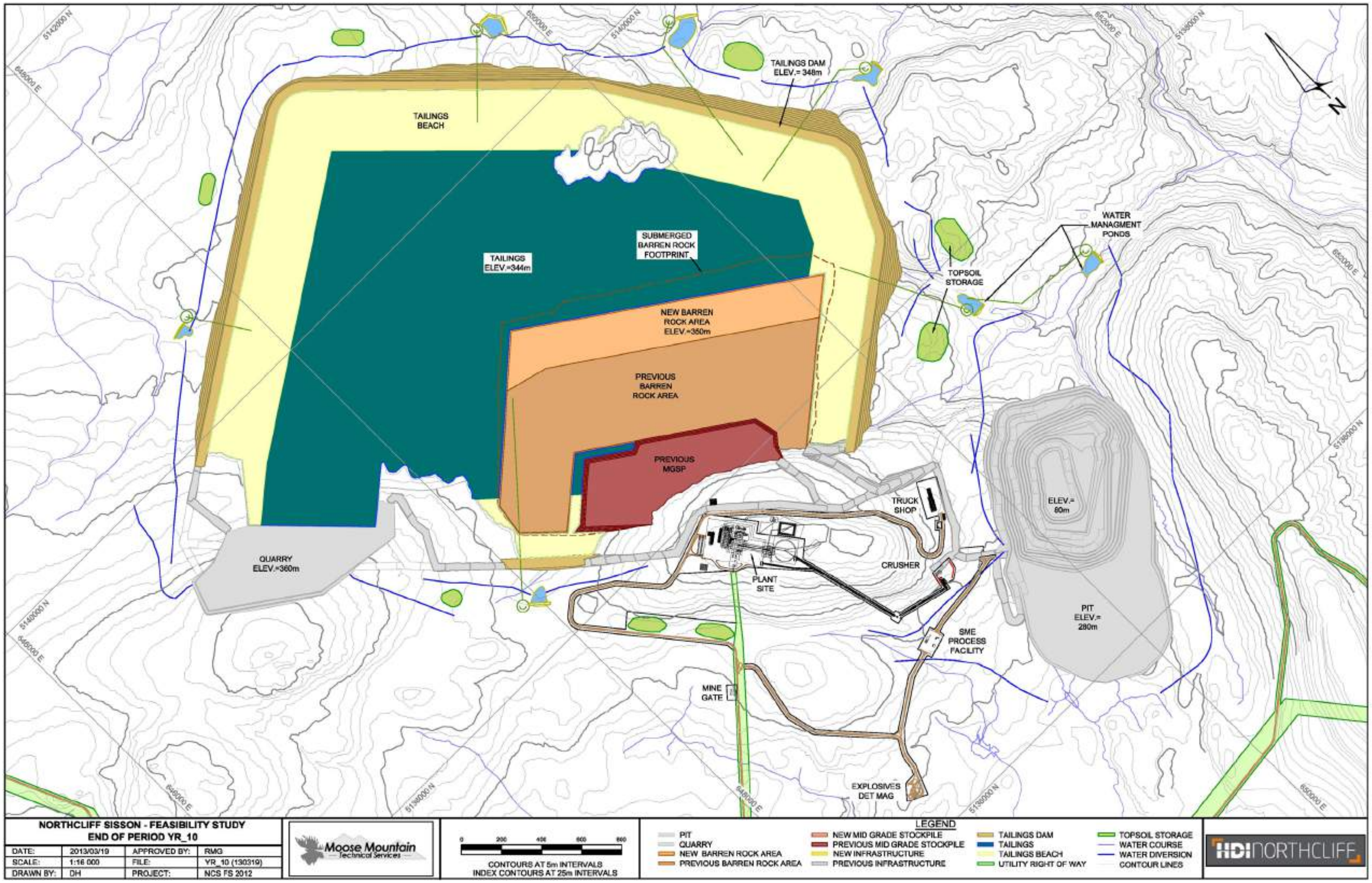

Figure 2.4 End of Period (EoP) Map, Production Year 10

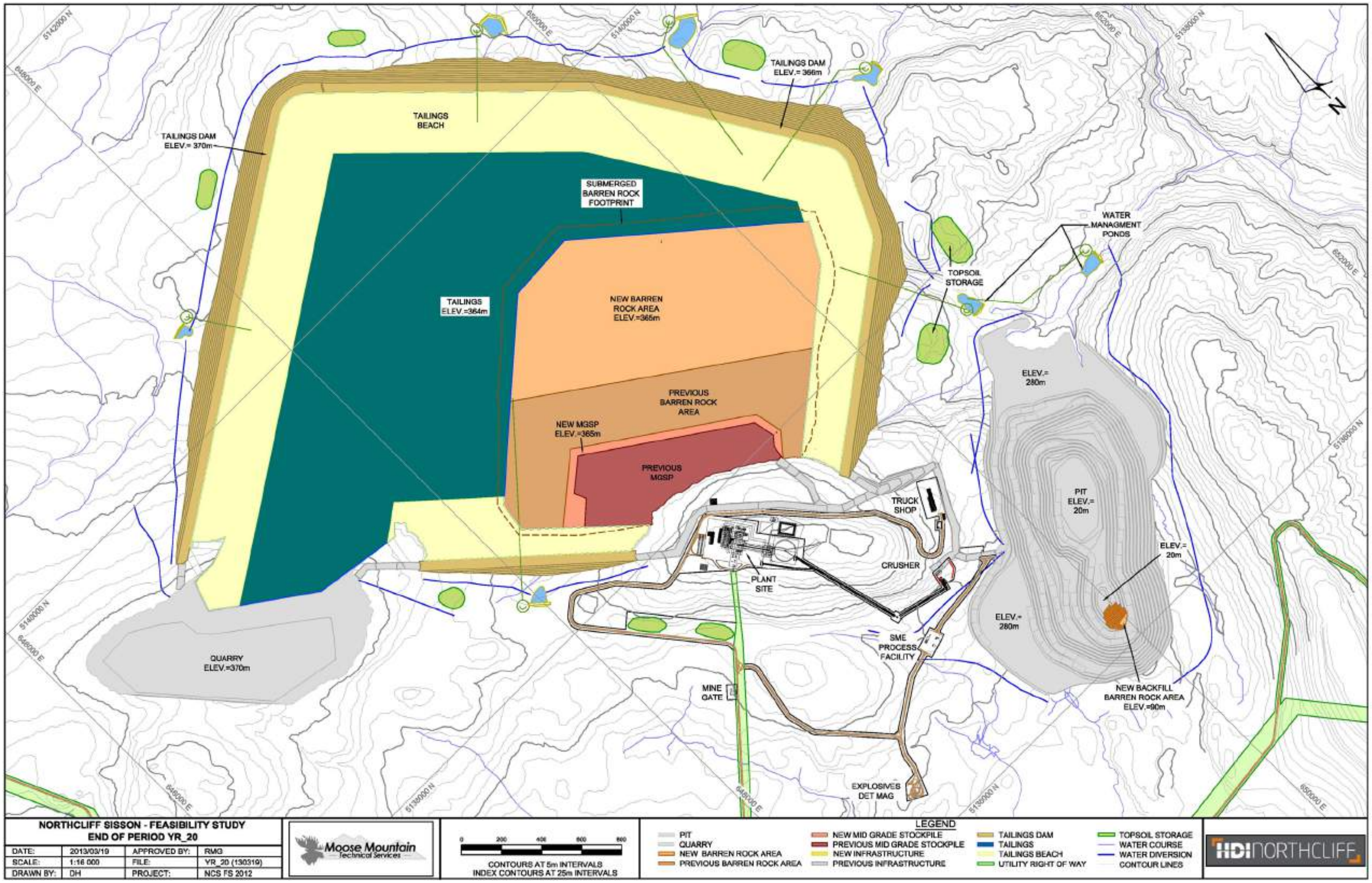

Figure 2.5 End of Period (EoP) Map, Production Year 20

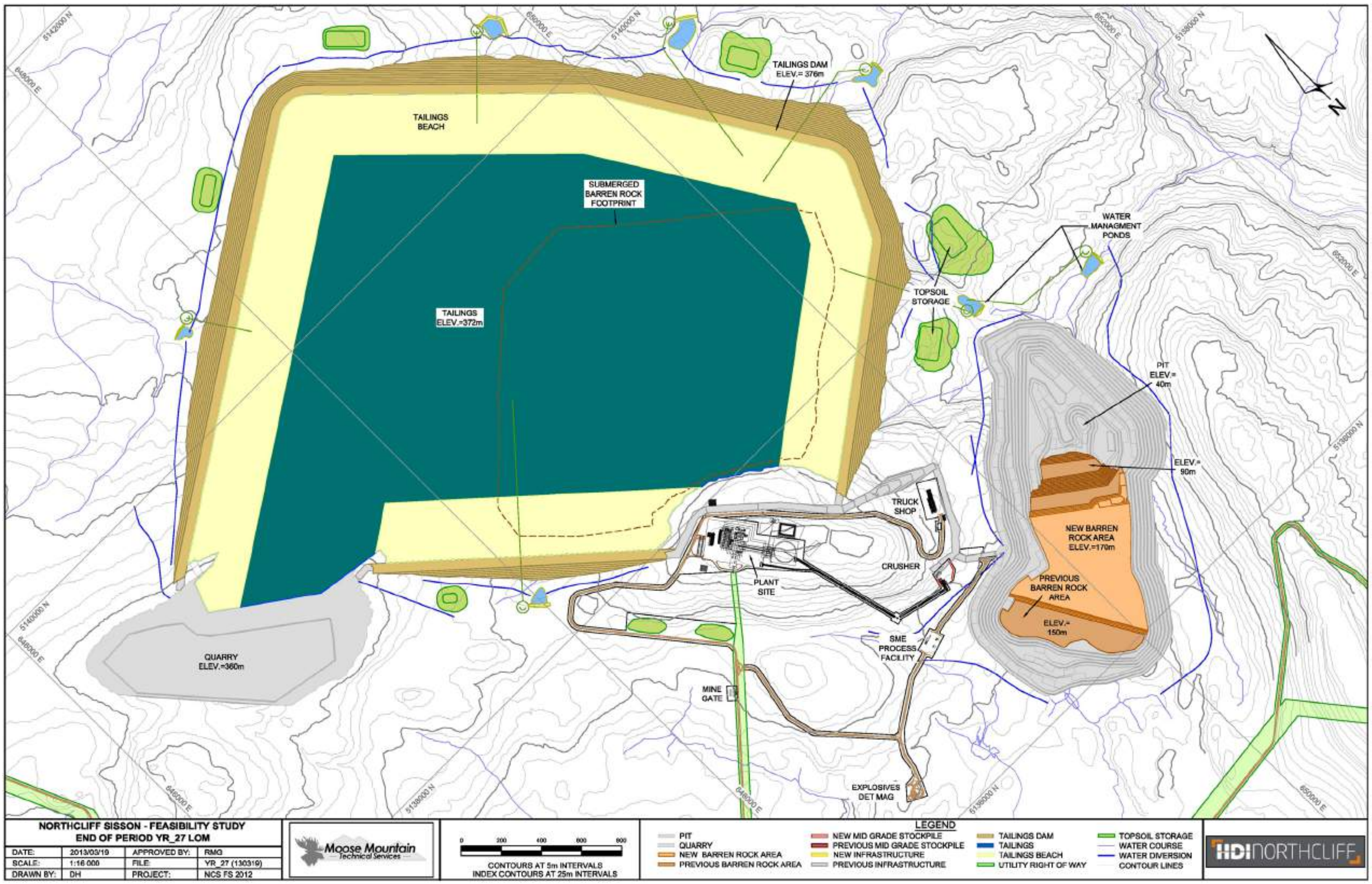

Figure 2.6 End of Period (EoP) Map, Production Year 27 (Life-of-Mine)

The Project will result in both direct and indirect losses of fish habitat, and thus result in “serious harm to fish that are part of a commercial, recreational or Aboriginal fishery” as defined in the federal *Fisheries Act* as amended in 2012. These losses total 544 “habitat units” (where one unit equals 100 m^2) of which 172 units are attributable to the deposition of tailings within the TSF and thus require listing of the watercourses in an amendment to Schedule 2 of the *Metal Mining Effluent Regulations*. The balance of the direct and indirect habitat losses require authorization under Section 35(2) of the *Fisheries Act*. A proposed project to offset all these losses and “serious harm to fish” has been developed in consultation with DFO and the New Brunswick Department of Natural Resources; it has been included in the Project application to DFO for authorization under the *Fisheries Act*. The offset project involves the removal of an old water-level control dam and road culvert on the Nashwaak River just below its exit from Nashwaak Lake, and its replacement with a forest road bridge. The offset project will enhance fisheries productivity by removing a barrier to fish migration into, and use of, Nashwaak Lake, and especially to restore access for alewife (gaspereau), a lake-spawning migratory species. The estimated cost of constructing and monitoring the performance of the offset project is $180,000.

The Project will also result in the loss of wetlands included in the GeoNB provincial wetland inventory. These losses must be compensated under the New Brunswick *Clean Water Act* and the associated *Watercourse and Wetland Alteration Regulation*. The cost of that compensation is estimated at $1.67 M.

2.2 PROJECT SCHEDULE

The Project schedule is as follows.

- **Construction**: Construction will proceed for a period of up to 24 months, commencing as soon as the EIA is completed, the applicable permits, approvals or other forms of authorization have been obtained, and there is a Proponent Board of Directors decision to proceed to construction. It is currently anticipated that construction will begin in late 2015.
- **Operation:** Operation will commence immediately following construction and will continue for an approximate period of 27 years.
- **Decommissioning, Reclamation and Closure**: Decommissioning of Project facilities and reclamation of the Project site will occur following the completion of operation. Though some reclamation will occur during operation (e.g. of redundant haul roads), almost all of the reclamation and closure work will start during the decommissioning and initial reclamation period, and will continue until the pit lake fills with water over about 12 years. Post-closure (i.e., when the pit lake is filled) will follow.

3 – ALTERNATIVES ASSESSMENT METHODOLOGY

The methodology adopted for this alternatives assessment follows the procedures described in the *Guidelines for the Assessment of Alternatives for Mine Waste Disposal* (Environment Canada, 2013). The methodology is described below with acknowledgement of the methodological steps described by Environment Canada (2013). The general approach consisted of the identification of candidate tailings management alternatives and pre-screening to filter out unfeasible alternatives from further detailed assessment. These steps resulted in a preferred tailings management technology and two TSF location alternatives. The final two TSF location alternatives were then evaluated using Multiple Accounts Analysis (MAA).

Multiple Accounts Analysis is a well-developed and widely-used method in applications such as evaluating mine development options. Basically, MAA proceeds by identifying the factors (called “accounts” and “sub-accounts”) to be used in comparing alternatives, and then giving each factor a numerical score for each alternative. The factors cover the range of influences on TSF location including environmental, socio-economic, technical, and economic factors. MAA then identifies numerical weights to be used in evaluating the relative contribution that each factor should make to the analysis. The scores are then multiplied by the weights, the products are summed, and the overall totals for the various alternatives are compared. The alternative with the highest overall merit score is considered “preferred”. Finally, sensitivity analyses are performed by varying the weights to determine if giving more or less weight to, say, environmental factors, changes the overall results of the analysis.

Since MAA is a quantitative method and some of the factors used in the analysis can only be characterized qualitatively based on expert knowledge and judgement, the numerical results of an MAA are necessarily approximate. A sensitivity analysis was used to gain insights into how varying the contribution of qualitatively characterized factors affects the MAA results. Moreover, an MAA cannot possibly incorporate all the factors that might be applied in comparing various alternatives, and must necessarily focus on those factors that are most useful in distinguishing among the alternatives. As a consequence, MAA results are indicative of the relative strength of the alternatives considered.

3.1 IDENTIFICATION OF CANDIDATE ALTERNATIVES (STEP 1)

A list of potential “reasonable” tailings management alternatives was prepared. The alternatives included tailings disposal technologies, tailings embankment construction methods, and TSF site locations.

The level of detail required for the candidate identification stage was conceptual but sufficient to allow for an understandable, reasonable and transparent decision process to either accept or eliminate alternatives from further consideration in the alternatives assessment. The general objective of this step was to demonstrate that all possible tailings management alternatives were considered in the alternatives assessment.

Environment Canada (2013) recommends the use of broad-reaching threshold criteria to constrain the range of options to a manageable number of alternatives to be included in the assessment. To be comprehensive and fully transparent, SML decided to include, at this step, all possible tailings management technologies, and all potential TSF site locations that were located sufficiently close to the process plant site to be potentially economically feasible. Planning studies for the Project indicated that tailings storage locations within 10 km of the plant site could potentially be economically feasible based on the projected unit costs for transferring tailings and waste rock to the impoundment area and for returning reclaim water to the process plant. In addition to economic considerations, increasing the distance from the open pit to the tailings storage facility adds environmental and social risks to the project and goes directly against the design principle of minimizing the project footprint.

3.2 PRE-SCREENING (STEP 2)

The pre-screening step was used to filter candidate alternatives using *pre-screening criteria*, with successful candidates being carried forward into the more detailed multiple accounts analysis. The pre-screening process filtered out alternatives that exhibited fatal flaws, non-compliance with regulatory requirements, or an obvious inability to achieve technical, economic, environmental or socio-economic targets. Fatal flaws were events or conditions that could present liabilities or technical challenges that are beyond the means of correction through simple mitigation or adaptation through feasible design changes.

As a general guideline, Environment Canada (2013) recommends that tailings management technologies be evaluated together with TSF site locations since the impacts at a particular site can vary based on the technology selected; however, at the Sisson Project location, and as discussed later in this report, filtered dry stack tailings disposal is not feasible for a number of reasons, and the other two technologies (conventional slurry and thickened (paste) tailings) both require storage behind confining engineered embankments. Since the two technologies would require about the same storage volume, the technologies and the TSF site alternatives could be independently pre-screened.

3.3 ALTERNATIVES CHARACTERIZATION (STEP 3)

Each potential TSF site location was characterized according to the four MAA “accounts” – environment, socio-economic, technical, and economic – to provide the information required to “score” the sub-accounts within each account of the MAA analysis. The Environmental Account characterized the local environment surrounding the proposed TSF in the regional context. The Socio-Economic Account characterized local access and land uses, including traditional Aboriginal use of land and resources. The Technical Account characterized the engineered elements of each alternative. The Economic Account characterized project economics such as capital and operating expenditures, and costs associated with closure, wetland compensation, and fish habitat offset.

3.4 MULTIPLE ACCOUNTS LEDGER (STEP 4)

Alternative TSF locations that passed the pre-screening in Step 2 and were characterized in Step 3 were assessed using the MAA method. The MAA employs a three-tiered approach relying on four generalized accounts, discipline-specific sub-accounts, and measurable indicators. The generalized accounts were environmental, socio-economic, technical and economic. Account-specific sub-accounts were identified based on the known environmental, socio-economic, technical and/or economic factors, and a quantitative indicator for each one was adopted wherever possible. These accounts, sub-accounts and indicators are documented in a “multiple accounts ledger”.

3.5 VALUE-BASED DECISION PROCESS (STEP 5)

The value-based decision process is the core feature of the MAA method where the relative merits of the TSF location alternatives were compared through a defined process of weighting, scoring and quantitative analysis described below.

3.5.1 Weighting

Weighting factors allowed the analysis to reflect the perceived relative importance of a given account or sub-account.

For this analysis, the sum of the weights across all accounts and sub-accounts was 100. Each account (environmental, socio-economic, technical and economic) was assigned a portion of the 100 weight “points”, then that portion was divided up among its sub-accounts. The Environment Canada guidance (Environment Canada 2013) recommended a base case weighting scale that is shown below in comparison to the 100-point scale used in this assessment (Table 3.1). The “Base Case” used in this MAA employed the 100-point scale.

Table 3.1 Correlation Between Environment Canada’s 13.5 Point Weighting Scale and the 100 Point Scale used in the Base Case for this Multiple Accounts Analysis

Account	Environment Canada Guidance Scale	Base Case Weighting Scale Used in this MAA
Environmental	6	44
Socio-Economic	3	22
Technical	3	22
Economic	1.5	12
Total	**13.5**	**100**

The analysis took the approach of applying equal weights to each sub-account/indicator within an account. This assumes that each sub-account/indicator holds equal importance within each account.

3.5.2 Scoring

A 6-point scoring method was adopted to determine a score for each sub-account using the “value scale” method described in the Environment Canada guidelines (Environment Canada 2013). On this scale, 6 is “best” and 1 is “worst”. The value scale for each sub-account is defined in Sections 9.1 through 9.4 of this report. For example, the amount of greenhouse emissions (in tonnes of CO_2 equivalent per year) was defined as a sub-account in the Environmental Account, and each alternative was scored according to the amount of its emissions and the indicator value ranges in the following table.

Indicator	
Range	**Score**
25,000 or Less	6
25,001 - 35,000	5
35,001 - 45,000	4
45,001 - 55,000	3
55,001 - 65,000	2
More than 65,000	1

For most sub-accounts, the indicator values were readily measured quantitative data (e.g., amount of greenhouse gas emissions, as in the example above, or the amount of aquatic habitat or wetlands affected), and the sub-account scoring was thus straight forward. For three sub-accounts, the indicator values were less robustly measurable, and the scores were subjected to sensitivity analysis as described in Section 3.6 below.

3.5.3 Quantitative Analysis

Using a spreadsheet, each indicator score (S) was multiplied by its weighting factor (W) to determine the weighted merit score (S x W) for each sub-account. The weighted scores were then summed ($\Sigma(S \times W)$) to produce a total merit score for each alternative which could then be compared to judge the relative merit of the alternatives.

3.6 SENSITIVITY ANALYSIS (STEP 6)

A sensitivity analysis was used to evaluate how the results of the MAA would change if the weights assigned to the accounts and sub-accounts were varied. In the case of three sub-accounts, as described in Section 10 of this report, a sensitivity analysis was also carried out for the indicator scores. These sub-accounts were Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons, Ease of Operation, and Ease of Closure. The sensitivity analysis on the indicator scores allowed an examination of the robustness of the MAA results given uncertainties in the available data/information they were based upon.

4 – IDENTIFICATION OF CANDIDATE ALTERNATIVES (STEP 1)

The alternatives assessment considered candidate alternatives in two categories:

1. **Tailings Management Technologies:** Three technologies were considered (un-thickened (conventional) slurry tailings, paste tailings, and filtered dry stack tailings). These technologies are described in Section 5 as they were pre-screened during the assessment process.
2. **TSF Locations:** Five TSF locations were considered, and are described in Section 6, as they were pre-screened during the assessment process. They are Sites 1b, 1c, 2, 3 and 4 as shown on Figure 4.1.

This identification process resulted in 15 candidate alternatives for tailings and waste disposal for the Sisson Project, as summarized in Table 4.1. In the table, each of Sites 1b, 1c, 2, 3 and 4 is repeated with the designation "-S", -T" and "-F" (conventional **S**lurry, **T**hickened paste and **F**iltered dry stack, respectively) to denote the different tailings management technologies at the site.

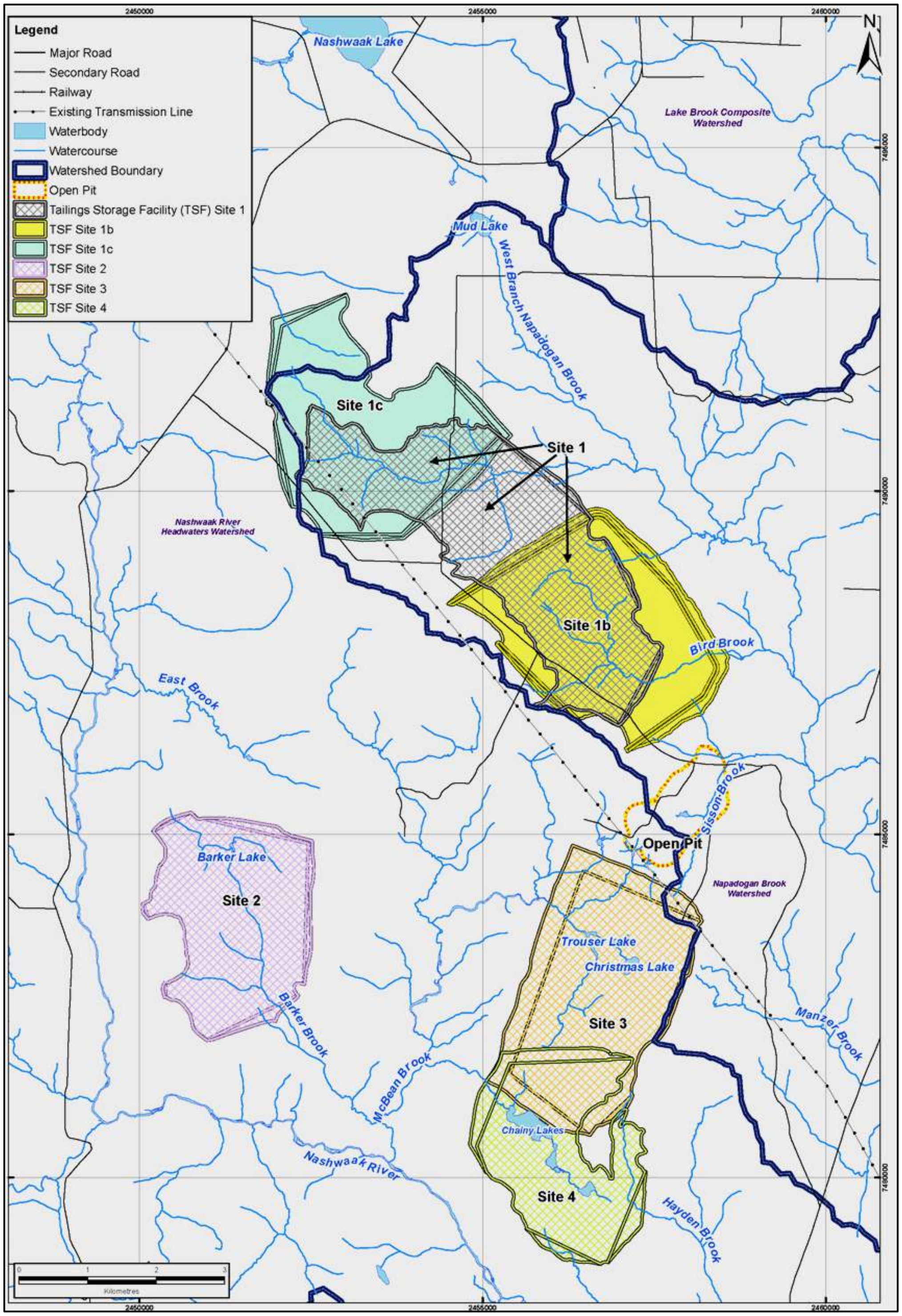

Figure 4.1 Alternate TSF Locations Assessed in Pre-Screening

Table 4.1 Candidate Alternatives

Alternative	Location	Construction Approach	Operations Approach	Closure Approach
Site 1b-S	Bird Brook	Construction of dams to impound Bird Brook	Subaqueous deposition of conventional slurry tailings and waste rock in the TIA.	Dry tailings cover of the TIA; passively drain residual TIA supernatant pond to the open pit lake for treatment and discharge.
Site 1b-T	Bird Brook	Construction of dams to impound Bird Brook; construction of separate water management pond; preparation of waste rock storage area.	Subaerial deposition of thickened paste tailings in TIA; manage large, separate, lined water management pond; separate storage of waste rock in prepared area.	Dry tailings cover; passively drain TIA contact water to water management pond and then to open pit lake for treatment and discharge; dry closure of separate waste rock storage facility.
Site 1b-F	Bird Brook	Preparation of TIA area for storage of filtered tailings; construction of separate water management pond; preparation of waste rock storage area.	Subaerial deposition of filtered tailings; manage large, separate, lined water management pond; separate storage of waste rock in prepared area.	Dry tailings cover; passively drain TIA contact water to water management pond and then to open pit lake for treatment and discharge; dry closure of separate waste rock storage facility.
Site 1c-S	West Branch Napadogan Brook	Construction of dams to impound West Branch Napadogan Brook	Subaqueous deposition of conventional slurry tailings and waste rock in the TIA.	Dry tailings cover of the TIA; pump residual TIA supernatant pond to the open pit lake for treatment and discharge.

Alternative	Location	Construction Approach	Operations Approach	Closure Approach
Site 1c-T	West Branch Napadogan Brook	Construction of dams to impound West Branch Napadogan Brook; construction of separate water management pond; preparation of waste rock storage area.	Subaerial deposition of thickened paste tailings in TIA; manage large, separate, lined water management pond; separate storage of waste rock in prepared area.	Dry tailings cover; pump TIA drainage to water management pond and then to open pit lake for treatment and discharge; dry closure of separate waste rock storage facility.
Site 1c-F	West Branch Napadogan Brook	Preparation of TIA area for storage of filtered tailings; construction of separate water management pond; preparation of waste rock storage area.	Subaerial deposition of filtered tailings; manage large, separate, lined water management pond; separate storage of waste rock in prepared area.	Dry tailings cover; pump TIA drainage to water management pond and then to open pit lake for treatment and discharge; dry closure of separate waste rock storage facility.
Site 2-S	Barker Lake	Construction of dams to impound Barker Lake	Subaqueous deposition of conventional slurry tailings and waste rock in the TIA.	Dry tailings cover of the TIA; pump residual TIA supernatant pond to the open pit lake for treatment and discharge.
Site 2-T	Barker Lake	Construction of dams to impound Barker Lake; construction of separate water management pond; preparation of waste rock storage area.	Subaerial deposition of thickened paste tailings in TIA; manage large, separate, lined water management pond; separate storage of waste rock in prepared area.	Dry tailings cover; pump TIA drainage to water management pond and then to open pit lake for treatment and discharge; dry closure of separate waste rock storage facility.

Alternative	Location	Construction Approach	Operations Approach	Closure Approach
Site 2-F	Barker Lake	Preparation of TIA area for storage of filtered tailings; construction of separate water management pond; preparation of waste rock storage area.	Subaerial deposition of filtered tailings; manage large, separate, lined water management pond; separate storage of waste rock in prepared area.	Dry tailings cover; pump TIA drainage to water management pond and then to open pit lake for treatment and discharge; dry closure of separate waste rock storage facility.
Site 3-S	Trouser Lake	Construction of dams to impound Trouser Lake	Subaqueous deposition of conventional slurry tailings and waste rock in the TIA.	Dry tailings cover of the TIA; pump residual TIA supernatant pond to the open pit lake for treatment and discharge.
Site 3-T	Trouser Lake	Construction of dams to impound Trouser Lake; construction of separate water management pond; preparation of waste rock storage area.	Subaerial deposition of thickened paste tailings in TIA; manage large, separate, lined water management pond; separate storage of waste rock in prepared area.	Dry tailings cover; pump TIA drainage to water management pond and then to open pit lake for treatment and discharge; dry closure of separate waste rock storage facility.
Site 3-F	Trouser Lake	Preparation of TIA area for storage of filtered tailings; construction of separate water management pond; preparation of waste rock storage area.	Subaerial deposition of filtered tailings; manage large, separate, lined water management pond; separate storage of waste rock in prepared area.	Dry tailings cover; pump TIA drainage to water management pond and then to open pit lake for treatment and discharge; dry closure of separate waste rock storage facility.

Alternative	Location	Construction Approach	Operations Approach	Closure Approach
Site 4-S	Chainy Lakes	Construction of dams to impound Chainy Lakes	Subaqueous deposition of conventional slurry tailings and waste rock in the TIA.	Dry tailings cover of the TIA; pump residual TIA supernatant pond to the open pit lake for treatment and discharge.
Site 4-T	Chainy Lakes	Construction of dams to impound Chainy Lakes; construction of separate water management pond; preparation of waste rock storage area.	Subaerial deposition of thickened paste tailings in TIA; manage large, separate, lined water management pond; separate storage of waste rock in prepared area.	Dry tailings cover; pump TIA drainage to water management pond and then to open pit lake for treatment and discharge; dry closure of separate waste rock storage facility.
Site 4-F	Chainy Lakes	Preparation of TIA area for storage of filtered tailings; construction of separate water management pond; preparation of waste rock storage area.	Subaerial deposition of filtered tailings; manage large, separate, lined water management pond; separate storage of waste rock in prepared area.	Dry tailings cover; pump TIA drainage to water management pond and then to open pit lake for treatment and discharge; dry closure of separate waste rock storage facility.

5 – PRE-SCREENING OF ALTERNATE TAILINGS MANAGEMENT TECHNOLOGIES (STEP 2)

A description of the three candidate tailings management technologies considered in the pre-screening – conventional slurry tailings, thickened (paste) tailings, and filtered dry stack tailings - and a discussion of the pre-screening employed in selecting the preferred technology, are presented below.

5.1 CONVENTIONAL SLURRY TAILINGS DISPOSAL

Conventional slurry tailings are typically discharged from the process plant at about 30% to 40% solids by total mass of slurry. These tailings may be pumped, flow by gravity, or some combination of both, depending on the available head and distance through pipelines from the plant to the TSF. The slurry is typically discharged through multiple off-takes from header pipes located around the periphery of the TSF confining embankments. The tailings solids settle and the resulting clear supernatant water is recovered from the TSF and pumped back for re-use in the process. The coarse fraction of the tailings typically settles rapidly and accumulates closer to the discharge points, forming a gentle “beach” with a slope of about 0.5 to 1%. Finer tailings particles tend to travel further and settle at a flatter slope to, and beneath, the supernatant pond. Selective tailings deposition is used to keep the supernatant pond away from the embankments, thereby reducing potential seepage losses, an important environmental mitigation and consideration.

Conventional slurry tailings has the advantages of being operationally simple and economical, of providing a stable water supply for use in the process plant, and of allowing for collection and treatment of all mine contact water streams associated with the mine site in a single location with one monitoring/treatment/discharge point. Conventional slurry tailings disposal also allow for the sub-aqueous storage and encapsulation of any PAG tailings and waste rock, a vital environmental mitigation and consideration. The large buffering volume within the TSF pond is an important component of the site water management plan.

5.2 THICKENED (PASTE) TAILINGS DISPOSAL

Thickened or paste tailings with higher slurry solids contents are produced in thickeners with the addition of flocculants to enhance liquid-solids separation. Therefore, a large proportion of the recoverable process water is reclaimed in the thickeners and the remaining thickened tailings are pumped to a TSF having similar embankments to those for conventional slurry tailings. Since thickened tailings are about the same density as the final settled density of slurry tailings, they require about the same size of TSF to accommodate tailings over the life of a mine. A thickened tailings TSF has no supernatant pond, so a separate, lined water management pond is required for storage of stormwater run-off and snowmelt from the TSF surface, as well as for process water storage. The pond needs to be lined since, unlike conventional slurry tailings disposal, there are no settled, fine tailings solids to provide a low-permeability barrier to seepage from the pond. Since a large volume of process water storage is required for start-up and winter operations, the water management pond needs to be correspondingly large resulting in an overall Project footprint, and consequent environmental effects, about the same as conventional slurry tailings.

The advantage of employing thickened tailings is improved conservation of water, and especially the avoidance of evaporative losses from a TSF supernatant pond. Compared to conventional slurry tailings, the disadvantages include:

- Higher processing costs for tailings thickening and thus higher energy use
- Higher pumping costs, and thus energy use, due to the thicker tailings, as costly and maintenance-intensive positive displacement pumps are typically required
- High pressure tailings pipelines are more difficult to operate and maintain
- Water management is complicated by the addition of a fully-lined external pond, and
- They do not provide for effective isolation of PAG tailings and waste rock from oxygen diffusion and potential acid generation, and are thus unfavourable from an environmental protection viewpoint.

5.3 FILTERED DRY STACK TAILINGS DISPOSAL

Filtered tailings are produced using pressure or vacuum force in presses, drum, or belt filtration units, and are typically dewatered to a moist cake-like consistency. The materials are then transported by conveyors or trucks to a dry stack where they can be compacted in lifts to improve density, trafficability, and stability. The embankments used to contain slurry or thickened tailings are not used; instead, the side slopes of the stack are covered in a rock shell. Like a thickened tailings TSF, a dry stack has no supernatant pond, so a separate, fully-lined water management pond is required for stormwater run-off, snowmelt and process water storage as described above for thickened tailings TSFs.

Compared to slurry or thickened tailings, the advantages of filtered tailings are that they allow improved water conservation, and they are denser and thus require slightly less land area for storage, even including the required water management pond. The disadvantages include the following:

- An external, lined water management pond is required.
- They do not provide for effective isolation of PAG tailings and waste rock from oxygen diffusion and potential acid generation, and are thus unfavourable from an environmental protection viewpoint.
- They require dewatering facilities and equipment that are expensive and complicated to build and operate, thus requiring higher energy use.
- Physical characteristics of tailings such as particle size distribution strongly influence the ability to dewater the tailings solids sufficiently so that they can be handled and placed in a compacted stack. The presence of excessive fines in the tailings may make it impractical to achieve a workable tailings product.
- In cold winter climates like New Brunswick, preventing snow or ice accumulations in the pile is a challenge. Adequate contingencies need to be provided for operations since placement of the tailings may be precluded by snow and ice on the surface of the stack, or by freezing of the tailings prior to placement. Subsequent thawing of frozen ice lenses or tailings could lead to large-scale instability problems of the stacked tailings.
- Wind-blown dust, and thus potential adverse environmental effects, can worsen in winter months as freeze-drying and other frost processes can loosen the tailings.
- Wet months may cause problems as moisture addition can result in rapid degradation of surface trafficability and prevent adequate compaction.
- The filtered tailings stack is susceptible to instability due to ice lenses or localized liquefaction if the pile becomes saturated due to rainfall, snow entrainment or percolation from run-off.

- The operating cost, and thus energy, required to transport the large quantity of tailings to the dry stack is significantly larger than for other tailings technologies.

It is noted that the Independent Review Panel for the Mount Polley TSF incident recommended that best available technology (BAT) be required of new mines, including due consideration of the use of filtered dry stack tailings. In this regard, it is important to note that the Panel's mandate was to investigate only matters affecting the physical stability of the Mount Polley TSF. It was not charged with investigating the environmental issues related to chemical stability of tailings. As noted above, filtered dry stack tailings (and thickened tailings) management does not provide for effective isolation of PAG tailings and waste rock from oxygen diffusion and potential acid generation, and are thus unfavourable from an environmental protection viewpoint. Indeed, water covers that are possible with conventional slurry tailings management are the preferred strategy for managing potentially reactive tailings and waste rock, a practice that is outlined in the global acid rock drainage (GARD) guide (International Network for Acid Prevention, 2009) and has been embraced worldwide. The Environmental Code of Practice for Metal Mines (Environment Canada, 2009) also recommends disposal of potentially acid generating waste rock or tailings under a water cover (R310).

Thus, while filtered dry stack tailings may be BAT from a physical stability viewpoint, they are not necessarily BAT when chemical stability is also considered. Much depends on the physical and environmental conditions of a particular mine site and, as outlined above, the Sisson Project site does not offer conditions that are conducive to the effective employment of filtered dry stack tailings management, since PAG tailings and waste rock must be isolated from oxygen diffusion in order to achieve long-term chemical stability of these materials.

5.4 TAILINGS MANAGEMENT TECHNOLOGIES PRE-SCREENING

Compared to conventional slurry tailings, the advantages of thickened tailings were considered to be more than offset by the disadvantages for a mine site like Sisson located in a cold winter climate with high annual net precipitation where water surpluses rather than deficits need to be managed. Filtered dry stack tailings present even greater technical and economic disadvantages. Thus, compared to conventional slurry tailings, the other tailings management technologies either carry technical challenges due to the Project location and climate, or are economically less desirable due largely to their energy requirements. At the same time, none of these considerations represent "fatal flaws" to the choice of tailings management technology.

However, conventional slurry tailings provide for the storage of PAG tailings and waste rock sub-aqueously and encapsulated in NPAG tailings, and thus effectively mitigate the potential for acid generation and consequent environmental effects. The other two technologies do not provide this vital environmental protection capability; this was considered a "fatal flaw" and these two technologies were thus pre-screened out of further consideration in the assessment as summarized in Table 5.1.

Table 5.1 Tailings Management Technologies Pre-Screening Summary

Pre-Screening Criterion	Rationale	Alternative		
		Conventional Slurry Tailings	**Thickened (Paste) Tailings**	**Filtered Dry Stack Tailings**
Does the alternative provide for the effective isolation of PAG tailings and waste rock from oxygen diffusion and potential acid generation?	Avoiding acid generation and associated metal leaching is a vital environmental protection objective.	Yes	No	No
Should the alternative be excluded from further assessment?		No	Yes	Yes

Thus, of the 15 candidate alternatives identified in Section 4, all the alternatives involving thickened and filtered dry stack tailings management were pre-screened out of further consideration in the alternatives assessment. The eliminated candidate alternatives are those numbered 1b-T and 1b–F, 1c-T and 1c–F, 2-T and 2–F, 3-T and 3–F, and 4-T and 4–F in Table 4.1.

6 – PRE-SCREENING OF ALTERNATE TSF LOCATIONS (STEP 2)

6.1 TAILINGS MANAGEMENT OBJECTIVES AND TSF LOCATION PRE-SCREENING CRITERIA

The principal objectives when considering where and how to store tailings were as follows:

1. The site and methods will ensure that the tailings are stored in a way that is, and will be, physically and chemically stable.
2. Potential ML/ARD materials can be managed to minimize the potential for oxidation and subsequent release of low pH leachate.
3. The design and construction methods are technically and economically feasible, and appropriate for the site conditions.
4. Adverse environmental effects are minimized and not significant.

As discussed in the CEAA Project Description (Stantec 2011), four main alternatives for locating the TSF were considered by Geodex (the previous Project owner) and subsequently by SML. SML refined Site 1 into two sites – 1b and 1c – thus yielding a total of five candidate alternative sites as identified in Section 4. The following important features should be emphasized:

- The topography of the Project area is characterized by rolling hills separated by broad valleys. The surface elevation typically ranges from approximately 300 to 350 m above mean sea level, with some hills rising to over 400 m. The uplands are typically well-drained, stream density is high, and small lakes and wetlands are common in low-lying areas. Thus, TSF site alternatives were sought near or at the top of individual drainages to avoid the need to divert water around them, and to take advantage of the natural topography to minimize the need for engineered embankments.
- For reasons described in Section 5, all waste rock will be stored sub-aqueously in the TSF.
- All TSF alternatives would be designed, built and operated to the same standards (see Appendix B) so there are no technical factors that distinguish them in terms of their resistance to earthquakes or extreme rainfall events, and their seepage management features.

The Project area in central New Brunswick has a very high density of streams on the landscape – a result of the low relief, shallowness of the depth to bedrock, and relatively wet climate. The high density can be appreciated by considering Figures 6.1, 6.2 and 6.3. Because of this high stream density, and the volume of tailings and waste rock to be stored in the TSF, none of the candidate alternatives could be located to avoid covering at least one watercourse, though lakes could be avoided. In this regard, it should be noted that all of the watercourses surveyed in the Project area, even the very small first order ones, support fish populations, though the species composition varies. Based on habitat surveys conducted for the Project, all watercourses in the Project area have the potential to support fish populations. Watercourses draining the Project site via West Branch Napadogan Brook (to the northeast and east) support primarily brook trout, slimy sculpin and American eel while those draining via McBean Brook (to the south), being generally warmer, support primarily brook trout, suckers, blacknose dace, creek chub and American eel. Detailed information on the fish species in each surveyed watercourse can be found in Stantec (2012). Thus, no TSF site alternative could be located to avoid direct effects on waters frequented by fish.

6.2 ALTERNATE TSF LOCATIONS

The alternate TSF locations considered in the pre-screening are shown on Figure 6.1 and are described below. Note that all distances refer to the distance from the ore processing plant site to the centre of each TSF alternate location.

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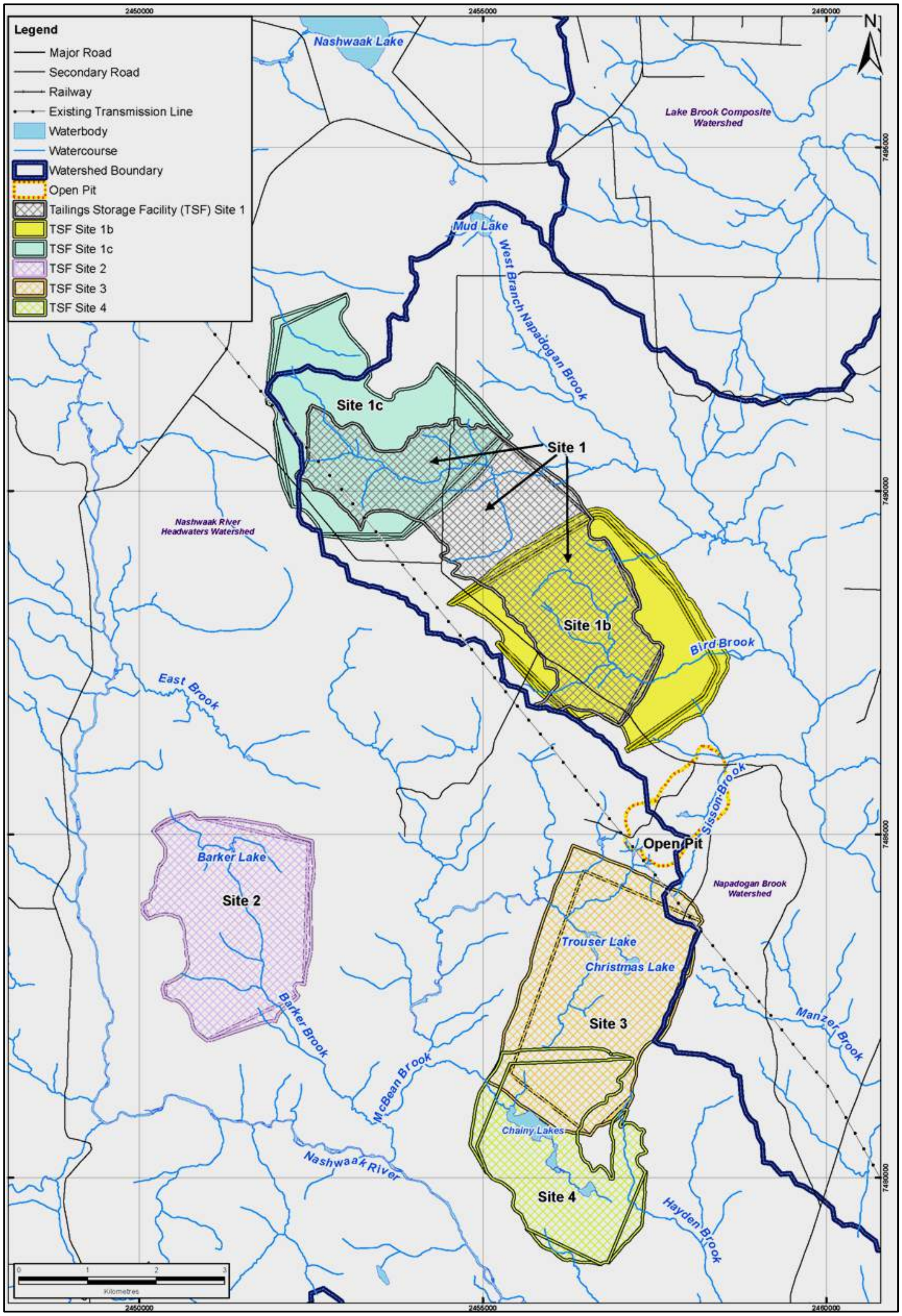

Figure 6.1 Alternate TSF Locations Assessed in Pre-Screening

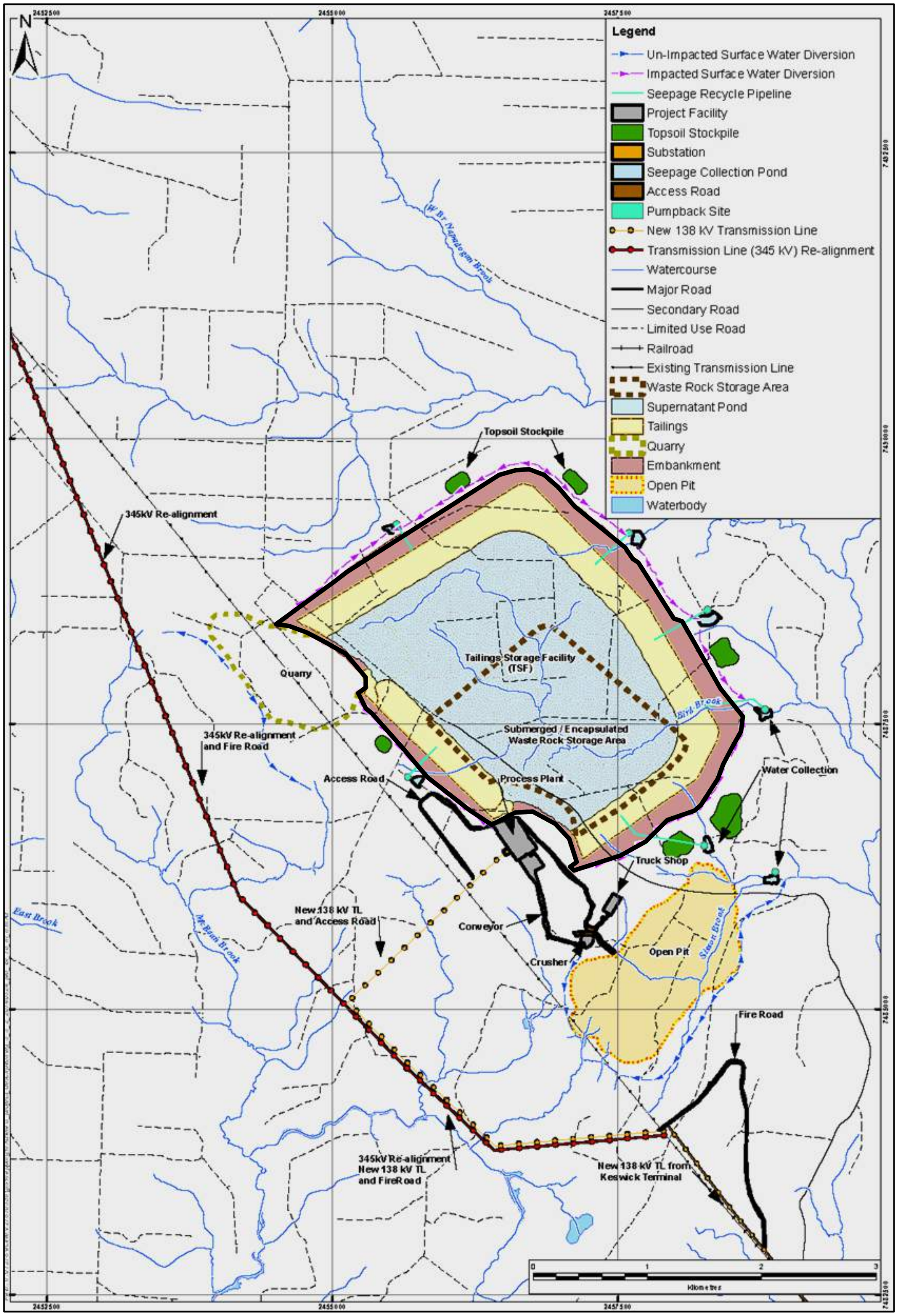

Figure 6.2 TSF Site 1b

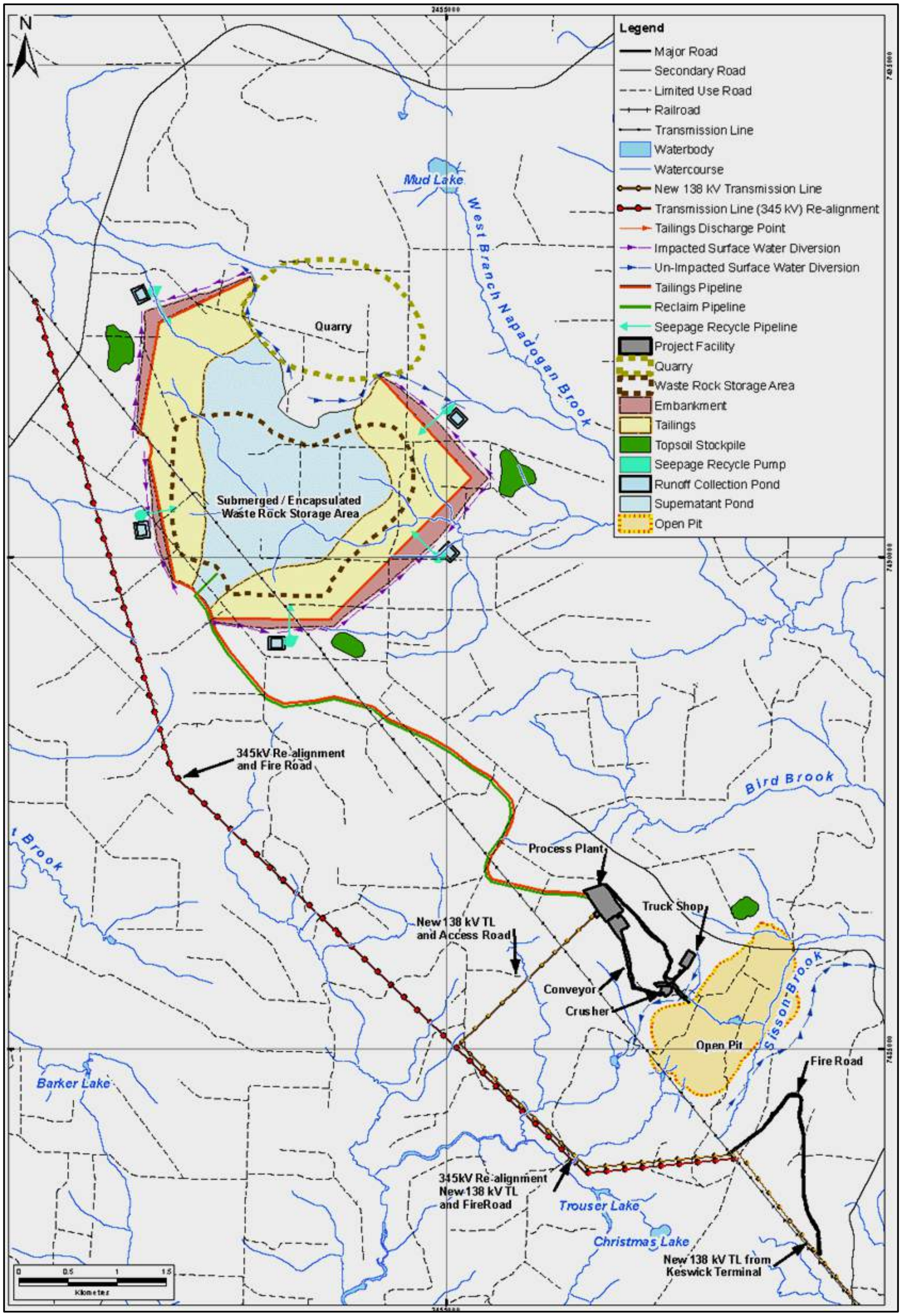

Figure 6.3 TSF Site 1c

6.2.1 Bird / West Branch Napadogan Brook (Site 1)

Site 1 had been proposed by the previous Project proponent (Geodex) and is relatively close (3.3 km) to the proposed ore processing plant site. Compared to the other alternatives, it has a relatively large footprint, but does take good advantage of the natural topography. It does not encroach on any lakes. It does cover much of the upper reaches of Bird Brook and one arm of West Branch Napadogan Brook, but does drain entirely to Napadogan Brook. Its proximity to the process plant means that the lengths of access roads, tailings and water pipelines, and power lines between the TSF and the plant site would be comparatively short.

Early in the feasibility studies, SML refined Site 1 into two site alternatives, Site 1b and Site 1c named “Bird Brook” and “West Branch Napadogan Brook”, respectively, in Table 4.1. Sites 1b and 1c are 1.5 km and 5.3 km from the plant site, respectively. A TSF at Sites 1, 1b or 1c can be designed and operated to meet the same design basis (Appendix B), and to control seepage to acceptable limits, so there was no compelling reason to carry all three sites through the pre-screening process. Sites 1b and 1c take up less land area than initially envisaged using Site 1, and avoid covering more watercourses than are absolutely necessary; this would reduce the potential environmental effects of Site 1. The smaller footprints would also contribute to meeting Environment Canada’s overall objective of the alternatives assessment process – “to minimise the environmental footprint of the disposal area” (Environment Canada 2013, Section 1.2).

6.2.2 Barker Lake (Site 2)

Barker Lake (Site 2), located approximately 5.8 km to the southwest of the proposed ore processing plant location, has the advantage of constraining hills on its west side. This alternative would be more costly to operate than Site 1 due to the distance from the process plant, and would thus cause additional environmental effects related to greater distances for trucking and infrastructure. More importantly, it would entail covering a lake and drains entirely to the Upper Nashwaak River watershed.

6.2.3 Trouser Lake (Site 3)

Trouser Lake (Site 3), located approximately 4.1 km to the south of the proposed ore processing plant location, has the advantage of constraining hills on the east side; however, it would result in the elimination of lakes (known to support a recreational fishery) and drains entirely to the Upper Nashwaak River watershed. This alternative would be more costly to operate than Site 1 due to the distance from the process plant with the attendant additional environmental effects related to greater distances for trucking and infrastructure.

6.2.4 Chainy Lakes (Site 4)

Chainy Lakes (Site 4), located approximately 6.1 km to the south of the proposed ore processing plant location, has the advantage of constraining hills on its northeast and southeast sides. However, it would result in the elimination of lakes (known to support a recreational fishery) and drains entirely to the Upper Nashwaak River watershed. This alternative would be more costly to operate than Site 1 due to the distance from the process plant with the attendant additional environmental effects related to greater distances for trucking and infrastructure.

6.3 TSF LOCATION PRE-SCREENING

The sole "fatal flaw" used to pre-screen tailings TSF locations was the requirement to cover a lake based on the following rationale:

- Lakes were identified in the EIA Report as valuable resources having particular ecological values as well as importance for Aboriginal and recreational fisheries, and environmental effects on these resources would very likely be deemed "significant", and
- Lakes are protected (classified as AL) under New Brunswick's Water Classification Regulation 2002-13 – Clean Water Act (Section 18) in order to safeguard habitat for aquatic life. Contaminants cannot be discharged into them. Any lake located within the TSF would need to be reclassified by the Minister through a Water Classification Order to allow for the discharge of contaminants that would not meet the applicable standards for this water classification.

For these reasons, only those candidate alternatives identified in Step 1 that avoided lakes (Sites 1b and 1c) were carried further in the multiple accounts evaluation and Sites 2, 3 and 4 were eliminated in the pre-screening step. The pre-screening rationale is summarized in Table 6.1.

Table 6.1 TSF Location Pre-Screening Summary

Pre-Screening Criterion	Rationale	Alternative				
		Site 1b	Site 1c	Site 2	Site 3	Site 4
Does the alternative cover any lakes?	Covering lakes would likely be deemed a significant environmental effect since their aquatic habitat is protected by regulation in New Brunswick, and they support recreational or Aboriginal fisheries.	No	No	Yes	Yes	Yes
Should the alternative be excluded from further assessment?		No	No	Yes	Yes	Yes

Thus, of the candidate alternatives identified in Table 4.1, only alternatives 1b-S and 1c-S were carried forward in the alternatives assessment**.** For the remainder of the document, these two alternatives are simply referred to as Site 1b and Site 1c, respectively.

7 – CHARACTERIZATION OF ALTERNATE TSF LOCATIONS (STEP 3)

Table 7.1 provides a summary of key quantitative parameters for TSF Site 1b and TSF Site 1c. These are the two alternatives that passed the pre-screening Step 2. Figures 7.1 and 7.2 present the areas of aquatic habitat, interior forest and wetland loss for sites 1b and 1c, respectively.

Table 7.1 Key Quantitative Parameters of the Two TSF Location Alternatives

Key Parameters	TSF Site 1b	TSF Site 1c
Technical		
Maximum embankment height (m)	80	95
Maximum embankment length (m)	8,810	8,100
Embankment volume (Mm^3)	35	37
TSF storage volume (Mm^3)	373	370
TSF footprint (ha)	785	750
Storage efficiency	10.7	10.0
Distance for road/pipeline alignment to TSF (km)	1	5
Environmental		
Area in Napadogan Brook watershed (%)	100	80
Area of aquatic habitat (m^2)	22,365	13,914
Area of wetland (ha)	161	202
Area of interior forest (ha)	109	70
GHG emissions (t CO_2e/yr)	16,484	64,009
Economic[1]		
Capital costs ($M)	101.9	128.1
Operational costs ($M)	139.9	382.1
Closure costs ($M)	20.5	20.6
Fish habitat offset costs ($)	180,000	180,000
Wetland compensation costs ($M)	1.67	1.07

7.1 CHARACTERIZATION OF TSF SITE 1B

7.1.1 Environmental Characterization

Site 1b is a relatively flat, poorly drained valley surrounded by forested hills and ridges except to the northwest. The mixed wood and deciduous forested uplands are well-drained while much of the wide valley is covered with mineral-poor, coniferous forested wetland. The forest cover on the site has been extensively influenced by forestry activities including harvesting and various silvicultural treatments, and most of the forest cover is young or at least partially cut-over in recent decades as a result. Bird Brook and a branch of Sisson Brook drain the site, both of which are tributaries to the West Branch Napadogan Brook which flows to Napadogan Brook, then to the Nashwaak and Saint John rivers to the Bay of Fundy. The site contains no lakes, listed environmentally sensitive areas, or known deer wintering areas. The New Brunswick Department of Environment and Local Government

[1] All costs have been discounted to the start of operations at a rate of 8% per annum.

require compensation for the loss of wetlands that are included in the GeoNB provincial wetland inventory.

The watercourses in the site support fish species common to central New Brunswick (e.g. brook trout, American eel, and slimy sculpin); the presence of Atlantic salmon has not been recorded. The loss of fish habitat and the consequent serious harm to fish within the site requires an offset project approved by DFO for the Project in order to be authorized under the federal *Fisheries Act*. Wildlife species are also common to central New Brunswick (e.g., moose, white-tailed deer, beaver, and other small mammals). Two mammal species at risk (Canada lynx and Eastern cougar) were previously recorded in the Project area, but only the first was recorded during field surveys for the Project. Bird species are typical for central New Brunswick; ten species were identified to be at-risk, rare or uncommon. There is an abundance of preferred habitat available in the general Project area for these wildlife and bird species.

7.1.2 Socio-Economic Characterization

The forest road network created over several decades of forestry operations provides ready access to the site at multiple locations. There are no permanent residences or cabin leases within the site, and it is part of a Crown timber licence managed by Acadian Timber Inc. Other land uses are typical of central New Brunswick – hunting, fishing, camping and general outdoor recreation. Multiple moose hunting blinds have been noted on the site. The Indigenous Knowledge Study (IKS) (Moccasin Flower Consulting 2013) indicated that Site 1b supports multiple uses by Aboriginal people, with some identified locations for hunting and fishing.

7.1.3 Technical Characterization

The TSF embankments will be constructed in stages as zoned earthfill and rockfill structures. The starter embankments will be completed at least a year before mill start-up, and will have a geosynthetic (HDPE) liner on the upstream face to provide containment for a start-up water pond and the first year of tailings deposition. The TSF embankments will be progressively raised by the modified centerline construction method using quarried rockfill. The maximum embankment height will be approximately 80 m, while the maximum embankment length is estimated to be 8,810 m. As a practical matter, NPAG and PAG waste rock cannot be mined separately due to the general dispersion of sulphur-bearing minerals throughout the ore body; thus, all waste rock will be stored sub-aqueously within the TSF and rockfill for the TSF embankments will be sourced from a quarry located at the western corner of the TSF. Transition and filter zones will be incorporated in the embankments to ensure compatibility and internal stability of the fill materials. A low permeability zone of compacted tailings will be constructed on the embankment side of the exposed tailings beaches using dozer compaction in hydraulic sand cells; its purpose is to mitigate seepage migration through the embankment.

NPAG tailings from the concentrator will be discharged to the TSF as a slurry with a solids content of 35% by weight at an average throughput of 30,000 tonnes per day, or approximately 10.5 M tonnes per year. The tailings will be discharged from the delivery pipelines at a series of offtakes located along the embankments. PAG tailings, approximately 5% of the total tailings by weight, will be separately pumped to the TSF and stored sub-aqueously to be encapsulated in the NPAG tailings. Figure 6.2 presents the pipelines and roads for site 1b.

Water management infrastructure will be constructed to divert non-contact surface runoff away from the mine facilities and to collect all contact water for recycle to the TSF during operations. Surface water runoff from the embankment face, seepage through the embankment fill material, and other runoff and seepage from disturbed areas in the vicinity of the TSF will be collected and directed to the water management ponds located at topographic low points along the downstream toe of the embankments. The water collected will be monitored and pumped back into the TSF if the water quality is such that it cannot be discharged without risking significant environmental effects downstream.

A stochastic operational water balance model was completed for the site (see summary in the EIA Report, Stantec (2013), Section 7.6.2). The model indicates that the project will operate in surplus conditions requiring the discharge of surplus water from about Year 8 of operations and during post-closure. Surplus water will be treated before discharge to meet permit requirements to be established by the Province of New Brunswick, and the authorized limits of deleterious substances set forth in Schedule 4 of the MMER.

The conceptual closure and reclamation plan is designed to return the entire project site to long-term physical, chemical and environmental stability, and to land uses that are agreed with stakeholders, First Nations and provincial regulators. Primary closure design features include grading, capping, and vegetating the TSF beaches, and establishing a closure pond that will drain naturally to the open pit via an overflow spillway and channel. The water management ponds around the TSF will return water to the TSF until the water quality is such that the water can be allowed to discharge. Until the pit lake water quality is such that it can be directly discharged according to provincial permit requirements, the lake level will be maintained at an elevation that ensures it is a groundwater sink by pumping surplus water for treatment before discharge.

7.1.4 Economic Characterization

Capital, operational, and closure costs were estimated from itemized project requirements during each of these phases. Costs have been estimated to ± 15% and are discounted at 8% annually to the start of operations, consistent with requirements for prospective mining developments at the Feasibility Study level. The construction costs of $101.9 M address waste and water management at the TSF with the majority of costs attributed to starter dam construction and acquisition of construction materials from a quarry. Operational costs of $139.9 M were attributed to embankment raises, distribution and disposal of tailings and waste rock, as well as water management. Closure costs of $20.5 M were attributed to landform stabilization, shaping, capping, revegetation, and construction of a spillway for pit lake filling at the end of operations.

The costs of constructing and monitoring a project to offset fish habitat losses ($180,000) and of compensating for the loss of wetlands that are included in the GeoNB provincial wetland inventory ($1.67 M) were assumed to be incurred at or close to the start of operations, and were therefore not discounted.

7.2 CHARACTERIZATION OF TSF SITE 1C

7.2.1 Environmental Characterization

Site 1c is a shallow basin with elevations and hills around its perimeter with gaps through which drainage flows to the east and northwest. It is comprised of well-drained forested uplands with wetlands in the lower-lying areas. The mixed wood and deciduous forested slopes of the surrounding hills are well-drained, while much of the basin is covered with mineral-poor, coniferous forested wetland. Like Site 1b, the terrestrial habitat of Site 1c consists primarily of immature and young forest resulting from several decades of forest harvesting activity in the area.

The site is drained primarily by West Branch Napadogan Brook to the east while small tributaries to the Nashwaak River drain part of the site to the northwest and west. The site contains no lakes (though there are some beaver ponds), listed environmentally sensitive areas, or known deer wintering areas. The New Brunswick Department of Environment and Local Government require compensation for the loss of wetlands that are included in the GeoNB provincial wetland inventory.

Though the watercourses in the site have not been the subject of baseline aquatic surveys, like Site 1b they are expected to support fish species common to central New Brunswick (e.g., brook trout, American eel, and slimy sculpin). The loss of fish habitat and the consequent serious harm to fish within the site requires an offset project approved by DFO for the Project to be authorized under the federal *Fisheries Act*. Wildlife and bird species are expected to be generally the same as at Site 1b.

7.2.2 Socio-Economic Characterization

The forest road network created over several decades of forestry operations provides ready access to Site 1c at multiple locations. There are no permanent residences or cabin leases within the site, and it is part of a Crown timber licence managed by Acadian Timber Inc. Other land uses are typical of central New Brunswick – hunting, fishing, camping and general outdoor recreation. The IKS (Moccasin Flower Consulting 2013) indicated the site supports multiple uses by Aboriginal people, with just one identified location for hunting on its southeastern corner. It is unknown whether the IKS inquired about the possibility of other sites with similar uses within the Site 1c footprint, and thus whether other such use sites exist.

7.2.3 Technical Characterization

For Site 1c, construction, operations, and environmental protection (i.e., seepage and general water management) would be the same as that proposed for Site 1b. More specifically, the TSF embankment at Site 1c would have the same embankment design using the same design basis (Appendix B), and occupy a basin with similar basin materials (shallow topsoil over dense glacial till (0.5 m to 10 m deep) then weathered bedrock (10 m to 20 m deep) over intact bedrock (granite)), as at Site 1b. It would be constructed of the same materials (quarried rock) with a seepage collection system beneath the embankment draining to water management ponds (WMPs), and would have the same toe ditches around the embankment perimeter also draining to the WMPs.

As at Site 1b, groundwater interception wells would be installed around the outside perimeter of the embankments if required to return seepage to the TSF that might jeopardize downstream water quality. Also as at Site 1b, NPAG tailings would be deposited into the TSF from spigots around the embankment crest; PAG tailings would be deposited, and waste rock would be stored subaqueously in the TSF; and water would be reclaimed from the TSF from a floating barge for use in the process plant. Thus, Site 1c would have the same design and operational features as at Site 1b to ensure that water and seepage are effectively and safely managed to ensure the protection of downstream water quality. Figure 6.3 presents the pipelines and roads for site 1c.

Rockfill for the TSF embankments would also be sourced from a quarry, likely at the northwest corner of the site. The maximum embankment height will be approximately 95 m, while the maximum embankment length is estimated to be 8,100 m. The primary difference from Site 1b would be the closure requirements that would also include partial capping, grading and vegetating the TSF surface to establish a closure pond. However, water from the closure pond would be transferred to the open pit using the reclaim water barge, pumps and pipeline rather than relying on an overflow spillway and channel.

7.2.4 Economic Characterization

Capital, operational, and closure cost were estimated from itemized project requirements during each of these phases. Costs have been estimated to ± 15% and are discounted at 8% annually to the start of operations, consistent with requirements for prospective mining developments at the feasibility study level. The construction costs of $128.1 M address waste and water management at the TSF with the majority of costs attributed to starter dam construction and acquisition of construction materials from a quarry. The differences in costs relative to Site 1b are due to the requirement of an additional 4 km haul road, 5 km of pipelines, and a larger starter embankment. Operational costs of $382.1 M were attributed to embankment raises, distribution and disposal of tailings and waste rock, as well as water management. The differences in costs relative to Site 1b are due to the energy requirements to pump tailings and reclaim water through an additional 5 km of pipelines, and the additional 4 km haul distance for waste rock disposal. Closure costs of $20.6 M were attributed to landform stabilization, shaping, capping, revegetation, and pit lake filling and are considered similar to Site 1b for the purpose of this comparison.

The costs of constructing and monitoring a project to offset fish habitat losses ($180,000) and of compensating for the loss of wetlands that are included in the GeoNB provincial wetland inventory ($1.07 M) were assumed to be incurred at or close to the start of operations, and were therefore not discounted.

7.3 CHARACTERIZATION SUMMARY

The characterization of Sites 1b and 1c discussed above demonstrates considerable similarities between the two sites. In particular, the topography and basin materials of the two sites present essentially the same design conditions for constructing stable TSF embankments and managing seepage. Table 7.2 provides a summary characterization of the two sites in terms of criteria that differentiate them and are used as indicators in the multiple accounts ledger (Section 8).

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Table 7.2 Characterization of Alternate TSF Locations Summary

Criterion	Rationale	TSF Site 1b	TSF Site 1c
Environmental			
Drainage to Napadogan Brook watershed	For efficient and effective water management, and especially to minimize the number of drainages that might be affected by seepage, it is best if the TSF site also naturally drains to the Napadogan watershed as does the rest of the Project site.	Drains entirely via the Napadogan Brook watershed to the Nashwaak River.	Approximately 80% of the site drains via the Napadogan Brook watershed to the Nashwaak River.
Area of aquatic habitat	The site should affect as little aquatic habitat as possible.	22,365 m^2	13,914 m^2
Area of wetland	The site should affect as little wetland as possible.	161 ha	202 ha
Area of interior forest	The site should affect as little interior forest as possible.	109 ha	70 ha
GHG emissions	GHG emission from operation of the TSF site (arising primarily from trucking waste rock from the open pit for storage within the TSF) should be as little as possible.	16,484 t CO_2e/yr	64,009 t CO_2e/yr
Socio-Economic			
Current use of land and resources for traditional purposes by Aboriginal persons	The site should affect Aboriginal current use as little as possible. The two sites have essentially the same natural environment and access, there is no evident reason to expect a difference in the intensity of Aboriginal current use between the two sites, and any real difference in use can be indicated by differences in the TSF footprint area.	Supports multiple uses by Aboriginal people, with some identified locations for hunting and fishing. The TSF site footprint area is 785 ha.	Supports multiple uses by Aboriginal people, with just one identified location for hunting on the southeastern corner. It is unknown whether the IKS inquired about the possibility of other sites with similar uses within the site footprint, and thus whether other such use sites exist. The TSF site footprint area is 750 ha.
Technical			
Storage efficiency	Storage efficiency is the ratio of available tailings storage volume to the embankment volume. Higher storage efficiency generally results in lower embankments and lower costs.	10.7	10.0
Distance for road/pipeline alignment to TSF site	The lengths of road and pipelines between the process plant and the site should be as short as possible to minimize construction, maintenance and operational costs (primarily energy).	1 km	5 km
Management of surplus water at closure.	Management of surplus water at closure should be as simple as possible to minimize long-term operational costs and environmental risks.	Water would drain naturally through an overflow spillway and channel to the open pit.	Water would be transferred to the open pit using the reclaim water barge, pumps and pipeline.
Economic			
Capital costs	Costs should be as low as possible to maximize Project feasibility while being consistent with SML's Principles of Responsible Mineral Development.	$M 101.9	$M 128.1
Operational costs		$M 139.9	$M 382.1
Closure costs		$M 20.5	$M 20.6
Wetland compensation costs		$M 1.67	$M 1.07

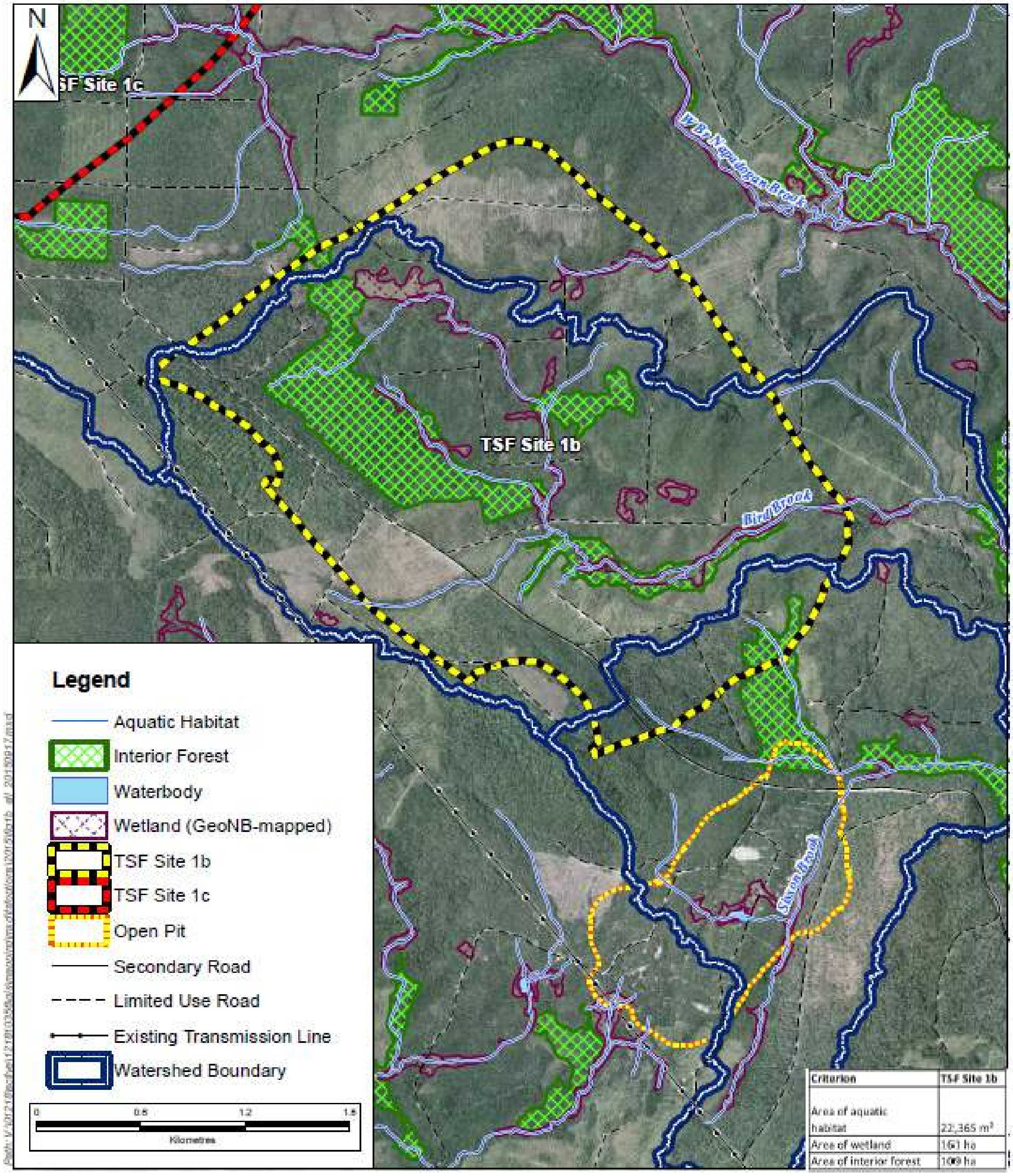

Figure 7.1 TSF Site 1b with Areas of Aquatic Habitat, Interior Forest and Wetland Loss [2]

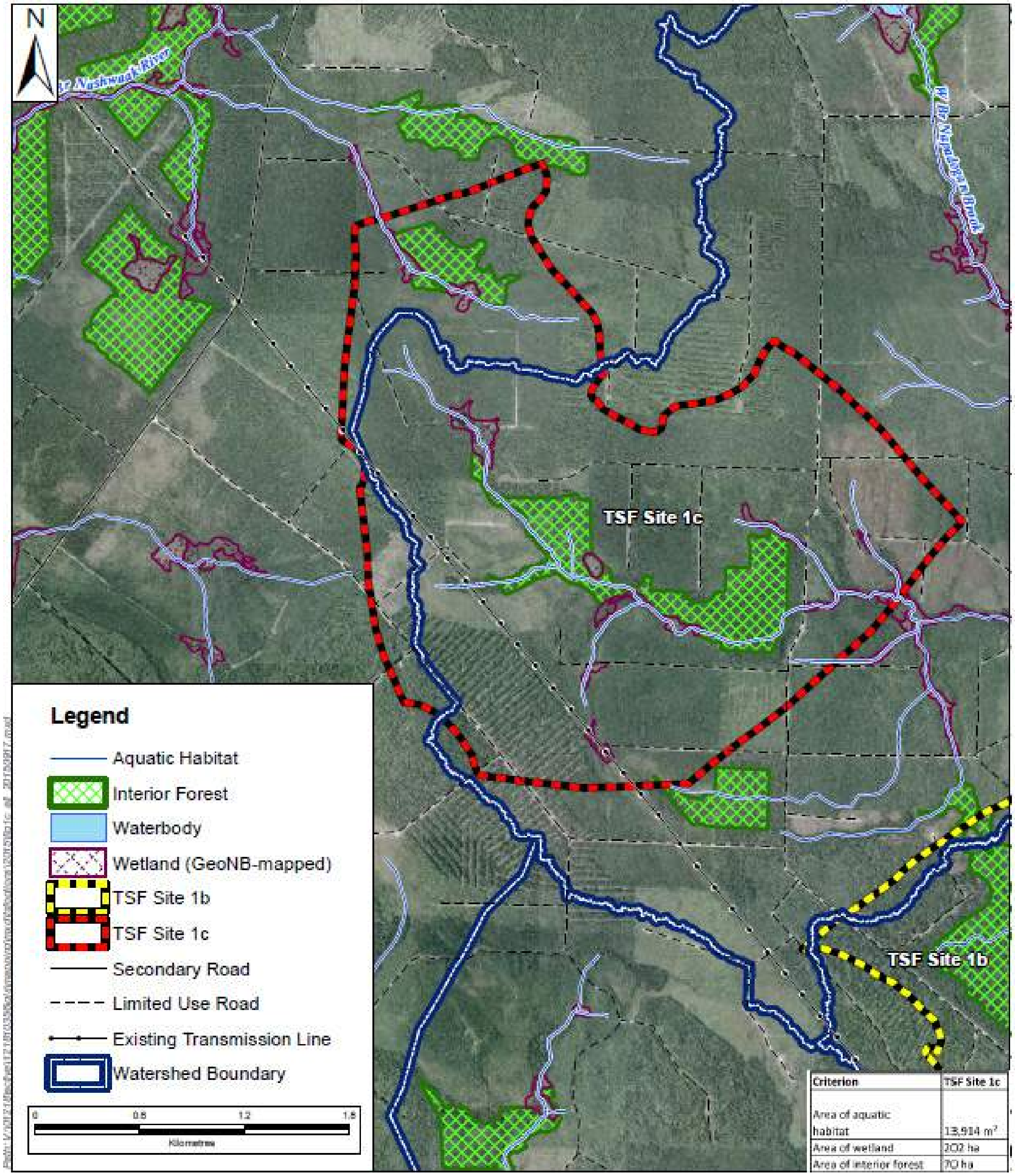

Figure 7.2 TSF Site 1c with Areas of Aquatic Habitat, Interior Forest and Wetland Loss [3]

[2, 3] The total wetland area reported on Figures 7.1 and 7.2 is the sum of the area of GeoNB mapped wetlands and the area of unmapped (field-identified) wetlands for sites 1b and 1c. Field delineation of unmapped wetlands was conducted for site 1b only. The area of unmapped wetlands for site 1c, as presented on the figures, has been estimated by prorating the mapped wetland area for site 1c by applying the same ratio of mapped wetland to unmapped wetland for site 1b to site 1c. Since field delineation of unmapped wetland was not done for site 1c, it is not possible to plot both mapped and unmapped wetland area for both sites. As such, only mapped wetlands (based on the GeoNB wetland layer) are represented graphically on the figures.

8 – MULTIPLE ACCOUNTS LEDGER (STEP 4)

In accordance with the Environment Canada guidance document, four accounts (environmental, socio-economic, technical and economic) were established for comparing the TSF site alternatives following the multiple accounts (Step 4) methodology described in Section 3.4. Compared to the analysis presented in Section 3.3 of the Sisson Project EIA Report (Stantec 2013), a socio-economic account was added to the present analysis to reflect the Environment Canada guidance and to recognize the importance of socio-economic factors such as Aboriginal land and resource use to the analysis and to capture their potential influence on the analysis. The sub-accounts in each account were selected for their importance and for their usefulness in distinguishing between the TSF site alternatives. Evaluation factors that could not usefully distinguish between the site alternatives were not included as sub-accounts. The accounts and sub-accounts are described below.

8.1 ENVIRONMENTAL ACCOUNT

Table 8.1 identifies the three environmental sub-accounts that were adopted for the environmental account, and Table 8.2 identifies the seven environmental indicators that were considered and excluded from the environmental sub-accounts.

Table 8.1 Environmental Sub-Accounts Considered in the Environmental Account

Environmental Sub-Account	Indicator	Description of Indicator	Rationale
Water and Fisheries Resources	Area Within Napadogan Brook Watershed	The principal potential sources of contaminants to the aquatic environment are the TSF (from seepage) and the open pit, especially after closure of the mine, as well as releases of treated water from the water treatment plant. The open pit area naturally drains primarily via Sisson Brook to West Branch Napadogan Brook, and will do so entirely (with treatment if necessary) once the pit fills during Closure of the Project. The indicator used was the proportion of a site in the Napadogan Brook watershed.	For efficient and effective water management, and especially to minimize the number of drainages that might be affected by seepage, the TSF site should naturally drain to the same watershed as the rest of the Project as much as possible.
	Area of Permanent Aquatic Habitat Loss	The area of permanent aquatic habitat loss is the total area of aquatic habitat that will be covered by the TSF. The indicator used was the area of lost habitat in square metres (m2).	To minimize the effects of the Project on the aquatic environment, the TSF site should affect as little permanent aquatic habitat as possible.
	Number of Streams Impacted	The indicator used was the number of streams impacted.	To minimize the effects of the Project on the aquatic environment, the TSF site should affect as few streams as possible.
Terrestrial Habitat	Area of Permanent Loss of Interior Forest	Interior forest is an important wildlife habitat type. Interior forest is defined as continuous stands of mature forest greater than 10 ha that are free of edge effect. The area of permanent interior forest loss is the total area of interior forest that will be lost within the TSF either as a result of covering an interior forest stand, or reducing the total area of a stand to less than 10 ha such that it is no longer considered interior forest. The indicator used was the area of lost interior forest in hectares (ha).	To minimize the effects of the Project on the terrestrial environment, the TSF site should affect as little interior forest as possible.
	Area of Permanent Wetland Loss	The area of permanent wetland loss is the total area of mapped wetland that will be covered by the TSF. The indicator used was the area of lost wetland in hectares (ha).	To minimize the effects of the Project on the wetland environment, the TSF site should affect as little wetland as possible.

Environmental Sub-Account	Indicator	Description of Indicator	Rationale
Air Quality	Greenhouse Gas Emissions	In response to comments from the Sustainability Working Group, an environmental indicator was added to encompass emissions of greenhouse gases (GHG) (as a surrogate for all air contaminant emissions) arising primarily from trucking waste rock from the open pit for storage within the TSF. The indicator used was the maximum annual GHG emissions arising from such trucking in tonnes of CO2 equivalent per year (t CO2e/yr).	To minimize potential effects on the atmospheric environment, the Project should generate as little greenhouse gas emissions as possible.
	Potential for dust emission.	The indicator used was road length as it was the single differentiating feature between the candidate TSF alternatives that was a major source of dust.	To minimize potential effects on the atmospheric environment, the Project should generate as little dust emissions as possible.

Table 8.2 Environmental Indicators Excluded from the Environmental Account

Excluded Environmental Indicator	Rationale for Exclusion
Footprint Area	The TSF footprint area is the total area covered by the embankments, tailings and water control works along the toe of the embankments. Rather than footprint area itself, it is the environmental values within the footprint that are relevant in comparing the alternate sites and these are adequately addressed by including the aquatic habitat, wetland, and interior forest sub-accounts. Footprint area was used as an indicator for other values in some cases.
Catchment Area	Given the Project site and the location of both alternatives at the top of drainages, this area largely duplicates footprint area and was thus also excluded.
Environmentally Sensitive Areas	Neither site contains environmentally significant areas, or deer wintering areas, and there is no reason to expect the potential presence of terrestrial species at risk to be different for the two sites.
Downstream Water Quality	Water discharged from the Project will be treated, as needed, to meet permit conditions that will be established by the Province of New Brunswick, so the quality of treated water released to the environment is not a distinguishing factor between the two alternatives. The only other potential source of environmental effects due to changes in downstream water quality is seepage through the TSF embankments. Apart from embankment lengths, the main factors which affect seepage (e.g., design of the TSF, depth to bedrock, permeability of the bedrock, characteristics of the surficial material and overburden) are expected to be similar at the two sites. While Site 1c would have shorter embankments than Site 1b, Site 1c is higher in the Napadogan Brook watershed where natural flows are lower and the effects of seepage on downstream water quality would thus be higher. In any case, the design, construction and operation of a TSF at either site would be undertaken to ensure that the environmental effects due to seepage on downstream water quality would not be significant. Thus, neither site offers evident advantages in terms of seepage and downstream water quality management.
Consequences of Dam Failure	The CDA dam classification guidelines include consideration of the receiving environment in the event of a dam failure and were used as a means of evaluating this indicator. In the case of a dam failure the environmental consequences are considered equal for both TSF locations.

8.2 SOCIO-ECONOMIC ACCOUNT

Within the socio-economic account, one sub-account was established: Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons.

Table 8.3 identifies the two socio-economic sub-accounts that were adopted for the socio-economic account, and Table 8.4 identifies the three socio-economic indicators that were considered and excluded from the socio-economic sub-accounts.

Table 8.3 Socio-Economic Sub-Accounts Considered in the Socio-Economic Account

Socio-Economic Sub-Account	Indicator	Description of Indicator	Rationale
Land and Resource Use	Traditional Use by Aboriginal Persons	The two sites have essentially the same natural environment and access, as modified by forestry operations through cutting and building access roads over many years. There is no evident reason to expect a difference in the intensity of use of land and resources for traditional purposes by Aboriginal persons between the two sites, and any real difference in use would be accounted for on the basis of the amount of area that is disturbed by each alternative. The indicator used was the Footprint Area measured in hectares.	The TSF site should affect as little use of land and resources for traditional purposes by Aboriginal persons as possible.
	Use by Non-Aboriginal Persons	The indicator used was the Footprint Area measured in hectares.	The TSF site should affect as little use of land and resources for traditional purposes by non-Aboriginal persons as possible.

Socio-Economic Sub-Account	Indicator	Description of Indicator	Rationale
Archaeology	Archaeological Potential	The indicator used was the area of lost aquatic habitat in square metres (m^2), relying on the province's model that generally equates area of aquatic habitat with archaeological potential, since the majority of archaeological finds are situated within close proximity to watercourses.	The TSF site should affect as little area of archaeological potential as possible.

Table 8.4 Socio-Economic Indicators Excluded from Socio-Economic Sub-Accounts

Excluded Socio-Economic Indicator	Rationale for Exclusion
Safety	The TSF would be designed, constructed and operated at either site to meet the same factors of safety prescribed by the CDA Guidelines, thus neither site offers any particular advantages or disadvantages regarding public safety.
Noise	Both TSF locations have a similar proximity to public roads and neither offers any particular advantages or disadvantages regarding effects on noise at the nearest noise sensitive receptors (recreational cabins or permanent residences).
Aesthetics	Both TSF locations have a similar orientation and proximity to public roads and neither offers any particular advantages or disadvantages regarding effects on visual aesthetics.

The Indigenous Knowledge Study (Moccasin Flower 2013, Figure 9) indicated more individually-reported "use locations" in Site 1b than in Site 1c, though the difference may well be an artifact of the study methodology as discussed in Section 7.2.2. To address the resulting uncertainty, a sensitivity analysis was carried out on the indicator score for the Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons sub-account.

8.3 TECHNICAL ACCOUNT

Table 8.5 identifies the three technical sub-accounts that were adopted for the technical account, and Table 8.6 identifies the four technical sub-accounts that were considered and excluded from the technical account.

Table 8.5 Technical Sub-Accounts Considered in the Technical Account

Technical Sub-Account	Indicator	Description of Indicator	Rationale
Storage Efficiency	Storage Efficiency	Storage efficiency is the ratio of available tailings storage volume to the embankment volume. Higher storage efficiency generally results in lower embankments and lower costs. The indicator used was the storage efficiency ratio.	The TSF storage efficiency should be as high as possible to minimize the cost of tailings storage.
Ease of Operation	Length of Road/Pipeline Required	The indicator used was the length of road/pipeline in metres (m).	The shorter the length of road and pipeline required, the less maintenance, infrastructure and potential for accidental releases.
	Number of Personnel Required	The indicator used was the number of personnel required during operations.	The less challenging the operation of the TSF is, the fewer the personnel that are required.
	Amount of Mechanical Equipment Required	The indicator used was the amount of mechanical equipment (pumps, loaders, etc.) required during operations.	The more simple and efficient the operation of the TSF is, the less mechanical equipment is required.
	Susceptibility to difficulties caused by weather (e.g., snow, wind, and rain).	The indicator used was the susceptibility to difficulties caused by weather which was qualitatively judged on a scale of low, medium or high.	The less susceptible the operation of the TSF to difficulties is, the more reliable the operation will be.
Ease of Closure	Water Management Requirements	The indicator used was the complexity of the water management requirements, qualitatively judged on a scale of low, medium or high.	The more simple and efficient the closure of the TSF is, the less mechanical equipment, pipelines, diversions, conveyances, etc. are required to move the supernatant pond into the Pit Lake in closure.

	Reclamation of Disturbed Areas	The indicator used was the area requiring reclamation in hectares (Ha).	The smaller the area requiring reclamation, generally the easier it is to achieve the closure objectives.

Table 8.6 Technical Indicators Excluded from the Technical Sub-Accounts

Excluded Technical Indicator	Rationale for Exclusion
Metal Leaching and Acid Generation	The same methods for the sub-aqueous storage of PAG tailings and both PAG and NPAG waste rock would be used at both sites. Thus, neither site offers advantages or disadvantages in terms of ML/ARD management.
Stability of Embankments	Site conditions and the availability of suitable construction materials were considered equivalent at the two sites, and the same design standards (Appendix B) will apply to both. Thus, neither site offers advantages or disadvantages in terms of embankment stability under seismic loads greater than anticipated in the design.
Ease of Construction	Neither TSF site alternative had obvious significant advantages or disadvantages for construction. The only major difference between the sites is the distance from the ore processing plant site; however, both sites have similar access from existing roads and to sources of borrow or quarry materials.

8.4 ECONOMIC ACCOUNT

Table 8.7 identifies the two economic sub-accounts that were adopted for the economic account.

Table 8.7 Economic Sub-Accounts Considered in the Economic Account

Included Economic Sub-Account	Indicator	Description of Indicator	Rationale
Mining Costs	Capital costs	The capital costs relating to waste and water management were estimated by the design engineers during the feasibility study. Costs were largely related to the construction of the starter dam embankment in each TSF location. The indicator used was $ CDN.	The economic feasibility of the Project is enhanced by the lowest possible capital costs that are consistent with safe and responsible Project implementation.
	Operational costs	Operational costs included estimates for the dam raises, disposal of tailings and waste rock, water management, etc. as estimated by the design engineers. The indicator used was $ CDN.	The economic feasibility of the Project is enhanced by the lowest possible operational costs that are consistent with safe and responsible Project implementation.
	Closure and reclamation costs	Closure and reclamation costs for each TSF location were estimated by the design engineers. The indicator used was $ CDN.	The economic feasibility of the Project is enhanced by the lowest possible closure and reclamation costs that are consistent with safe and responsible closure of the Project.
Environmental Costs	Fish habitat offset costs	The cost of a project to offset serious harm to fish due to the Project was estimated by the design engineers. The indicator used was $ CDN.	The economic feasibility of the Project is enhanced by the lowest possible fish habitat offset costs that are consistent with meeting the objective of offsetting serious harm to fish.
	Wetland compensation costs	The indicator used was the cost ($ CDN) of compensating for GeoNB-mapped wetlands lost due to the Project.	The economic feasibility of the Project is enhanced by the lowest possible wetland compensation costs that are consistent with the objective of compensating effectively for the loss of wetland function due to the Project.

9 – MULTIPLE ACCOUNTS ANALYSIS (STEP 5)

The following section documents the basis for scoring attributed to TSF Site 1b and TSF Site 1c for the various accounts and sub-accounts included in the MAA following the methodology described in Section 3.5.

9.1 ENVIRONMENTAL ACCOUNT

9.1.1 Water and Fisheries Resources Sub-Account

9.1.1.1 Area Within Napadogan Brook Watershed Indicator

The indicator used was the proportion (percentage) of a site in the Napadogan Brook watershed. The TSF site with the largest proportion of its catchment area in the Napadogan Brook watershed received the maximum score, and the other alternative received a lower score according to the indicator value ranges in the following table. Based on the adopted indicator value ranges presented below, TSF 1b (at 100%) scored 6 and TSF 1c (at 80%) scored 4.

Area Within Napadogan Brook Watershed Indicator		**TSF**
Range (%)	**Score**	
91 - 100	6	1b
81 - 90	5	
71 - 80	4	1c
61 - 70	3	
51 - 60	2	
50 or Less	1	

9.1.1.2 Area of Permanent Aquatic Habitat Loss Indicator

The indicator used was the area of lost habitat in square metres (m^2) due to the overall TSF footprint. The area of aquatic habitat in Site 1b was based on field measurements taken in 2011. Though some field surveys have been conducted within Site 1c, detailed aquatic surveys have not been conducted and the areas of aquatic habitat have not been field confirmed. The total length of watercourses within Site 1c is known based on digital elevation mapping (DEM) prepared for the Project. For the purposes of this analysis, the widths of watercourses in Site 1c were estimated based on stream order, as determined by aquatic scientists with field experience in the Project area. These widths multiplied by the known lengths (as obtained from a geographic information system) give the estimated amount of aquatic habitat in Site 1c.

The alternative with the smallest habitat loss is most desired, and thus received the maximum score. The other alternative received a lower score according to the indicator value ranges in the following table. Based on the adopted indicator value ranges presented below, TSF 1c (at 13,914 m^2) scored 6 and TSF 1b (at 22,365 m^2) scored 4.

Area of Permanent Aquatic Habitat Loss Indicator		TSF
Range (m^2)	Score	
15,000 or Less	6	1c
15,001 - 20,000	5	
20,001 - 25,000	4	1b
25,001 - 30,000	3	
30,001 - 35,000	2	
More than 35,000	1	

9.1.1.3 Number of Streams Impacted Indicator

The indicator used was the number of streams impacted within the TSF footprint. A total of five higher order tributary streams and Sisson Brook located in the TSF 1b area will be impacted. A total of eight higher order tributary streams and the tributary to the West Branch of the Napadogan Brook located in the TSF 1c area will be impacted.

The alternative with the least number of impacted streams is most desired, and thus received the maximum score. Based on the adopted indicator value ranges presented below, TSF 1b scored 6 and TSF 1c scored 3.

Number of Streams Impacted Indicator		TSF
Range (#)	Score	
6	6	1b
7	5	
8	4	
9	3	1c
10	2	
>10	1	

9.1.2 Terrestrial Habitat Sub-Account

9.1.2.1 Area of Permanent Loss of Interior Forest Indicator

The indicator used was the area of lost interior forest in hectares (ha). Interior forest is calculated using forest cover and other land use data, and buffering linear features, clearcuts, open water, and other edges by 100 m. Contiguous mature or overmature forest stands that are outside of the buffered areas and larger than 10 ha are defined as interior forest. The alternative with the smaller interior forest loss is desired, and thus received the maximum score. The other alternative received a lower score according to the indicator value ranges in the following table. Based on the adopted indicator value ranges presented below, TSF 1c (at 70 ha) scored 6 and TSF 1b (at 109 ha) scored 4.

Area of Permanent Loss of Interior Forest Indicator		TSF
Range (ha)	Score	
80 or Less	6	1c
81 - 100	5	
101 - 120	4	1b
121 - 140	3	
141 - 160	2	
More than 160	1	

9.1.2.2 Area of Permanent Wetland Loss Indicator

The indicator used was the area of lost wetland in hectares (ha). As with aquatic habitat, detailed wetland field surveys have not been conducted in Site 1c, though they have been conducted in Site 1b. A wetland model was prepared for both TSF alternatives to predict areas that are likely wetland. This model was based on DEM data and depth to water table maps. Field verifications were conducted at Site 1b to ground truth the wetland areas predicted by the model; 74% of the modelled wetlands were confirmed to in fact be wetlands. As Site 1c is located within an area with similar conditions as Site 1b, it is considered to be a fair approximation that 74% of the modelled wetlands are actual wetlands. Accordingly, the modelled wetlands in Site 1c were reduced by 26% in order to estimate the area of permanent wetland loss.

The alternative with the smallest wetland loss is desired, and thus received the maximum score. The other alternative received a lower score according to the indicator value ranges in the following table. Based on the adopted indicator value ranges presented below, TSF 1b (at 161 ha) scored 6 and TSF 1c (at 202 ha) scored 5.

Area of Permanent Wetland Loss Indicator		TSF
Range (ha)	**Score**	
200 or Less	6	1b
201 - 225	5	1c
226 - 250	4	
251 - 275	3	
276 - 300	2	
More than 300	1	

9.1.3 Air Quality Sub-Account

9.1.3.1 Greenhouse Gas Emissions Indicator

The indicator used was the maximum annual GHG emissions arising from trucking waste rock from the open pit to the TSF, in tonnes of carbon dioxide equivalent per year (t CO_2e/yr). The lowest GHG emissions are desired, and thus received the maximum score. The other alternative received a lower score according to the indicator value ranges in the following table. Based on the adopted indicator value ranges presented below, TSF 1b (at 16,484 t CO2e/yr) scored 6 and TSF 1c (at 64,009 t CO2e/yr 09 ha) scored 2.

Greenhouse Gas Emissions Indicator		**TSF**
Range (t CO2e/yr)	**Score**	
25,000 or Less	6	1b
25,001 - 35,000	5	
35,001 - 45,000	4	
45,001 - 55,000	3	
55,001 - 65,000	2	1c
More than 65,000	1	

9.1.3.2 Potential for Dust Emission Indicator

The indicator used to infer the potential for dust emissions was the road/pipeline length for each TSF alternative. The road/pipeline length was the single differentiating feature between the candidate TSF alternatives that was a major source of dust. The shortest road/pipeline length is desired, and thus received the maximum score. Based on the adopted indicator value ranges presented below, TSF 1b (1 km) scored 6 and TSF 1c (5 km) scored 2.

Potential for Dust Emissions Indicator		**TSF**
Range (km)	Score	
1	6	1b
2	5	
3	4	
4	3	
5	2	1c
6	1	

9.2 SOCIO-ECONOMIC ACCOUNT

9.2.1 Land and Resource Use Sub-Account

9.2.1.1 Traditional Use by Aboriginal Persons Indicator

The two sites have essentially the same natural environment and access, as modified by forestry operations through cutting and building access roads over many years. There is thus no reason based on natural resources or access to expect a difference in the intensity of use of land and resources for traditional purposes by Aboriginal persons between the two sites, and any real difference in use would be accounted for in the TSF footprint area. Thus the indicator used was the footprint area (ha). The alternative with the smallest area is desired, and thus received the maximum score. The other alternative received a lower score according to the indicator value ranges in the following table. Based on the adopted indicator ranges presented below, TSF 1c (at 750 ha) scored 6 and TSF 1b (at 785 ha) scored 5.

Traditional Use by Aboriginal Persons Indicator		**TSF**
Range (ha)	Score	
750 or Less	6	1c
751 - 800	5	1b
801 - 850	4	
851 - 900	3	
901 - 950	2	
More than 950	1	

The IKS (Moccasin Flower 2013, Figure 9) indicated more individually-reported “use locations” in Site 1b than in Site 1c, though the difference may well be an artifact of the study methodology; it is unknown whether the IKS inquired about the possibility of other such use sites within Site 1c, and thus whether other such use sites exist. The IKS study indicated extensive “multiuse” of the large block of Crown land in which the Project is located. To address the resulting uncertainty, and as noted in Section 3.6 above, a sensitivity analysis was carried out on the indicator score for this sub-account.

9.2.1.2 Use by Non-Aboriginal Persons Indicator

The two sites have essentially the same natural environment and access, as modified by forestry operations through cutting and building access roads over many years. There is thus no reason based on natural resources or access to expect a difference in the intensity of use of land and resources for traditional purposes by Aboriginal persons between the two sites, and any real difference in use would be accounted for in the TSF footprint area. Thus the indicator used was the footprint area (ha). The alternative with the smallest area is desired, and thus received the maximum score. The other alternative received a lower score according to the indicator value ranges in the following table. Based on the adopted indicator ranges presented below, TSF 1c (at 750 ha) scored 6 and TSF 1b (at 785 ha) scored 5.

Use by Non-Aboriginal Persons Indicator		TSF
Range (ha)	**Score**	
750 or Less	6	1c
751 - 800	5	1b
801 - 850	4	
851 - 900	3	
901 - 950	2	
More than 950	1	

9.2.2 Archaeology Sub-Account

9.2.2.1 Archaeological Potential Indicator

The indicator used was the area of lost aquatic habitat in square metres (m^2) due to the overall TSF footprint. Selection of this indictor relied on the province's model that generally equates area of aquatic habitat with archaeological potential, since the majority of archaeological finds are situated within close proximity to watercourses. The alternative with the smallest habitat loss (archaeological potential) is most desired, and thus received the maximum score. The other alternative received a lower score according to the indicator value ranges in the following table. Based on the adopted indicator value ranges presented below, TSF 1c (at 13,914 m^2) scored 6 and TSF 1b (at 22,365 m^2) scored 4.

Archaeological Potential Indicator		TSF
Range	Score	
15,000 or Less	6	1c
15,001 - 20,000	5	
20,001 - 25,000	4	1b
25,001 - 30,000	3	
30,001 - 35,000	2	
More than 35,000	1	

9.3 TECHNICAL ACCOUNT

9.3.1 Storage Efficiency Sub-Account

9.3.1.1 Storage Efficiency Indicator

The indicator used was the storage efficiency ratio. The alternative with the highest ratio received the maximum score, and the other alternative received a lower score according to the indicator value ranges in the following table. Based on the adopted indicator value ranges presented below, TSF 1b (at 10.7) scored 6 and TSF 1c (at 10.0) scored 5.

Storage Efficiency Indicator		TSF
Range	**Score**	
10.5 or More	6	1b
10.0 - 10.4	5	1c
9.5 - 9.9	4	
9.0 - 9.4	3	
8.5 - 8.9	2	
8.4 or Less	1	

9.3.2 Ease of Operation Sub-Account

9.3.2.1 Length of Road/Pipeline Indicator

The length of road pipeline indicator was used to reflect ease of operation associated with the following issues:

- Longer roads between the ore processing plant and the TSF require proportionately more maintenance, including more manpower and materials.
- Longer pipelines between the plant and TSF require proportionately higher pumping power, which often results in increased operating complexity; this is due in large part to the higher pressure pumps, pipelines, and fittings that are needed.
- Longer pipelines between the ore processing plant and TSF, and a consequent greater susceptibility of pipe blockage due to freezing or sanding, require proportionately more maintenance, including more manpower and materials.

The shortest road/pipeline length is desired, and thus received the maximum score. Based on the adopted indicator value ranges presented below, TSF 1b (1 km) scored 6 and TSF 1c (5 km) scored 2.

Length of Road/Pipeline Indicator		TSF
Range (km)	Score	
1	6	1b
2	5	
3	4	
4	3	
5	2	1c
>5	1	

9.3.2.2 Number of Personnel Indicator

The indicator used was the number of personnel that are required to operate the TSF. Site 1b has a relatively smaller embankment length and volume requiring less effort for embankment raises and spigot positioning for tailings deposition and also has a relatively short pipeline to operate and maintain. Site 1c has a relatively larger embankment length and volume requiring more effort for embankment raises and spigot positioning for tailings deposition and also has a relatively long pipeline to operate and maintain. The alternative that is easiest to operate due to smaller embankment length and volume and the shorter pipeline is most desired, and thus received the maximum score. Based on the adopted indicator value ranges presented below, TSF 1b scored 6 and TSF 1c scored 4.

Number of Personnel Indicator		TSF
Range	Score	
Smallest Workforce	6	1b
	5	
Larger Workforce	4	1c
	3	
Largest Workforce	2	
	1	

9.3.2.3 Amount of Equipment Indicator

The indicator used was the equipment that is required to operate the TSF. Site 1b has a relatively smaller embankment length and volume requiring less effort for embankment raises and spigot positioning for tailings deposition and also has a relatively short pipeline to operate requiring smaller pumps. Site 1c has a relatively larger embankment length and volume requiring more effort for embankment raises and spigot positioning for tailings deposition and also has a relatively long pipeline to operate requiring larger pumps. The alternative that is easiest to operate due to smaller embankment length and volume and the shorter pipeline is most desired, and thus received the maximum score. Based on the adopted indicator value ranges presented below, TSF 1b scored 6 and TSF 1c scored 4.

Amount of Equipment Indicator		TSF
Range	Score	
Smallest Equipment Requirement	6	1b
	5	
Larger Equipment Requirement	4	1c
	3	
Largest Equipment Requirement	2	
	1	

9.3.2.4 Susceptibility to Difficulties Indicator

Considering the proximity of the two locations, there are no site specific differences in climate that should render one location more susceptible to inclement conditions than the other; however, the length of the road/pipeline and the area of the TSF do expose the alternatives to slightly different susceptibility to difficulties resulting from the climate. For this indicator the shortest road/pipeline length and smallest TSF area are desired, and thus received the maximum score. Based on the adopted indicator value ranges presented below, TSF 1b (1 km and 785 Ha) scored 6 and TSF 1c (5 km and 750 Ha) scored 5.

Susceptibility to Difficulties Indicator		TSF
Range	Score	
Lowest Susceptibility	6	1b
	5	1c
Higher Susceptibility	4	
	3	
Highest Susceptibility	2	
	1	

9.3.3 Ease of Closure Sub-Account

9.3.3.1 Water Management Indicator

Water management was the major consideration in assessing the relative ease of closure of the two alternatives. Water management during Closure and Post-Closure is typically simpler when all the Project infrastructure is in close proximity. At the end of Operation for Site 1b, run-off from the TSF can drain by gravity through an engineered channel to the open pit to both accelerate filling of the pit and allow for a single water treatment plant and point of discharge. This will not be practical with Site 1c where, for the purposes of this assessment, it is assumed that TSF run-off would be pumped through a pipeline to the open pit. Thus, compared to TSF Site 1c, TSF Site 1b allows for a centralized approach to water treatment, and a single point of discharge for ease of managing and monitoring both water quality and potential environmental effects.

The alternative with the highest ease of closure was assigned the maximum score, and the other alternative received a lower score according to the indicator value ranges in the following table. The range of scores available for the “Medium” and “Moderate” indicator values allows some flexibility in applying expert knowledge and judgement to assigning an appropriate indicator score to an alternative. Based on the adopted indicator value ranges presented below, TSF 1b (at High) scored 6 and TSF 1c (at Medium) scored 4.

Water Management Indicator		**TSF**
Range	Score	
High	6	1b
Medium	5	
	4	1c
Moderate	3	
	2	
Low	1	

9.3.3.2 Reclamation of Disturbed Areas Indicator

The indicator used was the TSF surface area requiring reclamation in hectares. For this indicator the smallest TSF area is desired, and thus received the maximum score. Based on the adopted indicator value ranges presented below, TSF 1c (750 Ha) scored 6 and TSF 1b (785 Ha) scored 5.

Reclamation of Disturbed Areas Indicator		**TSF**
Range (ha)	Score	
750 or Less	6	1c
751 - 800	5	1b
801 - 850	4	
851 - 900	3	
901 - 950	2	
More than 950	1	

9.4 ECONOMIC ACCOUNT

As discussed in Sections 7.1.4 and 7.2.4, all costs were discounted at 8% annually to the start of operations, consistent with requirements for prospective mining developments at the feasibility study level.

9.4.1 Mining Costs Sub-Account

9.4.1.1 Capital Costs Indicator

Capital costs related to waste and water management were provided by the engineering team with Site 1b having an estimated cost of $101.9 M and Site 1c having an estimated cost of $128.1 M. The difference in costs for this indicator was largely related to the construction of the starter dam(s) in each option. The alternative with the lowest cost received the maximum score, and the other alternative received a lower score according to the indicator value ranges in the following table. Based on the adopted indicator value ranges presented below, TSF 1b (at $101.9 M) scored 6 and TSF 1c (at $128.1 M) scored 5.

Capital Costs Indicator		**TSF**
Range ($M)	Score	
110 or Less	6	1b
111 - 130	5	1c
131 - 150	4	
151 - 170	3	
171 - 190	2	
More than 190	1	

9.4.1.2 Operational Costs Indicator

Operational costs include estimates for the dam raises, disposal of tailings and waste rock, water management, etc. Operation costs were provided by the engineering team with Site 1b having an estimated cost of $139.9 M and Site 1c having an estimated cost of $382.1 M. The higher Site 1c costs are due to the greater distances over which tailings and return water need to be pumped, and over which waste rock must be hauled for storage in the TSF; as well, maintenance of pumps and pipework will be greater. The alternative with the lowest cost received the maximum score, and the other alternative received a lower score according to the indicator value ranges in the following table. Based on the adopted indicator value ranges presented below, TSF 1b (at $139.9 M) scored 6 and TSF 1c (at $382.2 M) scored 2.

Operational Costs Indicator		TSF
Range ($M)	Score	
150 or Less	6	1b
151 - 225	5	
226 - 300	4	
301 - 375	3	
376 - 450	2	1c
More than 450	1	

9.4.1.3 Closure and Reclamation Costs Indicator

Closure and reclamation costs for each TSF location were provided by the design engineering team with Site 1b having an estimated cost of $20.5 M and Site 1c having an estimated cost of $20.6 M. The primary difference in closure costs between the two TSF locations was related to the need to pump surplus water from Site 1c to the open pit rather than the gravity transfer afforded by Site 1b. The alternative with the lowest cost received the maximum score, and the other alternative received a lower score according to the indicator value ranges in the following table. For this sub-account, the costs were virtually the same, and both alternatives scored 6.

Closure and Reclamation Costs Indicator		TSF
Range ($M)	Score	
25 or Less	6	1b, 1c
26 - 30	5	
31 - 35	4	
36 - 40	3	
41 - 50	2	
More than 50	1	

9.4.2 Environmental Costs Sub-Account

9.4.2.1 Fish Habitat Offset Costs Indicator

The proposed offset project is the removal of an old water-level control dam and road culvert on the Nashwaak River just below its outlet from Nashwaak Lake, and its replacement with a forest road bridge. Since the amount of permanent aquatic habitat loss at Site 1b is much greater than at Site 1c, the offset project would be more than suitable to offset losses from the latter site. And since the offset project cannot be down-sized to suit just the losses that would occur from locating the TSF at Site 1c, the same offset project cost ($180,000) has been applied to both alternatives. Based on the adopted indicator value ranges presented in the table below, both alternatives scored 6.

Fish Habitat Offset Costs Indicator		TSF
Range ($)	Score	
200,000 or Less	6	1b, 1c
200,001 - 225,000	5	
225,001 - 250,000	4	
250,001 - 275,000	3	
275,001 - 300,000	2	
More than 300,000	1	

9.4.2.2 Wetland Compensation Costs Indicator

The most recent guidance on wetland mitigation from the Province of New Brunswick was provided in the 2003 Proposed Wetland Mitigation Guidelines for New Brunswick (NBDNR 2003). Currently, the Province requires that any loss of GeoNB-mapped wetlands be compensated, typically at a 2:1 ratio to accommodate for any lag in wetland function that constructed or restored wetlands might exhibit relative to the natural wetlands lost. Of the total amount of wetlands in TSF Sites 1b and 1c, 27.9 ha and 17.9 ha are GeoNB-mapped wetlands, respectively; thus the respective compensation areas would be 55.8 ha and 35.8 ha, respectively. (Note that while there is a larger area of modelled wetland in Site 1c than in Site 1b (see Section 9.1.3), much less of it is GeoNB-mapped wetland.) An acceptable method of wetland compensation in New Brunswick is to contract with Ducks Unlimited (DU) to undertake the work; DU's flat rate is $30,000 per hectare and this rate was used for the purposes of this analysis. Thus, the wetland compensation costs for TSF 1b would be $1.67 M and for TSF 1c would be $1.07 M. The alternative with the lowest cost received the maximum score, and the other alternative received a lower score according to the indicator value ranges in the following table. Based on the adopted indicator value ranges presented below, TSF 1c scored 6 and TSF 1b scored 4.

Wetland Compensation Costs Indicator		TSF
Range ($M)	Score	
1.25 or Less	6	1c
1.26 - 1.50	5	
1.51 - 1.75	4	1b
1.76 - 2.00	3	
2.01 - 2.25	2	
More than 2.25	1	

9.5 ACCOUNT WEIGHTING

As discussed in Section 3.5.1, MAA establishes numerical weights to be used in evaluating the relative contribution that each account or sub-account makes to the analysis. The weights introduce a “value bias” into the analysis, and varying the weights in a sensitivity analysis allows an examination of how different value sets affect the MAA results.

For this MAA, the sum of the weights across all accounts and sub-accounts was 100. Each account (environmental, socio-economic, technical and economic) was assigned a portion of the 100 weight “points”, then that portion was divided up among its sub-accounts. As discussed in Section 3.5.1, the Environment Canada guidance (Environment Canada 2013) recommended a base case account weighting scale based on a 13.5 point scale which was converted to the 100-point scale used in this assessment as shown in Table 9.1.

Table 9.1 Base Case Weighting

Account	Environment Canada Guidance Scale	Base Case Scale
Environmental	6	44
Socio-Economic	3	22
Technical	3	22
Economic	1.5	12
Total	**13.5**	**100**

The analysis took the approach of applying equal weights to each sub-account/indicator within an account. This assumes that each sub-account/indicator holds equal importance within each account. The sensitivity analysis (Section 10) generally varied only the relative weights of the accounts. As discussed above, this general approach was varied for the Land and Resource Use and Archaeology sub-accounts where testing the robustness of the MAA results to the sub-account indicator scores for Current Use of Land and Resources for Traditional Purposes by Aboriginal Persons and Archeological Potential was also considered necessary.

9.6 QUANTITATIVE ANALYSIS

A base case analysis was implemented with the account weighting provided in Section 9.5, and the sub-account indicator scores provided in Sections 9.1 through 9.4. The results of the base case analysis are presented in Table 9.1. Site 1b received a higher total merit score (538) than Site 1c (462), and is the preferred alternative.

Table 9.2 Base Case Analysis

TSF Site Alternative	Indicator Value		Indicator Score		Base Case		
	TSF 1b	TSF 1c	TSF 1b	TSF 1c	Weight	TSF 1b	TSF 1c
Environment Account							
Water and Fisheries Sub-Account							
Area in Napadogan Brook Watershed (%)	100	80	6	4	6.3	38	25
Area of Permanent Aquatic Habitat Loss (m^2)	22,365	13,914	4	6	6.3	25	38
Number of Streams	6	9	6	3	6.3	38	19
Water and Fisheries Sub-Account Merit Score					**18.9**	**101**	**82**
Terrestrial Habitat Sub-Account							
Area of Permanent Loss of Interior Forest (ha)	109	70	4	6	6.3	25	38
Area of Permanent Wetland Loss (ha)	161	202	6	5	6.3	38	31
Terrestrial Habitat Sub-Account Merit Score					**12.6**	**63**	**69**
Air Quality Sub-Account							
GHG emissions (t CO2e/yr)	16,484	64,009	6	2	6.3	38	13
Potential for Dust Emissions	1	5	6	2	6.3	38	13
Air Quality Sub-Account Merit Score					**12.6**	**75**	**25**
Environmental Account Merit Score					**44**	**239**	**176**
Socio-Economic Account							
Land and Resource Use Sub-Account							
Traditional Use by Aboriginal Persons	785	750	5	6	7.3	37	44
Use by Non-Aboriginal Persons	785	750	5	6	7.3	37	44
Land and Resource Use Sub-Account Merit Score					**14.7**	**73**	**88**
Archaeological Potential Sub-Account							
Archaeological Potential	22,365	13,914	4	6	7.3	29	44
Archaeological Potential Sub-Account Merit Score					**7.3**	**29**	**44**
Socio-Economic Account Merit Score					**22**	**103**	**132**
Technical Account							
Storage Efficiency Sub-Account							
Storage Efficiency	10.7	10.0	6	5	3.1	19	16
Storage Efficiency Sub-Account Merit Score					**3.1**	**19**	**16**
Ease of Operation Sub-Account							
Length of Road/Pipeline (km)	1	5	6	2	3.1	19	6
Number of Personnel	Smallest Workforce	Larger Workforce	6	4	3.1	19	13
Amount of Equipment	Smallest Equipment Requirement	Larger Equipment Requirement	6	4	3.1	19	13
Susceptibility to Difficulties	Lowest Susceptibility	Lowest Susceptibility	6	5	3.1	19	16
Ease of Operation Sub-Account Merit Score					**12.6**	**75**	**47**
Ease of Closure Sub-Account							
Water Management	High	Medium	6	4	3.1	19	13
Reclamation of Disturbed Areas (ha)	785	750	5	6	3.1	16	19
Ease of Closure Sub-Account Merit Score					**6.3**	**35**	**31**
Technical Account Merit Score					**22**	**129**	**94**
Economic Account							
Mining Cost Sub-Account							
Capital Costs ($ M)	101.9	128.1	6	5	2.4	14	12
Operational Costs($ M)	139.9	382.1	6	2	2.4	14	5
Closure Costs ($ M)	20.5	20.6	6	6	2.4	14	14
Mining Costs Sub-Account Merit Score					**7.2**	**43**	**31**
Environmental Cost Sub-Account							
Fish Habitat Offset Costs ($)	180,000	180,000	6	6	2.4	14	14
Wetland Compensation Costs ($ M)	1.67	1.07	4	6	2.4	10	14
Environmental Costs Sub-Account Merit Score					**4.8**	**24**	**29**
Economic Account Merit Score					**12**	**67**	**60**
Total Merit Score					**100**	**538**	**462**

10 – SENSITIVITY ANALYSIS (STEP 6)

10.1 WEIGHTING FACTOR SENSITIVITY ANALYSIS

As described in the MAA methodology (Section 3.6), sensitivity analyses were completed to determine how the MAA results would change by varying the relative weights assigned to different accounts. The account weighting cases that were considered in the sensitivity analysis are summarized in Table 10.1. They considered equal weighting of accounts and sub-accounts (Cases #1 and #2, respectively) and then represented a progression of increasing relative importance in the environmental and socio-economic accounts with decreasing relative importance in the technical and economic accounts (Cases #3 through #6).

Table 10.1 Account Weighting Cases Considered in the Sensitivity Analysis

Account	Sensitivity Case Weights					
	1	2 (Equal Sub-account Weights)	3	4	5	6
Environment	25	30	60	60	70	80
Socio-Economic	25	20	30	30	30	20
Technical	25	30	5	10	0	0
Economic	25	20	5	0	0	0
Total	**100**	**100**	**100**	**100**	**100**	**100**

The results of the weighting factor sensitivity analyses are summarized in Table 10.2 and are presented in detail in Table 10.3 and 10.4. The weighting factor sensitivity analysis results were that Site 1b consistently received a higher total merit score than Site 1c, and is the preferred alternative.

Table 10.2 Overall MCA Results – Total Merit Scores – Weighting Factor Sensitivity Analyses

Sensitivity Case	Account Weights	Total Merit Score	
		TSF Site 1b	TSF Site 1c
1	22 – 25 – 25 - 25	539	482
2	30 – 20 – 30 - 20	538	479
3	60 – 30 – 5 - 5	523	466
4	60 – 30 – 10 - 0	524	463
5	70 – 30 - 0 - 0	520	460
6	80 – 20 – 0 - 0	528	440

Table 10.3 Account Weighting Sensitivity Analysis Cases 1, 2 and 3.

	Indicator Value		Indicator Score		Sensitivity Case #1 (Equal Account Weights)			Sensitivity Case #2 (Equal Sub-Account Weights)			Sensitivity Case #3 (Account Weights 60-30-5-5)		
TSF Site Alternative	**TSF 1b**	**TSF 1c**	**TSF 1b**	**TSF 1c**	**Weight**	**TSF 1b**	**TSF 1c**	**Weight**	**TSF 1b**	**TSF 1c**	**Weight**	**TSF 1b**	**TSF 1c**
Environment Account													
Water and Fisheries Sub-Account													
Area in Napadogan Brook Watershed (%)	100	80	6	4	3.6	21	14	3.3	20	13	8.6	51	34
Area of Permanent Aquatic Habitat Loss (m^2)	22,365	13,914	4	6	3.6	14	21	3.3	13	20	8.6	34	51
Number of Streams	6	9	6	3	3.6	21	11	3.3	20	10	8.6	51	26
Water and Fisheries Sub-Account Merit Score					**10.7**	**57**	**46**	**10.0**	**53**	**43**	**25.7**	**137**	**111**
Terrestrial Habitat Sub-Account													
Area of Permanent Loss of Interior Forest (ha)	109	70	4	6	3.6	14	21	5.0	20	30	8.6	34	51
Area of Permanent Wetland Loss (ha)	161	202	6	5	3.6	21	18	5.0	30	25	8.6	51	43
Terrestrial Habitat Sub-Account Merit Score					**7.1**	**36**	**39**	**10.0**	**50**	**55**	**17.1**	**86**	**94**
Air Quality Sub-Account													
GHG emissions (t CO2e/yr)	16,484	64,009	6	2	3.6	21	7	5.0	30	10	8.6	51	17
Potential for Dust Emissions	1	5	6	2	3.6	21	7	5.0	30	10	8.6	51	17
Air Quality Sub-Account Merit Score					**7.1**	**43**	**14**	**10.0**	**60**	**20**	**17.1**	**103**	**34**
Environmental Account Merit Score					**25**	**136**	**100**	**30**	**163**	**118**	**60**	**326**	**240**
Socio-Economic Account													
Land and Resource Use Sub-Account													
Traditional Use by Aboriginal Persons	785	750	5	6	8.3	42	50	5.0	25	30	10.0	50	60
Use by Non-Aboriginal Persons	785	750	5	6	8.3	42	50	5.0	25	30	10.0	50	60
Land and Resource Use Sub-Account Merit Score					**16.7**	**83**	**100**	**10.0**	**50**	**60**	**20.0**	**100**	**120**
Archaeological Potential Sub-Account													
Archaeological Potential	22,365	13,914	4	6	8.3	33	50	10.0	40	60	10.0	40	60
Archaeological Potential Sub-Account Merit Score					**8.3**	**33**	**50**	**10.0**	**40**	**60**	**10.0**	**40**	**60**
Socio-Economic Account Merit Score					**25**	**117**	**150**	**20**	**90**	**120**	**30**	**140**	**180**
Technical Account													
Storage Efficiency Sub-Account													
Storage Efficiency	10.7	10.0	6	5	3.6	21	18	10.0	60	50	0.7	4	4
Storage Efficiency Sub-Account Merit Score					**3.6**	**21**	**18**	**10.0**	**60**	**50**	**0.7**	**4**	**4**
Ease of Operation Sub-Account													
Length of Road/Pipeline	1	5	6	2	3.6	21	7	2.5	15	5	0.7	4	1
Number of Personnel	Small Workforce	Medium Workforce	6	4	3.6	21	14	2.5	15	10	0.7	4	3
Amount of Equipment	Smallest Equipment Requirement	Larger Equipment Requirement	6	4	3.6	21	14	2.5	15	10	0.7	4	3
Susceptibility to Difficulties	Lowest Susceptibility	Lowest Susceptibility	6	5	3.6	21	18	2.5	15	13	0.7	4	4
Ease of Operation Sub-Account Merit Score					**14.3**	**86**	**54**	**10.0**	**60**	**38**	**2.9**	**17**	**11**
Ease of Closure Sub-Account													
Water Management	High	Medium	6	4	3.6	21	14	5.0	30	20	0.7	4	3
Reclamation of Disturbed Areas	785	750	5	6	3.6	18	21	5.0	25	30	0.7	4	4
Ease of Closure Sub-Account Merit Score					**7.1**	**39**	**36**	**10.0**	**55**	**50**	**1.4**	**8**	**7**
Technical Account Merit Score					**25**	**146**	**107**	**30**	**175**	**138**	**5**	**29**	**21**
Economic Account													
Mining Cost Sub-Account													
Capital Costs ($ M)	101.9	128.1	6	5	5.0	30	25	3.3	20	17	1.0	6	5
Operational Costs($ M)	139.9	382.1	6	2	5.0	30	10	3.3	20	7	1.0	6	2
Closure Costs ($ M)	20.5	20.6	6	6	5.0	30	30	3.3	20	20	1.0	6	6
Mining Costs Sub-Account Merit Score					**15.0**	**90**	**65**	**10.0**	**60**	**43**	**3.0**	**18**	**13**
Environmental Cost Sub-Account													
Fish Habitat Offset Costs ($)	180,000	180,000	6	6	5.0	30	30	5.0	30	30	1.0	6	6
Wetland Compensation Costs ($ M)	1.67	1.07	4	6	5.0	20	30	5.0	20	30	1.0	4	6
Environmental Costs Sub-Account Merit Score					**10.0**	**50**	**60**	**10.0**	**50**	**60**	**2.0**	**10**	**12**
Economic Account Merit Score					**25**	**140**	**125**	**20**	**110**	**103**	**5**	**28**	**25**
Total Merit Score					**100**	**539**	**482**	**100**	**538**	**479**	**100**	**523**	**466**

Table 10.4 Account Weighting Sensitivity Analysis Cases 4, 5 and 6.

	Indicator Value		Indicator Score		Sensitivity Case #4 (Account Weights 60-30-10-0)			Sensitivity Case #5 (Account Weights 70-30-0-0)			Sensitivity Case #6 (Account Weights 80-20-0-0)		
TSF Site Alternative	TSF 1b	TSF 1c	TSF 1b	TSF 1c	Weight	TSF 1b	TSF 1c	Weight	TSF 1b	TSF 1c	Weight	TSF 1b	TSF 1c
Environment Account													
Water and Fisheries Sub-Account													
Area in Napadogan Brook Watershed (%)	100	80	6	4	8.6	51	34	10.0	60	40	11.4	69	46
Area of Permanent Aquatic Habitat Loss (m^2)	22,365	13,914	4	6	8.6	34	51	10.0	40	60	11.4	46	69
Number of Streams	6	9	6	3	8.6	51	26	10.0	60	30	11.4	69	34
Water and Fisheries Sub-Account Merit Score					**25.7**	**137**	**111**	**30.0**	**160**	**130**	**34.3**	**183**	**149**
Terrestrial Habitat Sub-Account													
Area of Permanent Loss of Interior Forest (ha)	109	70	4	6	8.6	34	51	10.0	40	60	11.4	46	69
Area of Permanent Wetland Loss (ha)	161	202	6	5	8.6	51	43	10.0	60	50	11.4	69	57
Terrestrial Habitat Sub-Account Merit Score					**17.1**	**86**	**94**	**20.0**	**100**	**110**	**22.9**	**114**	**126**
Air Quality Sub-Account													
GHG emissions (t CO2e/yr)	16,484	64,009	6	2	8.6	51	17	10.0	60	20	11.4	69	23
Potential for Dust Emissions	1	5	6	2	8.6	51	17	10.0	60	20	11.4	69	23
Air Quality Sub-Account Merit Score					**17.1**	**103**	**34**	**20.0**	**120**	**40**	**22.9**	**137**	**46**
Environmental Account Merit Score					**60**	**326**	**240**	**70**	**380**	**280**	**80**	**434**	**320**
Socio-Economic Account													
Land and Resource Use Sub-Account													
Traditional Use by Aboriginal Persons	785	750	5	6	10.0	50	60	10.0	50	60	6.7	33	40
Use by Non-Aboriginal Persons	785	750	5	6	10.0	50	60	10.0	50	60	6.7	33	40
Land and Resource Use Sub-Account Merit Score					**20.0**	**100**	**120**	**20.0**	**100**	**120**	**13.3**	**67**	**80**
Archaeological Potential Sub-Account													
Archaeological Potential	22,365	13,914	4	6	10.0	40	60	10.0	40	60	6.7	27	40
Archaeological Potential Sub-Account Merit Score					**10.0**	**40**	**60**	**10.0**	**40**	**60**	**6.7**	**27**	**40**
Socio-Economic Account Merit Score					**30**	**140**	**180**	**30**	**140**	**180**	**20**	**93**	**120**
Technical Account													
Storage Efficiency Sub-Account													
Storage Efficiency	10.7	10.0	6	5	1.4	9	7	0.0	0	0	0.0	0	0
Storage Efficiency Sub-Account Merit Score					**1.4**	**9**	**7**	**0.0**	**0**	**0**	**0.0**	**0**	**0**
Ease of Operation Sub-Account													
Length of Road/Pipeline	1	5	6	2	1.4	9	3	0.0	0	0	0.0	0	0
Number of Personnel	Small Workforce	Medium Workforce	6	4	1.4	9	6	0.0	0	0	0.0	0	0
Amount of Equipment	Smallest Equipment Requirement	Larger Equipment Requirement	6	4	1.4	9	6	0.0	0	0	0.0	0	0
Susceptibility to Difficulties	Lowest Susceptibility	Lowest Susceptibility	6	5	1.4	9	7	0.0	0	0	0.0	0	0
Ease of Operation Sub-Account Merit Score					**5.7**	**34**	**21**	**0.0**	**0**	**0**	**0.0**	**0**	**0**
Ease of Closure Sub-Account													
Water Management	High	Medium	6	4	1.4	9	6	0.0	0	0	0.0	0	0
Reclamation of Disturbed Areas	785	750	5	6	1.4	7	9	0.0	0	0	0.0	0	0
Ease of Closure Sub-Account Merit Score					**2.9**	**16**	**14**	**0.0**	**0**	**0**	**0.0**	**0**	**0**
Technical Account Merit Score					**10**	**59**	**43**	**0**	**0**	**0**	**0**	**0**	**0**
Economic Account													
Mining Cost Sub-Account													
Capital Costs ($ M)	101.9	128.1	6	5	0.0	0	0	0.0	0	0	0.0	0	0
Operational Costs($ M)	139.9	382.1	6	2	0.0	0	0	0.0	0	0	0.0	0	0
Closure Costs ($ M)	20.5	20.6	6	6	0.0	0	0	0.0	0	0	0.0	0	0
Mining Costs Sub-Account Merit Score					**0.0**	**0**	**0**	**0.0**	**0**	**0**	**0.0**	**0**	**0**
Environmental Cost Sub-Account													
Fish Habitat Offset Costs ($)	180,000	180,000	6	6	0.0	0	0	0.0	0	0	0.0	0	0
Wetland Compensation Costs ($ M)	1.67	1.07	4	6	0.0	0	0	0.0	0	0	0.0	0	0
Environmental Costs Sub-Account Merit Score					**0.0**	**0**	**0**	**0.0**	**0**	**0**	**0.0**	**0**	**0**
Economic Account Merit Score					**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total Merit Score					**100**	**524**	**463**	**100**	**520**	**460**	**100**	**528**	**440**

10.2 INDICATOR SCORE SENSITIVITY ANALYSIS

Sensitivity analyses were completed to determine how the MAA results would change if the indicator scores for the Traditional Use by Aboriginal Persons and Archeology sub-accounts were varied. Sensitivity analyses were carried out using the Base Case and Sensitivity Weighting Case #5, which had the highest socio-economic weighting.

For the base case, the Traditional Use by Aboriginal Persons indicator was scored based on the area of the TSF footprint at each site (Section 9.2.1). On this basis, Site 1b (score = 5) was slightly less desirable than Site 1c (score = 6). For the sensitivity analysis, the indicator score for Site 1b was reduced to 4 and then 3 to reflect the possibility that it may be used more intensely for traditional purposes by Aboriginal persons.

For the base case, the Archaeological Potential indicator was scored based on area of aquatic habitat loss serving as a reliable predictor for archaeological potential. On this basis, Site 1b (score = 4) was less desirable than Site 1c (score = 6). For the sensitivity analysis, the indicator score for Site 1b was reduced to 3 and then 2 to reflect the possibility that it may have a higher archaeological potential than indicated by the loss of aquatic habitat.

The adjusted scores used in the sensitivity analyses are shown in Table 10.5.

Table 10.5 Sub-Account Scoring Scenarios Considered in the Sensitivity Analysis

Sub-Account	Base Case		Scenario 1		Scenario 2	
	Site 1b	Site 1c	Site 1b	Site 1c	Site 1b	Site 1c
Traditional Use by Aboriginal Persons	5	6	4	6	3	6
Archaeological Potential	4	6	3	6	2	6

The results of the sensitivity analysis for indicator scores are presented in detail in Tables 10.6 and 10.7.

Table 10.6 Scoring Sensitivity Analyses (Scenario 1)

	Indicator Value		Indicator Score		Base Case			Sensitivity Case #5 (Account Weights 70-30-0-0)		
TSF Site Alternative	TSF 1b	TSF 1c	TSF 1b	TSF 1c	Weight	TSF 1b	TSF 1c	Weight	TSF 1b	TSF 1c
Environment Account										
Water and Fisheries Sub-Account										
Area in Napadogan Brook Watershed (%)	100	80	6	4	6.3	38	25	10.0	60	40
Area of Permanent Aquatic Habitat Loss (m^2)	22,365	13,914	4	6	6.3	25	38	10.0	40	60
Number of Streams	6	9	6	3	6.3	38	19	10.0	60	30
Water and Fisheries Sub-Account Merit Score					**18.9**	**101**	**82**	**30.0**	**160**	**130**
Terrestrial Habitat Sub-Account										
Area of Permanent Loss of Interior Forest (ha)	109	70	4	6	6.3	25	38	10.0	40	60
Area of Permanent Wetland Loss (ha)	161	202	6	5	6.3	38	31	10.0	60	50
Terrestrial Habitat Sub-Account Merit Score					**12.6**	**63**	**69**	**20.0**	**100**	**110**
Air Quality Sub-Account										
GHG emissions (t CO2e/yr)	16,484	64,009	6	2	6.3	38	13	10.0	60	20
Potential for Dust Emissions	1	5	6	2	6.3	38	13	10.0	60	20
Air Quality Sub-Account Merit Score					**12.6**	**75**	**25**	**20.0**	**120**	**40**
Environmental Account Merit Score					**44**	**239**	**176**	**70**	**380**	**280**
Socio-Economic Account										
Land and Resource Use Sub-Account										
Traditional Use by Aboriginal Persons	785	750	4	6	7.3	29	44	10.0	40	60
Use by Non-Aboriginal Persons	785	750	5	6	7.3	37	44	10.0	50	60
Land and Resource Use Sub-Account Merit Score					**22.0**	**66**	**88**	**20.0**	**90**	**120**
Archaeological Potential Sub-Account										
Archaeological Potential	22,365	13,914	3	6	7.3	22	44	10.0	30	60
Archaeological Potential Sub-Account Merit Score					**7.3**	**22**	**44**	**10.0**	**30**	**60**
Socio-Economic Account Merit Score					**22**	**88**	**132**	**30**	**120**	**180**
Technical Account										
Storage Efficiency Sub-Account										
Storage Efficiency	10.7	10.0	6	5	3.1	19	16	0.0	0	0
Storage Efficiency Sub-Account Merit Score					**3.1**	**19**	**16**	**0.0**	**0**	**0**
Ease of Operation Sub-Account										
Length of Road/Pipeline	1	5	6	2	3.1	19	6	0.0	0	0
Number of Personnel	Small Workforce	Medium Workforce	6	4	3.1	19	13	0.0	0	0
Amount of Equipment	Smallest Equipment Requirement	Larger Equipment Requirement	6	4	3.1	19	13	0.0	0	0
Susceptibility to Difficulties	Lowest Susceptibility	Lowest Susceptibility	6	5	3.1	19	16	0.0	0	0
Ease of Operation Sub-Account Merit Score					**12.6**	**75**	**47**	**0.0**	**0**	**0**
Ease of Closure Sub-Account										
Water Management	High	Medium	6	4	3.1	19	13	0.0	0	0
Reclamation of Disturbed Areas	785	750	5	6	3.1	16	19	0.0	0	0
Ease of Closure Sub-Account Merit Score					**6.3**	**35**	**31**	**0.0**	**0**	**0**
Technical Account Merit Score					**22**	**129**	**94**	**0**	**0**	**0**
Economic Account										
Mining Cost Sub-Account										
Capital Costs ($ M)	101.9	128.1	6	5	2.4	14	12	0.0	0	0
Operational Costs($ M)	139.9	382.1	6	2	2.4	14	5	0.0	0	0
Closure Costs ($ M)	20.5	20.6	6	6	2.4	14	14	0.0	0	0
Mining Costs Sub-Account Merit Score					**7.2**	**43**	**31**	**0.0**	**0**	**0**
Environmental Cost Sub-Account										
Fish Habitat Offset Costs ($)	180,000	180,000	6	6	2.4	14	14	0.0	0	0
Wetland Compensation Costs ($ M)	1.67	1.07	4	6	2.4	10	14	0.0	0	0
Environmental Costs Sub-Account Merit Score					**4.8**	**24**	**29**	**0.0**	**0**	**0**
Economic Account Merit Score					**12**	**67**	**60**	**0**	**0**	**0**
Total Merit Score					**100**	**523**	**462**	**100**	**500**	**460**

Table 10.7 Scoring Sensitivity Analysis (Scenario 2)

	Indicator Value		Indicator Score		Base Case			Sensitivity Case #5 (Account Weights 70-30-0-0)		
TSF Site Alternative	TSF 1b	TSF 1c	TSF 1b	TSF 1c	Weight	TSF 1b	TSF 1c	Weight	TSF 1b	TSF 1c
Environment Account										
Water and Fisheries Sub-Account										
Area in Napadogan Brook Watershed (%)	100	80	6	4	6.3	38	25	10.0	60	40
Area of Permanent Aquatic Habitat Loss (m^2)	22,365	13,914	4	6	6.3	25	38	10.0	40	60
Number of Streams	6	9	6	3	6.3	38	19	10.0	60	30
Water and Fisheries Sub-Account Merit Score					**18.9**	**101**	**82**	**30.0**	**160**	**130**
Terrestrial Habitat Sub-Account										
Area of Permanent Loss of Interior Forest (ha)	109	70	4	6	6.3	25	38	10.0	40	60
Area of Permanent Wetland Loss (ha)	161	202	6	5	6.3	38	31	10.0	60	50
Terrestrial Habitat Sub-Account Merit Score					**12.6**	**63**	**69**	**20.0**	**100**	**110**
Air Quality Sub-Account										
GHG emissions (t CO2e/yr)	16,484	64,009	6	2	6.3	38	13	10.0	60	20
Potential for Dust Emissions	1	5	6	2	6.3	38	13	10.0	60	20
Air Quality Sub-Account Merit Score					**12.6**	**75**	**25**	**20.0**	**120**	**40**
Environmental Account Merit Score					**44**	**239**	**176**	**70**	**380**	**280**
Socio-Economic Account										
Land and Resource Use Sub-Account										
Traditional Use by Aboriginal Persons	785	750	**3**	6	7.3	22	44	10.0	30	60
Use by Non-Aboriginal Persons	785	750	5	6	7.3	37	44	10.0	50	60
Land and Resource Use Sub-Account Merit Score					**22.0**	**59**	**88**	**20.0**	**80**	**120**
Archaeological Potential Sub-Account										
Archaeological Potential	22,365	13,914	**2**	6	7.3	15	44	10.0	20	60
Archaeological Potential Sub-Account Merit Score					**7.3**	**15**	**44**	**10.0**	**20**	**60**
Socio-Economic Account Merit Score					**22**	**73**	**132**	**30**	**100**	**180**
Technical Account										
Storage Efficiency Sub-Account										
Storage Efficiency	10.7	10.0	6	5	3.1	19	16	0.0	0	0
Storage Efficiency Sub-Account Merit Score					**3.1**	**19**	**16**	**0.0**	**0**	**0**
Ease of Operation Sub-Account										
Length of Road/Pipeline	1	5	6	2	3.1	19	6	0.0	0	0
Number of Personnel	Small Workforce	Medium Workforce	6	4	3.1	19	13	0.0	0	0
Amount of Equipment	Smallest Equipment Requirement	Larger Equipment Requirement	6	4	3.1	19	13	0.0	0	0
Susceptibility to Difficulties	Lowest Susceptibility	Lowest Susceptibility	6	5	3.1	19	16	0.0	0	0
Ease of Operation Sub-Account Merit Score					**12.6**	**75**	**47**	**0.0**	**0**	**0**
Ease of Closure Sub-Account										
Water Management	High	Medium	6	4	3.1	19	13	0.0	0	0
Reclamation of Disturbed Areas	785	750	5	6	3.1	16	19	0.0	0	0
Ease of Closure Sub-Account Merit Score					**6.3**	**35**	**31**	**0.0**	**0**	**0**
Technical Account Merit Score					**22**	**129**	**94**	**0**	**0**	**0**
Economic Account										
Mining Cost Sub-Account										
Capital Costs ($ M)	101.9	128.1	6	5	2.4	14	12	0.0	0	0
Operational Costs($ M)	139.9	382.1	6	2	2.4	14	5	0.0	0	0
Closure Costs ($ M)	20.5	20.6	6	6	2.4	14	14	0.0	0	0
Mining Costs Sub-Account Merit Score					**7.2**	**43**	**31**	**0.0**	**0**	**0**
Environmental Cost Sub-Account										
Fish Habitat Offset Costs ($)	180,000	180,000	6	6	2.4	14	14	0.0	0	0
Wetland Compensation Costs ($ M)	1.67	1.07	4	6	2.4	10	14	0.0	0	0
Environmental Costs Sub-Account Merit Score					**4.8**	**24**	**29**	**0.0**	**0**	**0**
Economic Account Merit Score					**12**	**67**	**60**	**0**	**0**	**0**
Total Merit Score					**100**	**508**	**462**	**100**	**480**	**460**

The indicator score sensitivity analyses using Scenarios 1 and 2 and the Base Case Weighting and Weighting Sensitivity Case #5 (70-30-0-0) all indicated that Site 1b would be preferred over Site 1c. These results strongly suggest that the TSF site selection process would still favour the selection of Site 1b even if the values attributed to both the Traditional Use by Aboriginal Persons indicator and the Archaeological Potential indicator were both substantially misjudged by the assessor.

11 – SUMMARY AND CONCLUSIONS

An assessment of tailings management alternatives for the Sisson Project was undertaken in conformance with the guidance provided by Environment Canada (Environment Canada 2013) to provide information in support of amending Schedule 2 of the *Metal Mining Effluent Regulations*.

The pre-screening evaluation of tailings management technologies revealed that the preferred alternative is conventional slurry disposal.

A pre-screening evaluation of TSF locations was completed which revealed that the site alternatives 1b and 1c should be subject to the multiple accounts assessment.

The base case evaluation in the MAA clearly indicated that Site 1b is the preferred TSF location.

A sensitivity analysis was completed to determine what effect modifying the relative importance (weight) of the environmental, socio-economic, technical, and economic accounts would have on the overall merit scores. These alternate account weighting cases considered equal weighting of accounts and sub-accounts, and then represented a progression of increasing relative importance in the environmental and socio-economic accounts with decreasing relative importance in the technical and economic accounts. Under all alternate account weighting cases, the MAA continued to clearly indicate that Site 1b is the preferred TSF location.

Another sensitivity analysis varied the indicator score for the two indicators that had been scored based on proxy information – Traditional Use by Aboriginal Persons and Archaeological Potential. Under the two scenarios that were analyzed, the value of both indicators was lowered progressively for Site 1b, making it less desirable for these two assessment factors. Analysis of both indicator scoring sensitivity scenarios utilizing the Base Case Weighting and Weighting Sensitivity Case #5 (70-30-0-0) indicated a continuing preference for Site 1b.

The assessment of tailings management alternatives for the Sisson Project, completed in conformance with the Environment Canada guidance (Environment Canada 2013), resulted in the preferred tailings management alternative being conventional slurry disposal at the Site 1b TSF location.

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12 – REFERENCES

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13 – CERTIFICATION

This report was prepared and reviewed by the undersigned.

Prepared:

for: Ryan Stinson, M.Sc., R.P.Bio.
Senior Scientist

Reviewed:

Greg Smyth, B.Sc.
Project Manager | Associate

Approval that this document adheres to Knight Piésold Quality Systems: DF.

APPENDIX A

APT WASTE CHARACTERIZATION AND STORAGE

(Pages A-1 to A-3)

The process of refining tungsten concentrate to ammonium paratungstate (APT) is summarized in Section 3.4.2.2.3 and on Figure 3.4.8 of the EIA Report (Stantec 2013). This process generates two waste streams that will be disposed of within the TSF:

1. The first waste stream is undigested residue from the concentrate digestion process. It is generated as a filter cake (about 25% water, by weight), containing calcium hydroxide with trace minerals and oxides, at a rate of approximately 68 tonnes/day.
2. The second waste stream is raffinate[2] generated during the solvent extraction process that converts sodium tungstate to ammonium tungstate. The raffinate consists of 10% to 15% sodium sulfate in a sulphuric acid solution with minor concentrations of molybdenum, silicates and aluminum, and likely some trace metals. The raffinate will be mixed with lime and pH adjusted in an agitation tank, and will then be passed through a crystallizer to remove the metals and other constituents as a dry product at a rate of approximately 0.8 tonnes per day. The product is primarily sodium sulphate, with minor components of calcium sulphate (gypsum) and trace metals.

These two waste streams cannot be stored directly in the TSF because their effects on TSF water quality would reduce concentrator efficiency (e.g., calcium ions would adversely affect tungsten flotation recoveries) and seepage water quality (notably regarding sodium and sulphate). Therefore, they will be placed in storage cells within the TSF basin, but above the active TSF pond level during Operation. The cells will be double-lined with HDPE, and also equipped with a leak detection and recovery system, to ensure they will not leak during Operation. During Operation, precipitation recovered from an open cell will be pumped to treatment before reuse or discharge. Fences or other suitable safety measures will be used as needed to limit access by people or animals to the cells during Operation.

Over the life of the Project, there may be up to six of these cells, staged consecutively from the northwest to the northeast of the plant site between the elevations of approximately 335 masl and 370 masl. Only three cells are required to contain the estimated volume of solids described above: 400,000 m^3, 300,000 m^3 and 650,000 m^3 for Cells 1, 2 and 3, respectively. Figures 1 through 3 below depict the cells at the end of each period. Additional cells have been considered as a contingency measure in the event that the actual quantity or density of the wastes varies from the current estimate.

Cell 1 will be built and operated first (Figure 1) and, as it fills and the level of tailings, waste rock and water rises in the TSF, it will be capped and closed and Cell 2 will go into operation at a higher elevation (Figure 2). Similarly, Cell 2 will be operated, closed and superseded by Cell 3 at a higher elevation (Figure 3). The crest elevation of the Cell 3 embankments will be about 370 masl; at Closure the TSF pond elevation is at about 377 masl, so Cell 3 will be submerged under about 7 m of tailings and water.

The solids stored in each cell will be allowed to consolidate to the extent possible prior to closure of the cell. Methods that may be used to enhance consolidation include allowing the solids to air dry during the dry summer months prior to closure, or the use of wick drains and strip drains. Closure of

[2] In solvent extraction, a “raffinate” is the liquid stream which remains after solutes from the original liquid are removed through contact with an immiscible liquid.

a cell will involve capping it with a HDPE top liner before it becomes encapsulated by tailings within the TSF.

Once the cells are encapsulated within the TSF, it is highly unlikely that pore water in the tailings would interact with the material in the cells. The HDPE top and bottom liners present a very low permeability barrier to groundwater flow; therefore, seepage between the TSF and the groundwater beneath it would not flow through the cells, but preferentially around them. Furthermore, when the cells are closed and encapsulated, the groundwater conditions within the TSF will be such that seepage into or out of the cells is improbable.

The size, number and location of the cells will be confirmed during the Basic and Detailed Engineering design phases of the Project.

The cells will be designed to be stable, self-contained structures within the TSF, and gradually covered with tailings, so that their contents are securely isolated. Thus, in the highly unlikely event of a failure of TSF containment, the cells and their contents would remain intact.

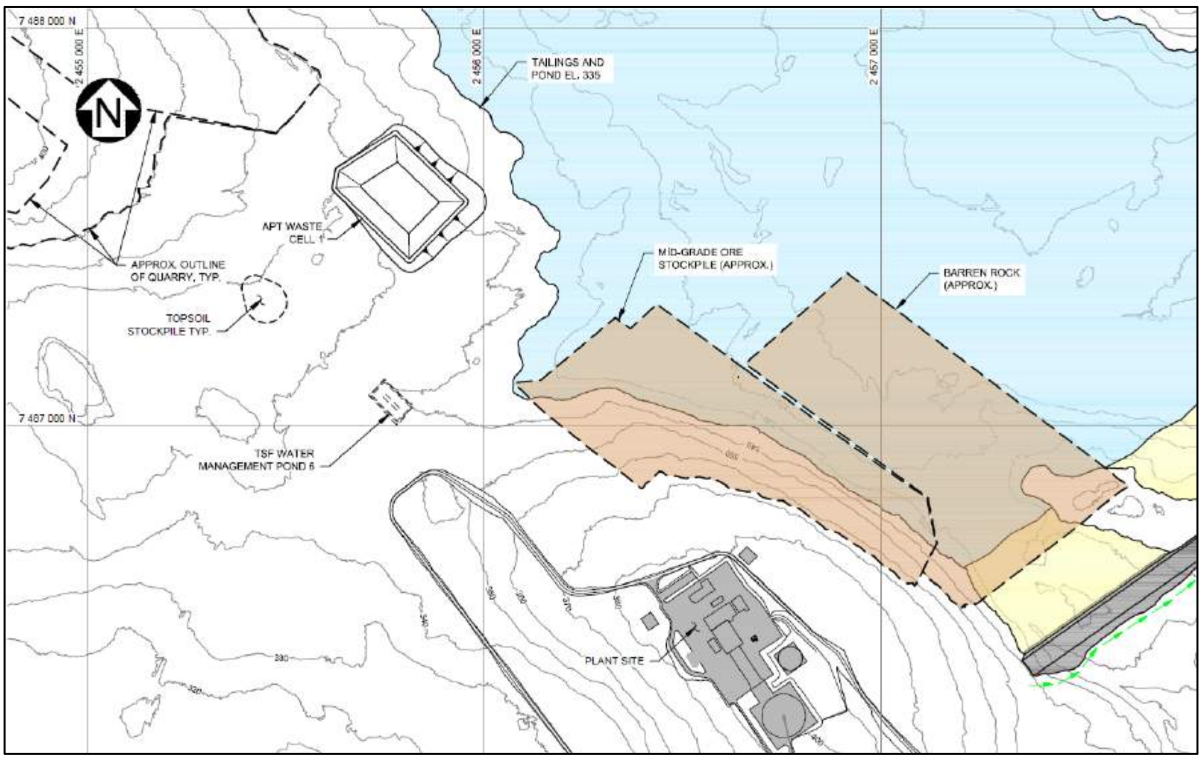

Figure 1 APT Waste Cell 1 – Years 1 to 8

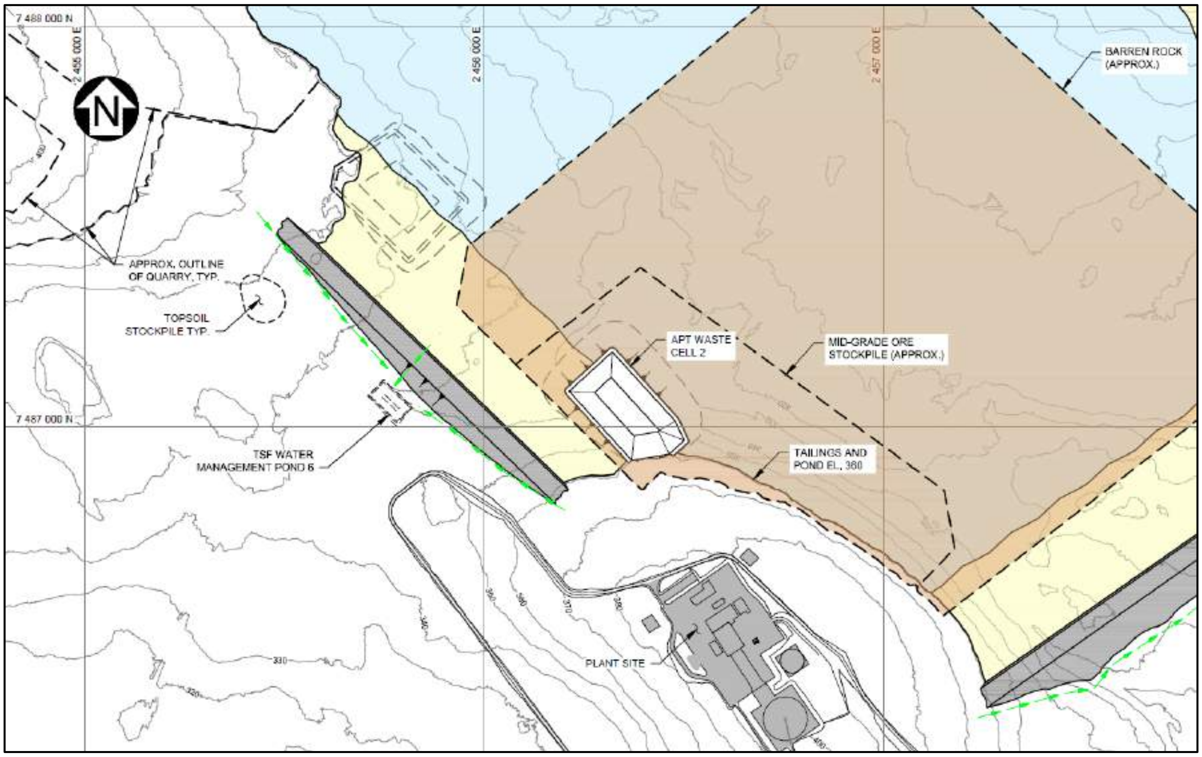

Figure 2 APT Waste Cell 2 – Years 9 to 14

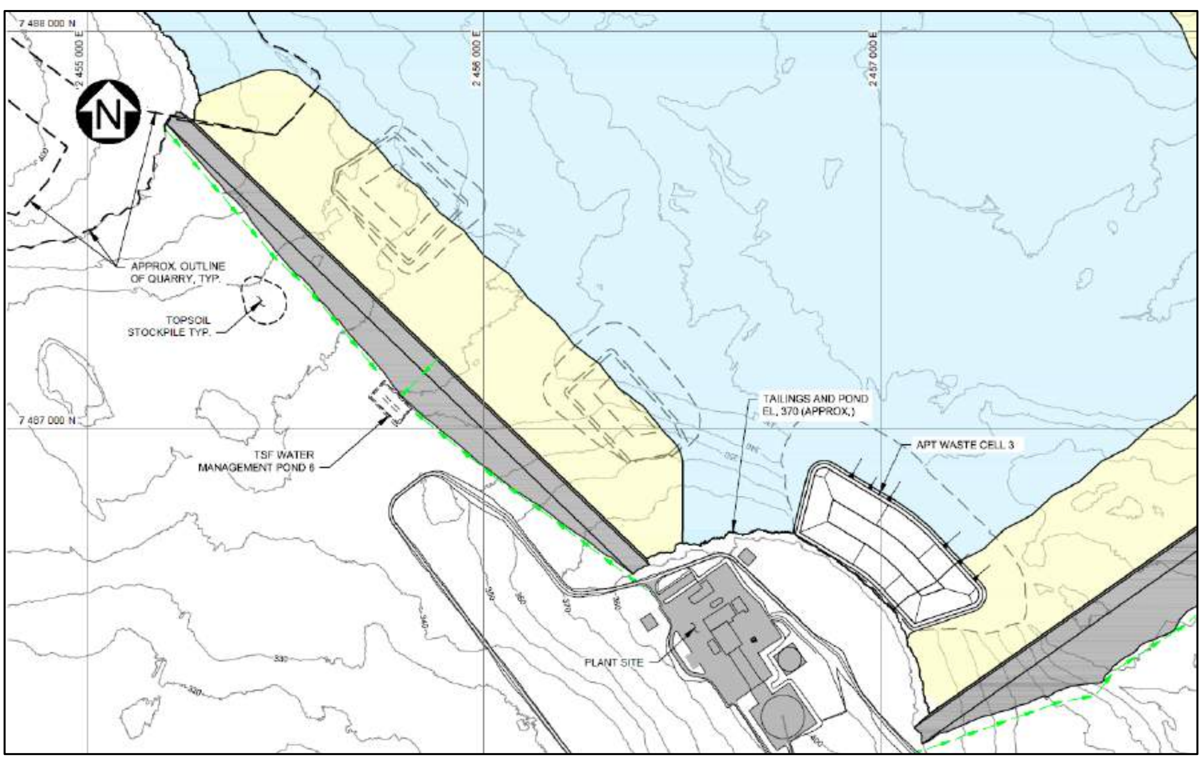

Figure 3 APT Waste Cell 3 – Years 15 to 27

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APPENDIX B

DESIGN BASIS FOR THE TSF

(Pages B-1 to B-2)

The TSF is being designed to exceed the requirements set forth in the Canadian Dam Association "Dam Safety Guidelines" (Canadian Dam Association 2007) to ensure it will readily withstand the effects of extreme storm events and earthquakes. These Guidelines are the recommended standard design practice for major impoundments, water management facilities and dams, and are used by the Province of New Brunswick in permitting structures like the Sisson TSF.

Application of the Dam Safety Guidelines requires that a "hazard classification" be made of the TSF to enable appropriate design earthquake and flood events to be determined based on the classification criteria provided by the Guidelines. The classification of a TSF is carried out by considering the potential incremental consequences of an embankment failure. The incremental consequences of failure are defined as the total damage from an event with dam failure minus the damage that would have resulted from the same event had the dam not failed. The incremental losses consider loss of life, environmental and cultural values, and infrastructure and economic impacts. At Sisson, a failure of the TSF embankment and resultant tailings or process water release could significantly affect downstream watercourses and habitats that have substantial ecological and societal value, and the hazard classification of the Sisson TSF was therefore set to ensure a design that will protect these values.

Storm Events

Selection of an appropriate Inflow Design Flood (IDF) was required to carry out a safety assessment of the TSF and to estimate flood storage requirements. The size of the IDF increases with increasing consequences of failure. Based on the hazard classification assigned to the Sisson TSF, an appropriate IDF is a probabilistically-derived event with a return period of two-thirds between the 1-in-1,000-year flood and the Probable Maximum Flood (PMF). The PMF is defined as the most severe flood that may reasonably be expected to occur at a particular location. Although the deterministically derived PMF does not have a probability of occurrence associated with it, it can be compared to approximately a 1-in-20,000 year event. To be conservative, the IDF for the Sisson TSF was set at the deterministically derived 24-hour PMF. The TSF is designed with sufficient capacity and freeboard to store the PMF at all times during Operation. The storm storage volume required during Operation is approximately 4.8 Mm^3, corresponding to an equivalent run-off depth of 0.58 m.

Earthquakes

An assessment of the regional seismicity has been carried out to enable selection of appropriate design earthquake events and ground motions.

<u>Seismicity Assessment</u>

As discussed in Section 6.3.1.3.1 of the EIA Report, Eastern Canada is located in a stable continental region within the North American tectonic plate, and has a relatively low rate of seismic activity. However, moderate to large earthquakes have occurred in the region and will occur in the future. Review of historical earthquake records and regional tectonics indicates that the Sisson Project site is situated in a region of low seismicity. A probabilistic seismic hazard analysis has been carried out using historical earthquake data and the regional tectonics to identify potential seismic sources and to estimate the maximum earthquake magnitude for each seismic source. The corresponding median maximum acceleration is 0.07g for a return period of 500 years.

<u>Design Earthquake</u>

Consistent with the current design philosophy for geotechnical structures such as dams, two levels of design earthquake have been considered: the Operating Basis Earthquake (OBE) for normal operations, and the Maximum Design Earthquake (MDE) for extreme conditions (ICOLD 1995). Values of maximum ground acceleration and design earthquake magnitude have been determined for both the OBE and MDE.

The Dam Safety Guidelines recommend that the mean maximum acceleration value should be used for dam design. This is likely to be similar or slightly higher (by about 20%) than the median value provided by Natural Resources Canada (NRCan 2013). Consequently, estimated mean maximum acceleration values have been adopted for the design earthquake events used in seismic stability analyses.

The OBE has been taken as the 1-in-500-year return period event for the design of the TSF. The probability of exceedance for this event is approximately 5% for a 27-year operating period. The mean average maximum acceleration is estimated to be 0.07g for the 1-in-500-year earthquake. A design earthquake magnitude of 7.0 on the Richter scale has been conservatively selected for the OBE based on a review of regional tectonics and historical seismicity. The TSF is expected to function in a normal manner after the OBE.

An appropriate MDE for embankment design has been selected based on the dam hazard classification defined for the TSF and the criteria for design earthquakes provided by the Dam Safety Guidelines. With this classification, the Dam Safety Guidelines require that a dam be designed for a probabilistically-derived event (known as the Earthquake Design Ground Motion) having an annual exceedance probability (AEP) of 1-in-5,000. Consequently, the MDE selected for the TSF is the 1-in-5,000-year earthquake which has an estimated mean average maximum acceleration of 0.37g. A design earthquake magnitude of 7.0 on the Richter scale has been conservatively selected for the MDE based on a review of regional tectonics and historical seismicity. Limited deformation of the tailings embankment is acceptable under seismic loading from the MDE, provided that the overall stability and integrity of the TSF is maintained and that there is no release of stored tailings or water (ICOLD 1995).

<u>Stability Analysis</u>

Embankment stability analyses were carried out for both static and seismic conditions under the following cases:

- Static conditions during Operation and Post-Closure
- Earthquake loading from the Operating Basis Earthquake (OBE) and the Maximum Design Earthquake (MDE), and
- Post-earthquake conditions using residual (post-liquefaction) tailings strengths.

The results of the stability analyses satisfy the requirements for factor of safety and indicate that the proposed design is acceptable to maintain both short-term (Operation phase) and long-term (Post-Closure) stability. The seismic analyses indicate that any embankment deformations during earthquake loading from the OBE or MDE will be minor and will not have a significant impact on embankment freeboard or result in any loss of embankment integrity. The results also indicate that the embankments are not dependent on tailings strength to maintain overall stability and integrity.