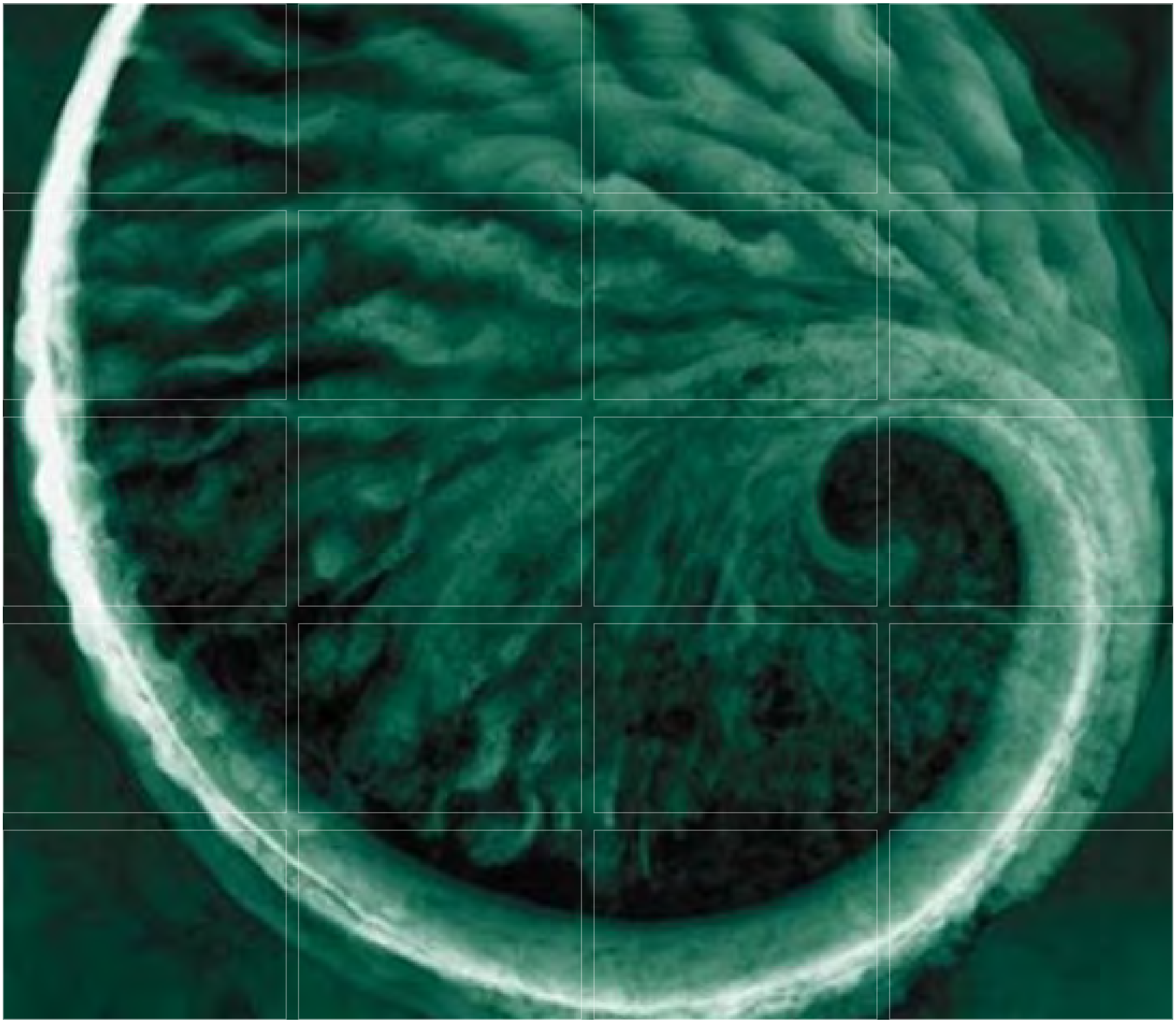

Prepared for:

CASINO
BUILDING OUR FUTURE TOGETHER

CASINO MINE PROJECT

BAT Study for Tailings and Waste Rock Management

Main Report

November 2018

ERM

The business of sustainability

Casino Mining Corporation

CASINO MINE PROJECT

BAT Study for Tailings and Waste Rock Management

November 2018

Project #0376359

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ACKNOWLEDGEMENTS

Casino Mining Corp. (CMC) has undertaken this Best Available Technology (BAT) study for tailings and waste rock management with the assistance of Environmental Resources Management Ltd. (ERM) as the BAT study facilitator, and Knight Piésold Ltd. (KP) as the design engineer for the tailings management and waste rock facilities. Other consultants who have provided input into the study include Lorax Environmental Services Ltd. (Lorax) for geochemistry, Contango Strategies Ltd. for treatment wetlands, Environmental Dynamics Inc. for terrestrial ecology and wildlife, Hemmera for socio-economics and community, Marsland Environmental Associates for water quality, and Palmer Environmental Consulting Group for fisheries.

CMC established the Tailings Working Group to participate in and provided input to the study. The value of the input provided by this group cannot be understated. Among others, First Nations' representatives were involved throughout the study and provided comments and feedback, and raised questions that were instrumental in advancing the study. CMC will continue to work with this group to seek their input on refinements to the Project's mine waste management plans as the project moves forward. CMC greatly appreciates the investment of time and technical insight that has been provided by the working group throughout the study.

EXECUTIVE SUMMARY

CASINO PROJECT

Casino Mining Corporation (CMC) is proposing to develop the Casino Project (the Project), an open pit copper and gold mine located approximately 200 km west of Carmacks, and 300 km northwest of Whitehorse in Yukon, Canada. The Project includes an open pit, processing facilities, heap leach facility, temporary stockpiles, and associated infrastructure. The mine site will be accessed via a 120 km all-weather access road that will connect to the existing Freegold Road 83 km from Carmacks. The mine's water supply will be provided from the Yukon River via an approximate 17 km above-ground pipeline.

The Project is designed to process approximately 120,000 tonnes per day (t/d) of sulphide ore through a concentrator facility to produce copper and molybdenum concentrates, and to leach oxide ore to produce gold-silver doré bars over the 22-year mine life. During the life-of-mine operations, the Project will produce an estimated 956 Mt of tailings, of which 20% is classified as potentially acid generating (PAG) and 658 Mt of potentially reactive waste rock and overburden materials.

The mine site and a portion of the access road are located within the traditional territory of Selkirk First Nation (SFN). A portion of the access road is located within the traditional territory of Little Salmon/Carmacks First Nation (LSCFN), and the water supply pipeline is located within the overlapping traditional territories of Tr'ondëk Hwëch'in (TH) and SFN. The Kluane First Nation (KFN) and White River First Nation (WRFN) traditional territories are located downstream from the proposed mine and aspects of the project are within the asserted traditional territory of the WRFN.

BACKGROUND

In January 2014, CMC submitted an application to the Yukon Environmental and Socio-Economic Assessment Board (YESAB) for screening in advance of submitting applications for regulatory authorizations. In February 2016, following two rounds of information requests in 2014 and 2015, the YESAB Executive Committee determined that the Casino Project would require a panel review under the *Yukon Environmental and Socio-Economic Assessment Act* (YESAA). In citing its reasons for requiring a panel review, the Executive Committee stated that while "perpetual sub-aqueous storage of tailings and waste rock behind an engineered structure has been a generally accepted method of disposing of mine tailings", there is a "growing debate among Yukon First Nations, experts in the mining and engineering industries, governments and members of the public within and outside of Yukon on how to ensure both the geochemical stability of PAG tailings and waste rock and the physical stability of tailings dams in perpetuity"[1].

Recognizing the importance of safe and environmentally sound management of tailings and mine waste rock, CMC decided to defer the commencement of the panel review process, and undertook a

[1] Environmental and Socio-economic Effects Statement Guidelines. Panel of the Board Review Casino Mining Corporation Casino Mine. Yukon Environmental and Socio-economic Assessment Board (YESAB). June 20, 2016.

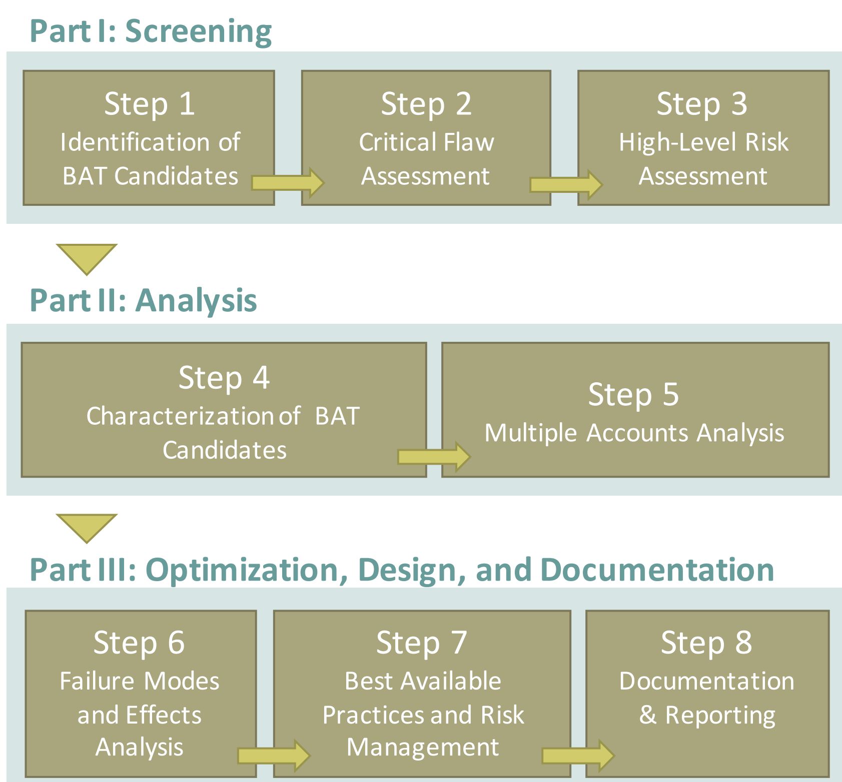
Best Available Technology (BAT) study to evaluate the design and approach for managing waste rock and flotation tailings. A BAT study considers and compares alternative locations, technologies, high level risks, and best available management practices for tailings and waste rock management.

Importantly, CMC established the Tailings Working Group (TWG) to provide input as the BAT study progressed. The TWG included representatives of First Nation governments, including their technical advisors, Yukon and federal government representatives, and a representative from YESAB. The group met in-person and by teleconference over 17 months (April 2017 to August 2018) to conduct the BAT study. The TWG reviewed the results and decisions made at each step of the study. Participation in the working group was without prejudice and does not constitute approval of the Project. The TWG functioned as an "information sharing" forum, rather than an advisory group.

METHODOLOGY

The BAT study followed the methods in Environment and Climate Change Canada's *Guidelines for the Assessment of Mine Waste Disposal* (2016), with supplemental analysis in two additional steps: 1) a high-level risk assessment, to identify lower-risk candidates; and 2) a failure modes and effects analysis, to identify and evaluate potential failure modes associated with the preferred alternative(s). Figure ES-1 identifies the steps in the BAT study.

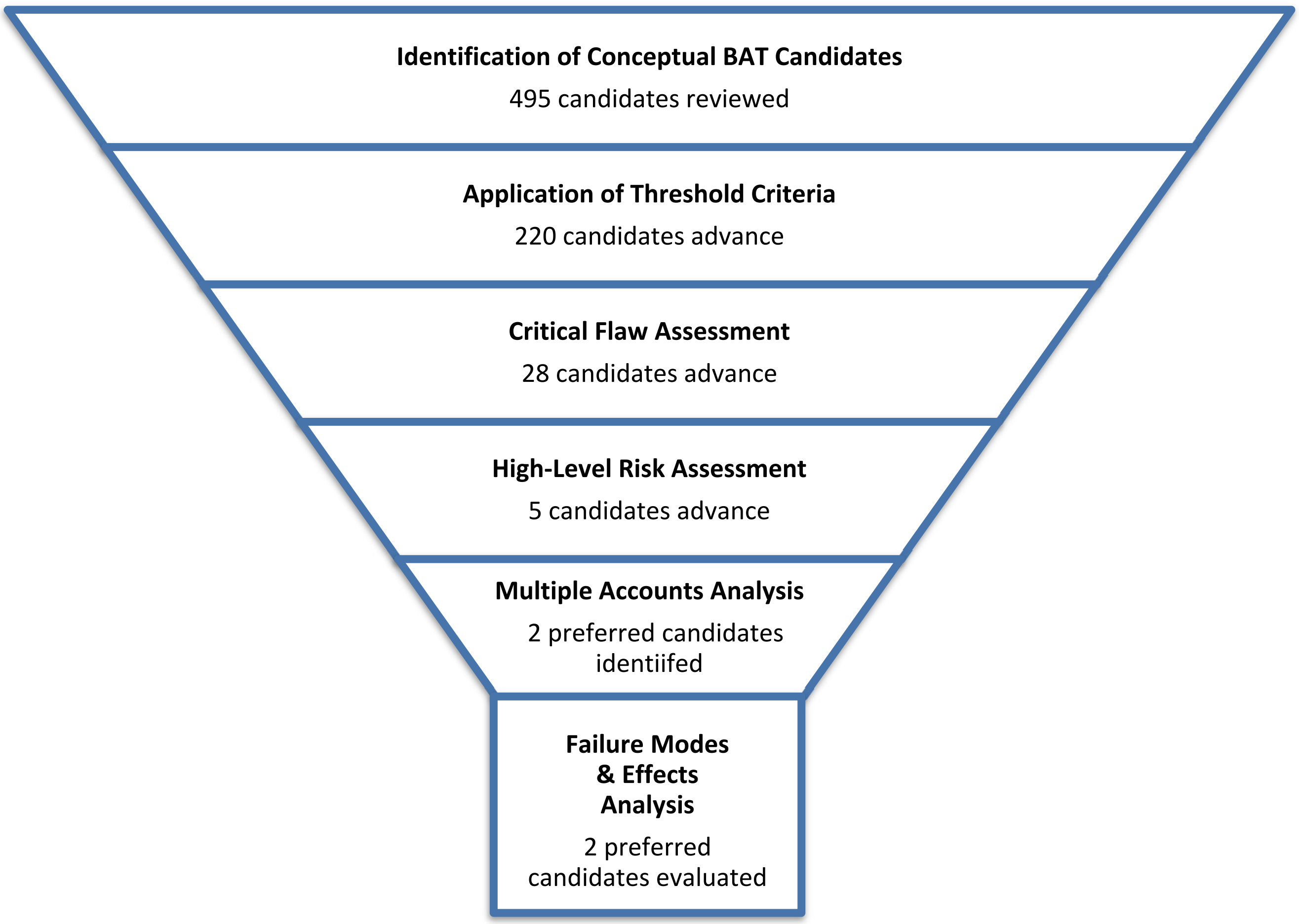
Figure ES-1. BAT Study Steps



BAT Process Overview

The BAT study began in April 2017, with initial engagement of the TWG, establishment of the TWG terms of reference, and review of the planned BAT study methods. Over the course of the study, BAT candidates were systematically identified, eliminated and refined, as summarized in Figure ES-2 and described in the sections below.

Figure ES-2. Candidate Refinement through the BAT Study



Identification of BAT Candidates

CMC identified a combined total of 495 conceptual candidates by considering 11 possible locations and 45 possible configurations for tailings and waste rock storage (i.e., thickened, paste or filtered tailings; and sub-aerial or sub-aqueous waste rock storage).

Threshold criteria, including distance (i.e., 20 km from the deposit), storage capacity (i.e., sufficient storage capacity in a single or combination of locations, for the anticipated volume of tailings and waste rock produced over the life of the mine), and site characteristics (i.e., topography, foundation conditions, terrain stability, water management, and accessibility), were used to identify realistic BAT candidates and narrow the number of conceptual candidates. Applying the threshold criteria resulted in the elimination of the Lower Dip Creek site (45 candidates) due to an unreasonably large upstream catchment area, and a further 23 configurations with paste tailings technology, as paste tailings technology was found to be incompatible with the climate in the Project area. In total, 220 candidates met the threshold criteria and advanced to the Critical Flaw Assessment step.

CRITICAL FLAW ASSESSMENT

The critical flaw assessment eliminated candidates with flaws that could not reasonably be managed or mitigated. In consultation with the working group, CMC determined that sites with discharge to the Yukon River (i.e., sites at Coffee Creek, Excelsior Creek, Canadian Creek, Lower Britannia Creek, Upper Britannia Creek, and Sunshine Creek) were unacceptable due to their proximity—and related risk of impact—to this important regional waterway. Additionally, candidates that involved filtered PAG tailings, and those with sub-aerial waste rock storage, were also eliminated. Twenty-eight candidates, comprising of 4 sites and 7 configurations, passed the critical flaw test and advanced to the high-level risk assessment.

HIGH-LEVEL RISK ASSESSMENT

The high-level risk assessment (HLRA) aimed to identify and eliminate those candidates with higher levels of risk. The risk assessment was conducted in two parts. First, a high-level comparison of the candidates was reviewed at a workshop with the TWG, which resulted in the elimination of some sites and configurations due to clear disadvantages. This included elimination of the Upper Casino Creek site as it had the highest dam and no significant advantage over the Middle Casino Creek site, and the Upper Dip Creek site was eliminated due to the larger and undisturbed catchment area, potential permafrost conditions, and higher habitat values. Two of the configuration types were also eliminated in the HLRA based on: 1) the inability to provide secondary containment of PAG tailings upstream of waste rock, to ensure that in the event of a dam failure, the PAG tailings will not be released from the TMF area; and 2) the number of acid-generating impoundments.

The second part of the HLRA involved comparing and evaluating the remaining candidates in consultation with the TWG with respect to their relative risks in terms of safety, environment, and technical execution. The conclusion of these two parts resulted in five of the lower-risk candidates being selected to advance to the multiple accounts analysis (MAA). As identified in Table ES-1, these sites included both the Middle Casino and Lower Casino sites, with either a ponded water cover or a water table cover over the waste rock and PAG tailings at closure, as well as a fifth candidate that was adjusted to include management of a portion of the NAG tailings stream as a filtered stack; this candidate was located at Lower Casino Creek, with a ponded water cover over the waste rock and PAG tailings at closure. This fifth candidate was included at the request of the TWG.

Table ES-1. Candidates for Multiple Accounts Analysis

Candidate	Location	NAG Tailings	Closure Concept
MC-25	Middle Casino	Thickened slurry	Water Table Cover
LC-25	Lower Casino	Thickened slurry	Water Table Cover
MC-28	Middle Casino	Thickened slurry	Ponded Water Cover
LC-28	Lower Casino	Thickened slurry	Ponded Water Cover
LC-34	Lower Casino	Thickened slurry + filtered stack	Ponded Water Cover

CHARACTERIZATION OF BAT CANDIDATES

The five remaining candidates were characterized across five accounts: technical, biophysical environment, human environment, economics, and consequences of dam failure and 48 indicators across 16 sub-accounts that were identified in conjunction with the TWG (Table ES-2). These relevant and differentiating accounts, sub-accounts and indicators also provided the framework for the MAA.

Table ES-2. Summary of Accounts, Sub-Accounts and Indicators

Account	Sub-Account	Indicator
Technical	Operational risk	Complexity of mine waste transport
		Complexity of operational water management
		Complexity of closure cover
		Complexity of embankment structure
	Geochemical Stability	ARD mitigation challenges (operations)
		ARD mitigation challenges (post-closure)
		Metal leaching potential (operations)
		Metal leaching potential (post-closure)
		Adaptability of ML/ARD mitigation strategy for early closure
	Water management	Control of operational water balance
		Complexity of underdrain system
		Complexity of post-closure water management
		Ability to implement active water treatment (post-closure)
	Physical stability	Extent of foundation for dam(s)/stacks
		Enhanced stability (post-closure)
Biophysical Environment	Air quality	Fugitive dust emissions (TMF surface)
		TMF hauling distance
	Groundwater	Seepage Management (operations)
		Seepage Management (post-closure)
	Surface water quality	Degradation of downstream water quality (operations)
		Degradation of downstream water quality (post-closure)
		TMF wetland requirements (post-closure)
	Fish and aquatic habitat	Extent of fish habitat loss (direct)
		Quality of lost fish habitat (direct)
		Changes to surface water hydrology (operations)
		Diversity of directly affected fish community
		Diversity of directly affected benthic invertebrate community
	Terrestrial habitat	Direct loss of wetlands
		Risk of metals uptake to wildlife (plant-based)
		Risk of metals uptake to wildlife (water-based)

(continued)

Table ES-2. Summary of Accounts, Sub-Accounts and Indicators (completed)

Account	Sub-Account	Indicator
Human Environment	Archaeology and cultural heritage	Disturbance to known archaeological site(s)
		Disturbance to historic sites
	First Nations' Interests	Cultural and/or spiritual relationship to the environment
		First Nations' ability to pursue land use and cultural activities
		Sensory disturbance during operations
	Recreational and commercial land use	Built structures
		Sensory disturbance during operations
	End land use	Post-closure landscape
Economics	TMF Economics	Net Present Cost
Consequences of Dam Failure	Fair weather failure	Volume of water (post-closure)
		Dam factor (post-closure)
		Tailings deposition
		Secondary impact of dam failure (post-closure)
	Flood-induced failure	Volume of water (post-closure)
		Dam factor (operations)
		Dam factor (post-closure)
		Tailings deposition
		Secondary impact of dam failure (post-closure)

MULTIPLE ACCOUNTS ANALYSIS

The multiple accounts analysis includes both scoring (data-based) and weighting (value-based) elements to quantitatively calculate the weighted merit rating of each candidate. Each indicator was scored on a scale of one (worst) to six (best) based on the performance of each of the five candidates. Then, each indicator, sub-account and account was given a weighting to reflect its importance in the decision-making process (i.e., indicators within a sub-account were weighted relative to each other, sub-accounts within an account were weighted relative to each other, and accounts were weighted relative to each other). CMC developed weightings in consultation with technical consultants, and provided the opportunity to members of the TWG to also provide their own weightings so that the results could be compared.

Figures ES-3 and ES-4 illustrate the merit ratings for each candidate based on the weightings developed by CMC. The results indicate that both candidates at the Middle Casino (MC) site have significantly higher ratings than the candidates at the Lower Casino (LC) site. Candidates without a closure pond also have higher merit ratings. Overall, MC-25 (Middle Casino, water table cover) has the highest rating, followed by MC-28 (Middle Casino, ponded water cover).

Figure ES-3. Multiple Accounts Analysis – Results by Candidate (CMC's Weightings)

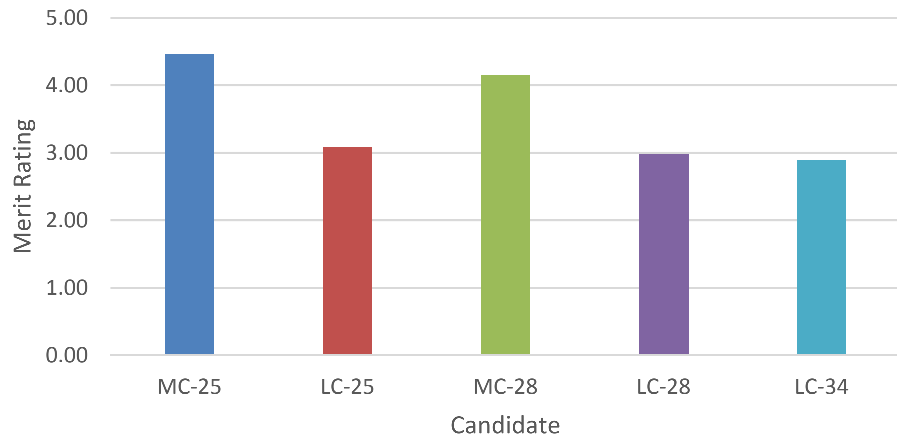


Figure ES-4. Multiple Accounts Analysis – Results by Sub-Account (CMC's Weightings)

Note: Higher account merit rating indicates higher preference.

CMC reviewed the MAA results with the TWG. The group recognized that the difference between the two highest-rated candidates is the type of closure cover, and thus recommended that both MC-25 and MC-28 be evaluated in the failure modes and effects analysis (FMEA).

FAILURE MODES AND EFFECTS ANALYSIS

CMC held several meetings with the TWG to conduct the FMEA, which included both the identification of potential failure modes, and the evaluation of the risk posed by each failure mode. In total, 88 potential failure modes were identified and discussed, and a risk rating was calculated for each failure mode (Table ES-3). Results of the FMEA highlighted the difference in closure cover between MC-25 and MC-28. Risks associated with the water table closure concept (MC-25) relate to the ability to maintain saturation and avoid oxidation of PAG materials in the post-closure phase, whereas risks identified for the closure pond concept (MC-28) include those related to long-term embankment stability and seepage management.

Table ES-3. FMEA Risk Ratings

	Number of Failure Modes			
Risk Rating	MC-25 and MC-28	Specific to MC-25	Specific to MC-28	Totals
Very Low	7	0	0	7
Low	23	3	4	30
Medium	19	9	10	38
High	8	4	1	13
Very High	0	0	0	0
Totals	**57**	**16**	**15**	**88**

CONCLUSIONS AND NEXT STEPS

The BAT study has identified two preferred candidates, MC-25 and MC-28. Both candidates involve zoned storage of thickened NAG and PAG tailings, and waste rock stored behind a cyclone sand embankment located in one facility at the Middle Casino Creek site. The preferred design concept is waste rock located upstream of the NAG tailings, and PAG tailings located within a defined cell within the waste rock storage area.

The candidates differ in terms of closure, and both Ponded Water Cover (MC-28) and a Water Table Cover (MC-25) are identified as viable closure alternatives. Both MC-28 and MC-25 have been evaluated in the FMEA, and the risks identified in the FMEA will be further investigated and mitigated during final design.

Following the results of the BAT Study, CMC will continue to engage with the Tailings Working Group through the advancement of the engineering of the MC-25 and MC-28 options.

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GLOSSARY AND ABBREVIATIONS

Terminology used in this document is defined where it is first used. The following list will assist readers who may choose to review portions of the document.

%	percent
°	degree
°C	degrees Celsius
ARD	acid rock drainage
asl	above sea level
BAP	Best Available Practices
BAT	Best Available Technology
BAT Candidate	tailings and waste rock management alternative including site, technology(ies), and configuration
BC	British Columbia
C&M	Care and maintenance (temporary closure)
CA	Canadian Creek
CAP	oxide cap
CAPEX	Capital costs
CCME	Canadian Council of Ministers for the Environment
Cd	cadmium
CDA	Canadian Dam Association
CMC	Casino Mining Corporation
CO	Coffee Creek
CO_2/year	tonnes of carbon dioxide per year
Cu	copper
ECCC	Environment and Climate Change Canada
ECCC Guidelines	*Guidelines for the Assessment of Alternatives for Mine Waste Disposal*, published by Environment and Climate Change Canada (2016)

ERM	Environmental Resources Management Consultants Canada Ltd.
ESE	Environmental and Socio-economic
EX	Excelsior Creek
Fe	iron
FMEA	failure modes and effects analysis
ha	hectare
HLRA	high-level risk assessment
HYP	hypogene
ICOLD	International Commission on Large Dams
IDF	inflow design flood
IERP	Independent Engineering Review Panel
KFN	Kluane First Nation
km	kilometre
km^2	square kilometre
KP	Knight Piésold Ltd.
kPa	kilopascal
$L/s/km^2$	liter per s per square kilometre
LB	Lower Britannia Creek
LC	Lower Casino
LGO	low grade ore
Lorax	Lorax Environmental Services Ltd.
LSCFN	Little Salmon/Carmacks First Nation
m	metre
m^2	square metre
MAA	multiple accounts analysis
MAC	Mining Association of Canada
MC	Middle Casino

MCE	maximum credible earthquake
MDMER	Metal and Diamond Mining Effluent Regulations
MEA	Marsland Environmental Associates
mg/dm²/day	milligrams per decametre squared per day
ML	metal leaching
mm	millimetre
Mm^2	million square metres
Mm^3	million cubic metres
Mn	manganese
Mo	molybdenum
Mt	megaton
Mt	million tonnes
NAG	Non Acid Generating
Ni	nickel
NO_2	nitrogen dioxide
OPEX	Operating costs
PAG	Potentially Acid Generating
PECG	Palmer Environmental Consulting Group Ltd
PM_{10}	particulate matter 10 micrometers or less
$PM_{2.5}$	particulate matter 2.5 micrometers or less (fine particles)
PMF	probable maximum flood
Se	selenium
SFN	Selkirk First Nation
SHCF	secondary hydraulic containment feature
SM	sand with non-plastic fines
SO_2	sulphur dioxide
SO_4	sulphate

SOR	Statutory Order and Regulation
SU	Sunshine Creek
SUP	supergene
SUS	Supergene Sulphide Mineralization
t/m^3	tonnes per cubic metre
TDS	total dissolved solids
TH	Tr’ondëk Hwëch’in
the Project	Casino Mine Project
TMF	tailings management facility
tpd	tonnes per day
TWG	Tailings Working Group
U	uranium
UB	Upper Britannia Creek
UD	Upper Dip Creek
WRFN	White River First Nation
YCDC	Yukon Conservation Data Centre
YCSR	Yukon Contaminated Sites Regulation
YESAA	*Yukon Environmental and Socio-economic Assessment Act*
YESAB	Yukon Environmental and Socio-economic Assessment Board
Zn	zinc

1. INTRODUCTION

This report describes the Best Available Technology (BAT) study related to tailings and waste rock management conducted for the proposed Casino Mine Project (the Project). Best Available Technology is the site-specific combination of technologies and techniques that is economically achievable and that most effectively reduces the physical, geochemical, ecological, social, financial and reputational risks associated with tailings management to an acceptable level during all phases of the life cycle, and supports an environmentally and economically viable mining operation.

The BAT study was conducted in consultation with First Nations, regulatory authorities, and other stakeholders, and followed the *Guidelines for the Assessment of Alternatives for Mine Waste Disposal* (the Guidelines; ECCC 2016), supplemented with additional analysis in two additional steps.

1.1 CASINO MINE PROJECT

Casino Mining Corporation (CMC) is proposing to develop the Project located 150 km northwest of Carmacks, Yukon. The proposed Project is a 22 year mine life open pit copper-gold mine that will process 120,000 tonnes per day of sulphide ore through a concentrator facility to produce copper and molybdenum concentrate, and 25,000 tonnes per day of oxide ore will be heap leached to produce gold doré.

The Project is located in a northern climate typified by long, cold, dry winters, and short, warm, wet summers. The surrounding landscape displays smooth, rolling topography marked by sharply incised valleys. The area has a low-to-moderate seismic hazard.

Project components include an open pit, processing plant, heap leach facility, tailings management facility (TMF), ore stockpiles, power plant, 1,000-person accommodation camp, water supply and distribution system, communication infrastructure, and ancillary features (e.g., administrative buildings, warehouses). The Project will be accessed by road via the Klondike Highway to Carmacks. From Carmacks, access will follow the existing gravel Freegold Road for 83 km, from which point a 120 km access road will be constructed to the site. The mine's make-up water supply will be provided from the Yukon River via an approximate 17 km aboveground pipeline.

Construction of the Project is expected to occur over four years, with direct annual employment peaking at approximately 1,000 workers. Over the 22-year mine life, the Project is expected to provide direct annual employment for an average of 600 workers.

The mine site and a portion of the access road are located within the traditional territory of Selkirk First Nation (SFN). A portion of the access road is located within the traditional territory of Little Salmon/Carmacks First Nation (LSCFN), and the water supply pipeline is located within the traditional territory of Tr'ondëk Hwëch'in (TH). The Kluane First Nation (KFN) and White River First Nation (WRFN) traditional territories are located downstream from the proposed mine and aspects of the project are within the asserted traditional territory of the WRFN.

1.2 ACTIVITIES TO DATE

The design of the Casino Project TMF has been subject to iterative review and optimization since the first assessment of mine waste management in 2008. This BAT study benefits from the information provided by these previous studies (Table 1.2-1), supplemented by fresh analysis, and consideration of new alternatives as well as changing requirements and expectations in regard to the safe operation and closure of TMFs in Canada and globally.

Table 1.2-1. Overview of Casino Project Mine Waste Management Assessments to Date

Year	Achievement	Type	Date	Prepared by
	Mine Waste Management Assessment	Report	Jan 18, 2008	Knight Piésold Ltd.
2010	Tailings Management Facility Construction Material Alternatives study	Report	Jun 15, 2010	Knight Piésold Ltd.
	Tailings Management Facility Alternative Assessment	Report	Jul 20, 2010	Knight Piésold Ltd.
2012	Report on Revised Tailings Management Facility Seepage Assessment	Report	Dec 19, 2012	Knight Piésold Ltd.
	Report on Feasibility Design of the Tailings Management Facility1	Report	Dec 20, 2012	Knight Piésold Ltd.
2013	Mine Development Concept Alternatives Assessment	Draft Report	May 31, 2013	pHase Geochemistry Inc.
	Casino Waste Rock and Ore Geochemical Static Test Assessment	Report	Dec 3, 2013	Lorax Environmental Services Ltd.
	Casino Geochemical Source Term Development	Report	Dec. 4, 2013	Lorax Environmental Services Ltd.
2014	Casino Kinetic Testwork 2014 Update for Ore, Waste Rock and Tailings	Report	Dec 15, 2014	Lorax Environmental Services Ltd.
2014-15	TMF design reviewed by YESAB			
2015	TMF Dam Breach Inundation Study	Report	Sep 21, 2015	Knight Piésold Ltd.
	Effects of Casino TMF Dam Breach on Terrestrial Wildlife	Memorandum	Oct 7, 2015	Environmental Dynamics Inc.
	Evaluation of a Casino Mine Dam Breach on Fisheries Values	Memorandum	Dec 11, 2015	Palmer Environmental Consulting Group
	TMF Dam Breach Inundation Study – Socio-Economic Assessment	Memorandum	Oct 15, 2015	Hemmera
	Casino Project Mine Waste Management Alternatives Assessment	Report	Dec 2015	CMC
	Tailings Management Facility Risk Assessment (Section B.4.3.2.1 of Supplementary Information Report #2)	Report Section	Dec 2015	CMC
2016	Environmental and Socio-Economic Effects (ESE) Statement Guidelines for Casino Mine	Guidelines	Jun 20, 2016	Issued by YESAB Executive Committee
2016	CMC engaged Independent Engineering Review Panel (IERP) to review TMF design			
	PAG Waste Placement Optimization	Memorandum	Dec 23, 2016	Knight Piésold Ltd.

(continued)

Table 1.2-2. Overview of Casino Project Mine Waste Management Assessments to Date (completed)

Year	Achievement	Type	Date	Prepared by
2016-18	CMC optimized the TMF design based the results of the TMF Dam Breach Inundation Study and input from the Independent Engineering Review Panel (IERP)			

Note: (1) TMF feasibility design was prepared in 2012 and subject to review and comments from YESAB in 2014 and 2015.

1.2.1 Mine Waste Management Alternatives Assessment (2015)

CMC conducted a Mine Waste Management Alternatives Assessment[2] for the Project in 2015. This report summarized the assessments conducted in 2008 and 2010, the multiple accounts analysis conducted in May 2013 and the summary included in the Project Description (Chapter 4) of the Project Proposal. The assessment considered both the preferred method for managing mine waste, and the selection of the preferred location for mine waste storage.

Four tailings disposal options were considered: 1) slurried tailings behind a valley-fill dam constructed of local borrow material; 2) slurried tailings behind a valley-fill dam constructed of cyclone sand; 3) thickened tailings and paste tailings, also requiring a storage dam; and 4) filtered ("dry stack") tailings for disposal of non-acid generating (NAG) tailings, and an embankment dam for the potentially acid generating (PAG) tailings and waste rock. Environmental and technical factors considered for the analysis included elements such as wildlife habitat loss, impacts on fish, seepage potential, and geotechnical stability.

The assessment concluded that the preferred alternative for mine waste management was slurried tailings co-disposed with waste rock, contained by a cyclone sand impoundment located in the Casino Creek catchment. It also concluded that the use of cyclone sand for embankment construction was the preferred option, due to its smaller footprint (including avoidance of large borrow requirements outside the TMF footprint), less operational complexity, and reduced impoundment storage requirements and dam height. Conventional tailings slurry deposition was determined to be the most appropriate tailings technology, as anticipated production rates exceed what could be managed via filtered tailings technology.

Subsequently, using the cyclone sand embankment and impoundment of conventional tailings slurry as the preferred technology, ten potential TMF locations were identified within 20 km of the deposit. An initial screening assessment excluded six sites due to insufficient storage capacity, effects to sensitive fish habitat, or other excluding factors. The remaining four sites included Casino Creek (upstream of the confluence with Brynelson Creek), Lower Casino Creek (approaching the confluence with Dip Creek), Canadian Creek, and a "multiple sites" option designed to keep all waste in the upper reaches of watersheds and not directly located on areas frequented by fish.

[2] Appendix B.4B of the Casino Project Supplementary Information Report (Dec 2015). Report prepared by Casino Mining Corporation, December 2015. Accessible at https://casinomining.com/_resources/Casino_014-0002_SIR-B_December_18_2015/Individual_Sections_and_Appendices/B.04B_Mine_Waste_Alternatives_Assessment.pdf

A multiple accounts analysis (MAA), comparing the technical, environmental, socio-economic, and economic factors of the four sites, was conducted by an expert committee based on the *Guidelines for the Assessment of Alternatives for Mine Waste Disposal*[3]. The expert committee included participants from CMC, Knight Piésold (KP), Palmer Environmental Consulting Group Ltd (PECG), Lorax Environmental Services Inc. (Lorax), Marsland Environmental Associates (MEA), and Brodie Consulting. The results of the MAA indicated that the preferred location for the TMF was in the Casino Creek catchment upstream of the confluence with Brynelson Creek.

Three sensitivity analyses were then conducted to test the sensitivity of the results. Sensitivity scenarios included: excluding non-discriminatory indicators (i.e., those where the weighted score varied by more than 30%); re-considering the importance of permitting and community perception; and assigning the technical account a higher weight. All sensitivity analyses indicated that the preferred location for the TMF was the Casino Creek catchment upstream of the confluence with Brynelson Creek.

1.2.2 Independent Engineering Review Panel

CMC initiated the independent engineering review process at the conceptual design stage of the TMF to provide oversight and guidance throughout the life-cycle of the TMF and as a means to provide effective environmental risk management. The Independent Engineering Review Panel (IERP) is comprised of three principal members and one advisor, with additional expertise to be called upon as needed.

The IERP reviewed the TMF design as presented in the 2012 feasibility design report, assessed potential alternative storage technologies and assessed the alternate locations study for the Casino Project's TMF. The IERP confirmed that the design concept forming the basis of CMC's 2014 YESAB submission represents the best available technology for storing solid waste from the Casino Project. It also provided guidance and made recommendations to enhance the design of the TMF and to meet internationally accepted standards and good practices.

The IERP endorsed certain optimization concepts under consideration by CMC, and made specific recommendations with regards to placement of potentially acid generating material and minimizing stored water in the TMF.

The IERP review is part of CMC's quality assurance program to ensure that both best available technology (BAT) and "international good practice" are incorporated into the site investigation and selection, design, construction, operation, and closure of the Casino TMF. An independent engineering review will be conducted at distinct phases of the project development, including: basic engineering, advanced engineering, capital construction, pre-operations, and at regular intervals during operations. Review and input to closure planning will also be provided. The IERP will have unimpeded access to all technical data necessary to enable them to assess the TMF on an ongoing basis for compliance of the design, construction and operation of this facility with internationally accepted standards and practices.

[3] Environment Canada (2011). Guidelines for the Assessment of Alternatives for Mine Waste Disposal. [*Note: these Guidelines were updated in 2016 with adjustments to the methodology for multiple accounts analysis. As such, the 2015 Mine Waste Management Alternatives Assessment for the Casino Project uses a different methodology than included in this BAT study*.]

1.2.3 Optimized TMF Design

CMC's optimized design concept for tailings and mine waste management was developed in 2016 by CMC working in concert with KP and reflects the results of the TMF Dam Breach Inundation Study as well as input and recommendations made by the IERP, including efforts to minimize potential for water contact with the embankment by extending the beach area.

Under the optimized design, risks associated with PAG tailings were managed by maximizing the NAG beach during operations and closure, and containing the process pond water upstream of tailings and waste rock and away from the main embankment. Additionally, a waste rock buffer was placed between NAG and PAG tailings to contain PAG tailings in the event that a TMF embankment failure occurs. Inflow design flood (IDF) requirements provide for 9 Mm^3 storm storage during mine operations.

The optimized TMF design was used as a base case scenario to develop alternative candidates in the BAT study, so the evaluation of candidates benefitted from the historical studies as well as proposed design developments and the IERP recommendations.

1.3 REGULATORY CONTEXT

1.3.1 *Yukon Environmental and Socio-economic Assessment Act*

The Project is a reviewable project pursuant to section 47(2)(c) of *Yukon Environmental and Socio-economic Assessment Act* (YESAA; S.C. 20, c.7) as follows:

> *"47 (2) An activity listed under paragraph (1)(a) – and not excepted under paragraph (1)(b) – is subject to assessment if proposed to be undertaken in Yukon and if*
>
> > *(c) an authorization or the grant of an interest in land by a government agency, an independent regulatory agency, municipal government or first nation is required for the activity to be undertaken"*

Schedule 3 item 3(b) of the Assessable Activities, Exceptions and Executive Committee Projects Regulation (SOR/2005-379) requires an Executive Committee Screening for the construction, decommissioning, and closure of a gold mine with production capacity exceeding 300 t/day.

In January 2014, CMC submitted a Project Proposal to the Yukon Environmental and Socio-economic Assessment Board (YESAB) Executive Committee for screening[4]. After reviewing the proposal and supplemental information reports, in February 2016, the YESAB Executive Committee referred the Project to a panel review. In June 2016, the Executive Committee issued the Environmental and Socio-economic (ESE) Statement Guidelines[5] for the Project. The Guidelines identify the information that must be included in CMC's ESE Statement to be submitted to the Executive Committee. The ESE Statement will first be reviewed by the Executive Committee. Then, a three person panel comprised of three non-chair members of the YESAB will review the Project in consultation with the public, First Nations, and Yukon and federal governments.

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[4] https://casinomining.com/project/yesab-proposal/

[5] http://3pikas.ca/casino/2016-06-20%20Final%20ESE%20Statement%20Guidelines%20Casino.pdf

Section 4.5.2 of the ESE Statement Guidelines details information that is to be included in the ESE Statement related to tailings and mine waste, summarized in Table 1.3-1. The ESE Statement Guidelines also identify the following potentially affected First Nations:

- Kluane First Nation;
- Little Salmon/Carmacks First Nation;
- Selkirk First Nation;
- Tr'ondëk Hwëch'in; and
- White River First Nation.

Table 1.3-1. ESE Statement Guidelines relating to Tailings and Mine Waste Management

Requirement	Achievement
Section 4.5.2.1 – Tailings Management Facility Design	
Provide details on the alternative methods considered for tailings disposal. Include: • Use of dry stack tailings management facility • Alternate TMF/TMF embankment designs, including use of alternate embankment materials • Any other reasonable disposal options	This BAT study considers alternative methods of tailings disposal including use of dry stack tailings technology. Alternative embankment designs and materials were considered in the previous TMF alternatives assessment (CMC 2015).
Provide a comparison of each method in relation to economic viability, technical feasibility, and potential social and environmental effects. In economic viability include estimated long term costs associated with post-closure.	These parameters are considered in the comparison provided by the MAA.
This alternatives analysis is to be supported by information not contained in the project proposal documents submitted to the Executive Committee during the earlier screening process. Include: • Life-cycle costs • Evaluation of risk • Evaluation and consideration of effects to environmental and socio-economic values and required mitigation measures • Comparison of best practices and best available technology • Consideration of alternatives for the disposal of mine wastes that result in perpetual management of major infrastructure with high failure consequence, is not required • A comparison of the potential adverse effects, and remediation and other mitigation options associated with a dam breach or equivalent failure scenario for each of the TMF design options. • Additional consideration of a dry tailings alternative (e.g., co-disposal of tailings and waste rock in the present impoundment as proposed, with drains underneath the impoundment) • Detailed evaluation of selected TMF design • A summary of who will participate in the alternatives assessment of Tailing Management Facility design and how (e.g., First Nations, Decision Bodies and stakeholders)	This BAT study is supported by new alternative designs and analysis, including the listed requirements.

(continued)

Table 1.3-1. ESE Statement Guidelines Relating to Tailings and Mine Waste Management (completed)

Requirement	Achievement
Section 4.5.2.2 – Tailings Disposal Location	
Provide details on the alternative locations considered for tailings disposal. Include: • Use of a single tailings repository • Use of multiple tailings repositories • Use of different locations • Use of the open pit	This BAT study considers alternative locations for tailings disposal, including the use of multiple repositories, different locations, and the open pit.
Provide a comparison of each method in relation to economic viability, technical feasibility, and potential social and environmental effects.	This BAT study compares five potential alternatives in terms of technical, economic, environmental, social, and consequence of dam failure factors.
This alternatives analysis is to be supported by information not previously contained in the project proposal documents submitted to the Executive Committee during the earlier screening process. Include: • Life-cycle costs • Consideration of risk • Consideration of effects to values • Comparison of best practices and best available technology • Detailed evaluation of selected TMF location • A summary of who will participate in the alternatives assessment of tailings disposal location and how (e.g., First Nations, Decision Bodies and stakeholders)	This BAT study considers new information, including the listed requirements.

1.3.2 Mining Association of Canada's *Towards Sustainable Mining* Initiative

CMC is a member of the Mining Association of Canada (MAC). As members, CMC must uphold the principles and protocols of MAC, including, those outlined in the Tailings Management Protocol[6], and follow the guidance provided in the *Guide to the Management of Tailings Facility* (MAC 2017). The MAC Tailings Guide is an internationally recognized document that addressed many of the topics discussed in the BAT Study, including:

- Risk assessment and management;
- BAT and BAP for tailings management;
- Independent review; and
- Designing and operating for closure.

The MAC Tailings Guide has incorporated suggestions from international tailings professionals to reflect lessons learned from recent dam failure incidents in order to prevent such incidents from happening again. Specifically, the third editions of the Tailings Guide retains a strong emphasis on

[6] http://www.mining.ca/towards-sustainable-mining/protocols-frameworks/tailings-management-protocol

management systems, but with an increased emphasis on technical aspects, especially those critical to the physical and chemical stability of tailings facilities. As such, the MAC Tailings Guide has informed the BAT process outlined herein, and will be used to guide the ongoing engineering design of the Casino Project TMF.

1.3.3 Metal and Diamond Mining Effluent Regulations

The Metal and Diamond Mining Effluent Regulations (MDMER) under subsections 34(2), 36(5) and 38(9) of the *Fisheries Act* regulate the deposit of mine effluent, waste rock, tailings, low-grade ore and overburden into natural waters frequented by fish. Using a natural water body frequented by fish for mine waste disposal (or as a tailings impoundment area) requires an amendment to Schedule 2 of MDMER to list the natural water body and designate the body as a tailings impoundment area. Proponents seeking to use a natural water body frequented by fish must conduct an assessment of alternatives for mine waste disposal pursuant to ECCC Guidelines, described in Section 1.3.4.

Based on previous studies of mine waste alternatives for the Casino Project (as described in Section 1.2.1), CMC does not require a Schedule 2 amendment. However, the assessment of tailings and waste rock management alternatives conducted as part of the BAT study does meet the ECCC Guideline requirements, with several additional enhancements.

1.3.4 ECCC Guidelines

The *Guidelines for the Assessment of Alternatives for Mine Waste Disposal* (ECCC 2016)[7] describe the process that must be undertaken when a proponent is considering using a natural water body frequented by fish for tailings disposal[8]. The Guidelines advise that at least one alternative should not impact a natural water body that is frequented by fish.

The Guidelines were initially developed by Environment Canada in 2011 and updated by ECCC in 2013 and again in 2016[9]. Section 2 of the Guidelines sets out a process by which to identify, screen, and evaluate alternatives for mine waste disposal, including options related to locations, technologies, and other factors. The ECCC Guidelines include a methodology for MAA, which provides a systematic and transparent decision-making tool. The seven-step process outlined by the Guidelines is designed to be robust, transparent, replicable, and address issues of bias and subjectivity in decision-making.

[7] Available from: https://www.canada.ca/en/environment-climate-change/services/managing-pollution/publications/guidelines-alternatives-mine-waste-disposal.html (Accessed July 15, 2018)
[8] Includes disposal of deleterious substances (such as tailings, waste rock, low-grade ore, overburden, and any effluent that contains any concentration of the deleterious substances specified in the MMER, and of any pH), to a natural water body frequented by fish.
[9] The 2016 update uses a process of "scoring and weighting", rather than the "ranking and scaling" approach described in previous iterations of the guidelines. This change is intended to improve transparency in the process.

2. BAT STUDY METHODOLOGY

The BAT study considers the ESE Statement Guidelines for the Casino Project and follows the ECCC Guidelines (with supplemental analysis), industry guidance (including updates to the MAC Tailings Guide), and studies that have been conducted for other proposed mine projects in BC including:

- **Blackwater Gold Project (New Gold Inc.)**: Evaluation of Alternative Tailings Technologies for the Blackwater Project (December 2015); and
- **KSM Project (Seabridge Gold Inc.)**: Best Available Technology (BAT) Study for Tailing Management at the KSM Project (June 2016).

The ECCC Guidelines have been adapted to include the following steps (Figure 2-1):

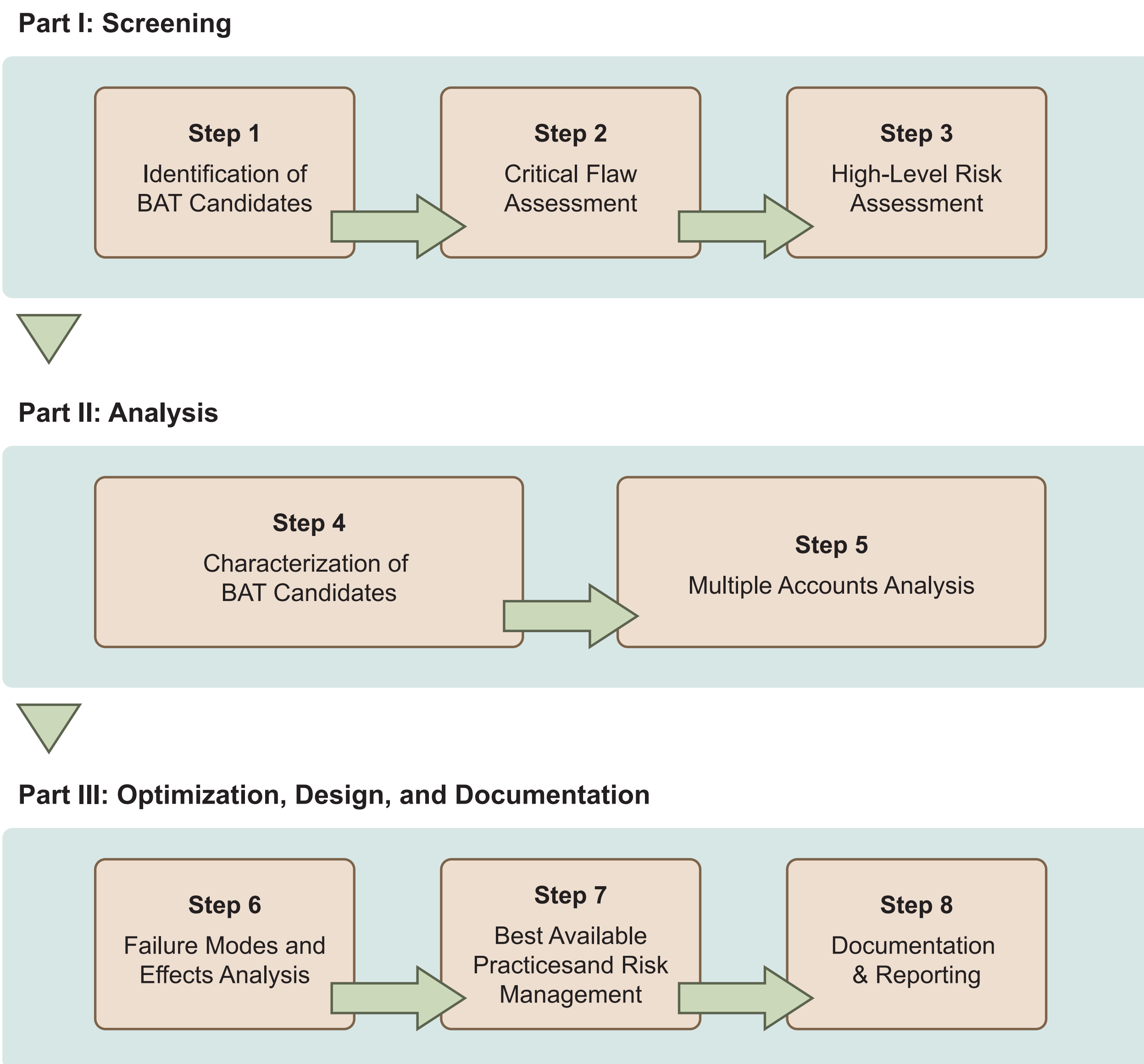
1. After an initial screening for critical flaws that would render a candidate infeasible, a "high-level risk assessment" (HLRA) has been added (Step 3) to review and compare the candidates in regard to their potential safety, environment and technical execution risks.
2. A failure modes and effects analysis (FMEA) has been added (Step 6) to provide a detailed risk assessment of the preferred BAT candidate(s). The intent of the FMEA is to reduce risk and incorporate best available practices (e.g., risk mitigation, contingency including monitoring and emergency response plans) into the tailings and waste rock management plans. This step will further mitigate the residual risk of the preferred BAT candidate and will inform further design and the definition of best available practice for the Project.

The study comprises a series of steps over three parts, as described below. The screening steps are designed to identify viable candidates, and to focus on those with relatively lower risks. The analytical steps compare and contrast the remaining candidates using the MAA framework established in the ECCC Guidelines, leading to the selection of a preferred BAT candidate. The final steps consider potential risks and failure modes of the preferred BAT candidate and BAP, describe the candidate based on the available information, and consider the next steps for engineering and design.

Part I: Screening

- **Step 1: Identification of BAT Candidates** – This step identifies a long-list of tailings and waste rock disposal alternatives for the Project, referred to as "BAT candidates". Possible candidates are identified at a conceptual level with no initial judgments of their feasibility. For each candidate, specific locations, technologies, and configurations (layouts) of materials and infrastructure are defined. Threshold criteria are used to identify those candidates that are reasonable, conceivable, and realistic, but this step is not intended to evaluate feasibility in detail. Candidates that meet the threshold criteria are carried forward to Step 2.

Figure 2-1
BAT Study Steps



- **Step 2: Critical Flaw Assessment** – The remaining BAT candidates are screened in order to identify and eliminate alternatives with critical flaws. A critical flaw is a flaw that is so unfavourable that it alone is sufficient to eliminate an alternative from further consideration for tailings and waste rock disposal. Flaws may relate to an inability to design, operate, or receive necessary approvals for a project; public perception; corporate policy; ability to honour existing commitments to First Nations and stakeholders; or other risks.

  Screening criteria are yes-or-no questions designed to identify critical flaws. There is no standard set of screening criteria or questions; instead, they are considered and defined to reflect the specific context for a project. If a critical flaw is identified and the candidate is not considered further; the rationale for elimination is documented. Candidates without critical flaws are carried forward to the high-level risk assessment in Step 3.

- **Step 3: High-Level Risk Assessment** – The HLRA is intended to narrow down the remaining candidates and focus on those candidates that have relatively lower risks. The HLRA compares and rates key safety, environmental and technical execution risks for each candidate. The HLRA describes and assesses the safety, environmental and technical risks for each candidate. The risk profiles of the candidates are considered and lower risk candidates are selected for further evaluation in Part II.

Part II: Analysis

- **Step 4: BAT Candidate Characterization** – Each remaining candidate is characterized in terms of technical design, project economics, and potential environmental and social impacts. The characterization is based on factual information including the candidate design concepts at this stage, and the environmental and social baseline information relevant to each candidate.

- **Step 5: Multiple Accounts Analysis** – The MAA follows the process described in the ECCC Guidelines, including scoring, weighting, and calculation of weighted merit ratings, and sensitivity analysis. Based on the characterization of candidates in Step 4, the MAA provides a robust, systematic, and transparent evaluation of each remaining BAT candidate.

Part III: Optimization, Design, and Documentation

- **Step 6: Failure Modes and Effects Analysis** – Following the selection of the preferred BAT candidate, a FMEA is conducted to identify and characterize risks from accidents, failures of an engineered system, and other malfunctions. The FMEA evaluates risks specific to the preferred BAT candidate, with the objective of prioritizing issues, and ultimately eliminating and/or reducing the potential for failure.

- **Step 7: Best Available Practices and Risk Management Measures** – The FMEA identifies areas where additional mitigations and contingencies could be implemented to minimize risks, based on best management practices for tailings and waste rock management. These mitigations and management practices directly inform the development of BAP and overall risk management measures for the preferred BAT candidate. In this step, best available practices will be identified to reduce residual Project risks identified during the FMEA. These measures include additional design elements, operational practices, and contingencies that reduce risk. This step will provide a preliminary evaluation of BAP and management measures for the preferred BAT candidate, which will ultimately be further developed and refined through detailed engineering and design, as well as through impact assessment, regulatory review, and permitting processes.

- **Step 8: Documentation and Reporting** – The BAT study process and outcomes are described in this report. The preferred BAT candidate is described alongside the risk management measures and BAP identified to date, and next steps for engineering and design are identified.

The results of each step are documented in Sections 7 through 12.

3. TAILINGS WORKING GROUP

3.1 OVERVIEW

CMC established the Tailings Working Group (TWG) to provide input on the BAT study. The TWG was involved throughout the study, and members provided valuable input into the selection and refinement of mine waste management technologies, locations and management practices. The terms of reference were reviewed by the TWG (**Appendix A)**.

CMC has engaged the TWG at each step of the BAT study, and working group members have worked collaboratively with CMC on many aspects of the study. CMC has taken time to investigate and respond to TWG comments, questions and suggestions on various aspects of the study. This has resulted in modifications to the study approach and changes to documents as well as additional research to support conclusions as the study advanced. Key elements of the TWG's input throughout the BAT study is highlighted throughout Sections 7 to 12 of this report.

3.2 MEMBERSHIP

CMC invited representatives from First Nation, Yukon, and federal governments to participate in the TWG and the BAT study, including the groups and agencies identified in Table 3.2-1. All members (Table 3.2-2) received meeting invitations and materials (including meeting notes and summary reports) and were invited to provide comments. First Nations' representatives included experts in tailings and water management and TMF design; however, presentations and other materials were designed to support the involvement of those who are less specialized in these topics.

Table 3.2-1. Tailings Working Group Membership

Category	Invited Participants
First Nations	• Selkirk First Nation** • Little Salmon Carmacks First Nation • Tr'ondëk Hwëch'in** • White River First Nation* • Kluane First Nation
Yukon Government	• Yukon Environmental and Socio-Economic Assessment Board (YESAB)* • Yukon Ministry of Energy, Mines and Resources* • Major Projects Yukon*
Federal Government	• Canadian Northern Economic Development Agency*

Notes: (*) Participated in at least one meeting; (**) Participated in most meetings

The TWG also included CMC and its consultants: ERM (BAT study facilitator), KP (TMF design engineer) and Lorax (geochemical expert consultant). CMC arranged for other technical consultants to participate as required. For example, fisheries, water quality, wetland treatment and wildlife expert consultants participated in the MAA.

Table 3.2-2. Summary of BAT Study Engagement

Date	Description	Step(s)	Engagement	Documentation[1]
Apr 11-12, 2017	**Workshop 1 – BAT Study Methodology**: CMC held a workshop with the TWG to present the proposed BAT study methodology, including proposed engagement of the TWG throughout the study.	All	In person	• TWG Terms of Reference • Presentation slides • Meeting notes
May 26, 2017	**BAT Study Engagement Plan:** Based on input provided at the April 2017 workshop, CMC prepared an engagement plan outlining details related to information sharing and engagement over the course of the BAT study.	All	Email, SharePoint	• BAT Study Engagement Plan
Jun 9, 2017	**Threshold and Screening Criteria**: CMC sought input from the TWG on the proposed threshold and screening criteria, as required for Steps 1 and 2 of the BAT study.	Step 1 Step 2	Email, SharePoint	• Threshold and Screening Criteria (summary report)
Sep 23, 2017	**Long-list of Candidates:** CMC summarized the results of Step 1 and reviewed the long-list of candidates. The TWG was invited to identify other candidates that met the threshold criteria. **Critical Flaw Assessment:** CMC provided the completed table identifying critical flaws for the long-list of candidates. **HLRA Definitions:** CMC provided the risk category definitions for review and comment.	Step 1 Step 2 Step 3	Email, SharePoint	• Identification of BAT Candidates, and Critical Flaw Assessment (summary report) • Geochemical Implications of Unsaturated Tailings Storage (technical memorandum)
Oct 10, 2017	**WebEx 1:** CMC hosted an online meeting to review and discuss the critical flaw assessment results and HLRA definitions.	Step 1 Step 2 Step 3	WebEx	• Presentation slides • Meeting notes
Oct 16, 2017	**HLRA Background:** CMC provided background information on each category, to support the HLRA, in advance of the HLRA workshop.	Step 3	Email, SharePoint	• HLRA background tables
Oct 18-19, 2017	**Workshop 2 – High-Level Risk Assessment:** CMC held a 2-day workshop to collaboratively undertake the HLRA, including discussion of relative risks and elimination of higher risk candidates. The workshop also reviewed and updated the critical flaw assessment results.	Step 2 Step 3	In person	• Presentation slides • Meeting notes
Dec 8, 2017	**Detailed Descriptions:** CMC provided detailed descriptions of each of the remaining candidates.	Step 3	Email, SharePoint	• Candidate concept sheets • Mechanically Dewatered NAG Tailings Assessment (letter) • Multiple Sites Assessment (technical memorandum)

(continued)

Table 3.2-2. Summary of BAT Study Engagement (continued)

Date	Description	Step(s)	Engagement	Documentation[1]
Jan 25, 2018	**WebEx 2:** CMC hosted an online meeting to progress the HLRA and select candidates for the MAA.	Step 3	WebEx	• Presentation slides • Meeting notes (WebEx 2/3 combined)
Feb 2, 2018	**WebEx 3:** CMC hosted an online meeting to conclude the HLRA and select candidates for the MAA.	Step 3	WebEx	• Meeting notes (WebEx 2/3 combined) • HLRA summary table
Mar 26, 2018	**List of Accounts, Sub-accounts, and Indicators**: CMC distributed a draft list of characterization criteria to the TWG for review in advance of the April 2018 workshop. Updated concept sheets for the remaining five candidates were also provided.	Step 4	Email, SharePoint	• MAA Characterization Criteria (summary report) • Candidate concept sheets (updated)
Apr 12-13, 2018	**Workshop 3 – Multiple Accounts Analysis:** CMC held a 2-day workshop with the TWG to review the characterization of the five remaining candidates and to begin the MAA. In addition to participation by First Nations and Yukon government, this workshop included various technical consultants who had undertaken field baseline studies in the Project area.	Step 4 Step 5	In person	• Presentation slides • Meeting notes • Multiple Sites Assessment (technical memorandum) – Updated
Jun 8, 2018	**Multiple Accounts Analysis Update:** CMC distributed an updated list of accounts, sub-accounts, and indictors reflecting revisions as a result of discussion in Workshop 3.	Step 5	Email, SharePoint	• Multiple Accounts Analysis: Update (memorandum) • MAA Ledger (spreadsheet) • Candidate concept sheets (updated)
Jun 12, 2018	**WebEx 4 – Multiple Accounts Analysis:** CMC presented preliminary results of the MAA and sought feedback from the TWG. CMC also provided the TWG with an opportunity to identify their own weightings to be considered in the analysis.	Step 5	WebEx	• Presentation slides
Jun 26-27, 2018	**Workshop 4 – Failure Modes and Effects Analysis (FMEA):** CMC hosted a two day workshop to review the results of the MAA and initiate the FMEA, including identification of failure modes and associated risks.	Step 6	In person	• FMEA Risk Register (spreadsheet)
Jul 17, 2018	**WebEx 5 – FMEA (Part 2):** CMC hosted online meetings to continue the FMEA, including discussion of each identified failure mode and rating of likelihood, consequence, and overall risk level for each failure mode. This meeting covered risks related to embankment stability, tailings characterization, and closure.	Step 6	WebEx	• FMEA Risk Register (spreadsheet)

(continued)

Table 3.2-2. Summary of BAT Study Engagement (completed)

Date	Description	Step(s)	Engagement	Documentation[1]
Jul 20, 2018	**WebEx 6 – FMEA (Part 3):** CMC presented risks related to closure, water management, mine site infrastructure, and mine operations.	Step 6	WebEx	• FMEA Risk Register (spreadsheet)
Jul 27, 2018	**WebEx 7 – FMEA (Part 4):** CMC presented risks related to mine operations.	Step 6	WebEx	• FMEA Risk Register (spreadsheet)
July 30, 2018	**WebEx 8 – FMEA (Part 5):** CMC presented risks related to mine operations and specific risks related to the water table closure concept.	Step 6	WebEx	• FMEA Risk Register (spreadsheet)
Aug 8, 2018	**WebEx 9 – FMEA (Part 6):** CMC presented risks specific to the water table closure concept and the ponded water closure concept.	Step 6	WebEx	• FMEA Risk Register (spreadsheet)
Aug 10, 2018	**WebEx 10 – FMEA (Part 7):** CMC presented risks specific to the water table closure concept and the ponded water closure concept.	Step 6	WebEx	• FMEA Risk Register (spreadsheet)

Note: (1) Documentation is listed for the event it first relates to, although many documents were referred to in later engagements as well.

3.3 ENGAGEMENT OUTCOMES

CMC engaged the TWG throughout the BAT Study, including in the development of the study approach and methodology, identification of tailings and waste rock management candidates, critical flaw analysis, high-level risk assessment, multiple accounts analysis, selection and refinement of the preferred candidate, and failure modes and effects analysis. Engagement began in April 2017 with a two-day workshop to present the overall BAT study process and seek feedback from the TWG in regard to their desired level of involvement. Based on the workshop discussions, CMC prepared an engagement plan to guide consultation with the TWG over the course of the study (**Appendix B**).

Feedback was solicited on each step of the BAT study, ranging from written comments on various inputs and outputs, to interactive WebEx meetings and in-person workshops at key points in the process. The following sections describe the engagement process and outcomes at each step of the BAT study. Table 3.2-2 summarizes CMC's engagement with the TWG over the course of the BAT study, including workshops, online meetings, and document sharing. Comments received throughout the BAT study, and CMC's responses, are documented in meeting notes from TWG workshops and other meetings (**Appendix B)** and in supporting materials (**Appendices D, E, and F**). The steps are described in more detail in Sections 7 through 12, in which input from the TWG is highlighted.

While this report summarizes engagement from the TWG in the BAT study, CMC intends to continue to engage the TWG throughout the next levels of design of the TMF and the preparation and submission of the ESE Statement. CMC looks forward to continued engagement with the TWG throughout the panel review process and into construction, operations and closure of the Project.

3.3.1 BAT Study Approach and Methodology

CMC initiated the BAT study with a two-day workshop with the TWG in Whitehorse, YK in April 2017. A description of the proposed BAT study methodology was shared with TWG members in advance. The objectives of the workshop were to:

- Provide an update on the Casino project, including permitting, environmental assessment, and engineering to date;
- Explain the proposed approach, including the various steps of the BAT study; and
- Seek input on the proposed approach.

The workshop was attended by representatives of Yukon and federal governments, and First Nations (TH, SFN, and WRFN). The workshop provided an overview of tailings and waste rock management practices in general, and also discussed specific considerations for tailings and waste rock management for the Project.

<u>Outcomes</u>

In the workshop, First Nations representatives requested an increased level of engagement in the BAT study than had originally been proposed by CMC, and expressed an interest in being involved at each step. A concept for the engagement was discussed in the workshop, and CMC subsequently developed an engagement plan, which described opportunities for TWG involvement at each step, and plans for regular meetings (in-person or online) (**Appendix B**).

Participants also requested a platform for sharing documents and information and CMC subsequently established a secure SharePoint site for the TWG.

Regarding the terms of reference for the TWG, participants stated that their participation in the working group was without prejudice and did not constitute approval of the Project. There was also a request to describe the TWG as an "information sharing" forum, rather than an advisory group. CMC subsequently adjusted the terms of reference to reflect these comments (**Appendix A**).

3.3.2 Threshold and Screening Criteria (Steps 1 and 2)

CMC drafted the threshold criteria and screening criteria and shared the criteria with the TWG on June 9, 2017 for review and comment. Feedback was received from SFN and TH. The criteria were subsequently adjusted and used in the development of the long-list of candidates and critical flaw assessment. The final criteria were presented in the WebEx held on October 10, 2017.

<u>Outcomes</u>

Changes to the threshold criteria provided clarification that the storage capacity could be achieved through a single or combination of locations. Changes to the screening criteria adjusted the focus of two of the criteria to ensure that they were useful in the local context, and with the level of detail available at this stage of the study.

3.3.3 Long-list of Candidates (Step 1) and Critical Flaw Assessment (Step 2)

CMC developed a long-list of candidates and—based on that long-list, and on the revised screening criteria—conducted the critical flaw assessment. The results are summarized in the summary report entitled *Identification of BAT Candidates and Critical Flaw Assessment*, which was shared with the TWG on September 23, 2017. CMC hosted a WebEx meeting on October 10, 2017 to discuss the results with the TWG, and the discussion was revisited in the workshop on October 18, 2017.

<u>Outcomes</u>

The TWG provided comments on the long-list of candidates throughout Steps 1 to 3. In response, CMC provided additional explanation, supplemental information, and considered additional candidates, including:

- CMC provided additional information about paste technology to support the exclusion of candidates utilizing this technology. This information was provided in Workshop 2 (October 18-19, 2017).
- Additional candidates suggested by the TWG were considered, and conceptual level drawings were generated, where required. This included consideration of distributed storage candidates (i.e., use of multiple, smaller sites), sequenced mine development through in-pit waste rock disposal, and use of an isolated part of the Canadian Creek catchment. Related information

is provided in the *Multiple Sites Assessment* memorandum from KP (December 6, 2017, updated April 9, 2018; **Appendix D**).

- CMC provided additional information about the geochemical characteristics of the deposit, and the acid-generating potential of PAG tailings, to support the elimination of candidates involving filtered PAG tailings. This information is summarized in a memorandum from Lorax Environmental entitled *Geochemical Implications of Unsaturated Tailings Storage* (December 27, 2017; **Appendix E**).

CMC and the TWG revisited these topics between October 2017 and April 2018, until the parties were satisfied that outstanding questions had been resolved (meeting notes detailing these discussions are provided in **Appendix B**).

For the screening criteria, based on the TWG's comments, the application of one of the screening criteria was reconsidered, and candidates eliminated on the basis of this criterion were subsequently re-instated. CMC also provided additional information to support the elimination of other candidates.

3.3.4 High-level Risk Assessment (Step 3)

The HLRA was originally envisioned to be conducted over the course of a two-day workshop (October 18 and 19, 2017). However, additional information was requested by the TWG during the workshop, and the process and schedule for the HLRA was adjusted to allow for the HLRA to be further discussed through subsequent WebEx meetings. Following the October workshop, CMC developed the remaining candidates in more detail to provide more robust design concepts, and the risk assessment methodology was revised to improve comparisons between the remaining candidates.

The HLRA continued with WebEx meetings on January 26 and February 2, 2018. At the end of the HLRA, five candidates were identified as having relatively lower levels of safety, environmental, and/or technical risks. The working group agreed that these five candidates would be evaluated further in Steps 4 and 5.

<u>Outcomes</u>

To support the HLRA, CMC developed detailed descriptions of remaining candidates, including the following supplemental materials:

- *Mechanically Dewatered NAG Tailings Assessment*: This letter from KP (December 22, 2017) describes a plausible filtered NAG tailings candidate as conceptually designed for the Middle Casino Creek valley. This assessment is provided in **Appendix F**.
- *Candidate concept sheets:* Concept sheets were developed for each remaining candidate. Each concept sheet provided a map and elevation profile detailing the configuration of waste materials, and written descriptions of storage and water management concepts, technical considerations, closure concept, and summary of key safety, environmental, and technical execution hazards. Concept sheets are provided in **Appendix G**.

Following the HLRA sessions on January 25 and February 2, 2018, the TWG selected five candidates for further evaluation based on the above information and results of the comparative risk assessment.

3.3.5 Characterization of Candidates (Step 4)

In consultation with the TWG, the remaining five candidates were described and characterized to provide sufficient information to compare the candidates in the MAA. CMC drafted a list of characterization criteria to describe and compare the remaining candidates. The list of criteria was shared with the TWG on March 26, 2018, in advance of the MAA workshop. At the MAA workshop (April 12 and 13, 2018), CMC reviewed the list of accounts, sub-accounts, and indicators with the working group. Discussion resulted in the addition, adjustment, and removal of various indicators with the goal of ensuring that all important (and differentiating) elements were addressed without duplication.

<u>Outcomes</u>

CMC revised the characterization criteria, and associated descriptions for each candidate, as a result of feedback received in the April workshop. In addition, CMC considered comments from the TWG in updated design concepts for the remaining candidates.

3.3.6 Multiple Accounts Analysis (Step 5)

After incorporating feedback from the April 2018 workshop, CMC provided updated materials to the working group on June 8, 2018, including:

- A memorandum summarizing the updated list of indicators and changes since the April workshop;
- The completed multiple accounts ledger (Excel spreadsheet) including descriptions of each indicator for each remaining candidate, and scales and scores for each candidate; and
- Updated concept sheets for each candidate reflecting minor design changes to address comments from the working group.

CMC invited comments on these materials from the working group.

On June 12, 2018, CMC hosted a WebEx meeting to review the preliminary results of the MAA, including calculations based on CMC's weightings, and sensitivity analysis. At this time, CMC provided working group participants with an opportunity to provide their own value-based weightings to see how their results may (or may not) differ from CMC's results.

On June 26, 2018, CMC reviewed the results and discussed the results of the MAA in a workshop, including changes as a result of comments provided by the TWG to date. At this time, CMC answered questions about the weighting process and sensitivity analysis.

<u>Outcomes</u>

In discussion with the TWG there were some further refinements to the indicators at the June 26, 2018 workshop. No members of the TWG elected to provide their own weightings for the MAA. However, the TWG raised no significant concerns or issues with the preliminary results of the MAA or sensitivity analysis.

Based on the preliminary results of the MAA, the TWG requested that two candidates (with the same location and design, and different closure concept) be compared and assessed further in the FMEA in Step 6. CMC agreed that this was a sensible approach.

3.3.7 Failure Modes and Effects Analysis (Step 6)

The FMEA was initiated in a workshop with the TWG on June 26 and 27, 2018. During the workshop, the TWG identified possible failure modes, agreed on definitions for likelihood and consequence ratings, and began rating the risks for each failure mode. The risk rating exercise continued over a series of six subsequent WebEx teleconferences.

Outcomes

At the end of the FMEA, the FMEA risk register included 88 potential failure modes, each rated in terms of its likelihood, consequence, and overall risk level. The TWG collaborated in the development of this risk register, which reflects the groups' interests, concerns, and technical expertise related to TMF design and operation. The risk register will be a resource for CMC for ongoing design and risk management.

4. BASELINE CONDITIONS

This section provides an overview of the characteristics of the physical, biological, and human environments in the Project area. These summaries are derived from the Casino Project Proposal for Executive Committee Review (January 2014)[10] and associated appendices documenting the results of baseline studies in the Project area.

Local study areas for the baseline studies were defined in the Project Proposal for each valued ecosystem component. For reference, Figure 4-1 illustrates the largest local study area (air quality) in relation to the mine site and surrounding geography.

4.1 PHYSICAL ENVIRONMENT

4.1.1 Climate and Air Quality

The Project is located in a northern climate typified by long, cold, dry winters, and short, warm and wet summers. At 1,200 m elevation, the mean temperature in January is -18°C, while the mean temperature in July is +11°C. At the extremes, the temperature can range from -50°C to +30°C. Annual rainfall averages 305 mm, of a total annual precipitation of 460 mm.

Based on dustfall measurements collected between 2010 and 2013, most measurements were less than the detection limit of 0.11 mg/dm^2/day. NO_2 and SO_2 were also below the detection limit, and PM_{10} and $PM_{2.5}$ were below the Canadian Air Quality Objectives. Greenhouse gas emissions in the Yukon (kilotonnes of equivalent CO_2/year) are generally very low and do not contribute to global emission levels.

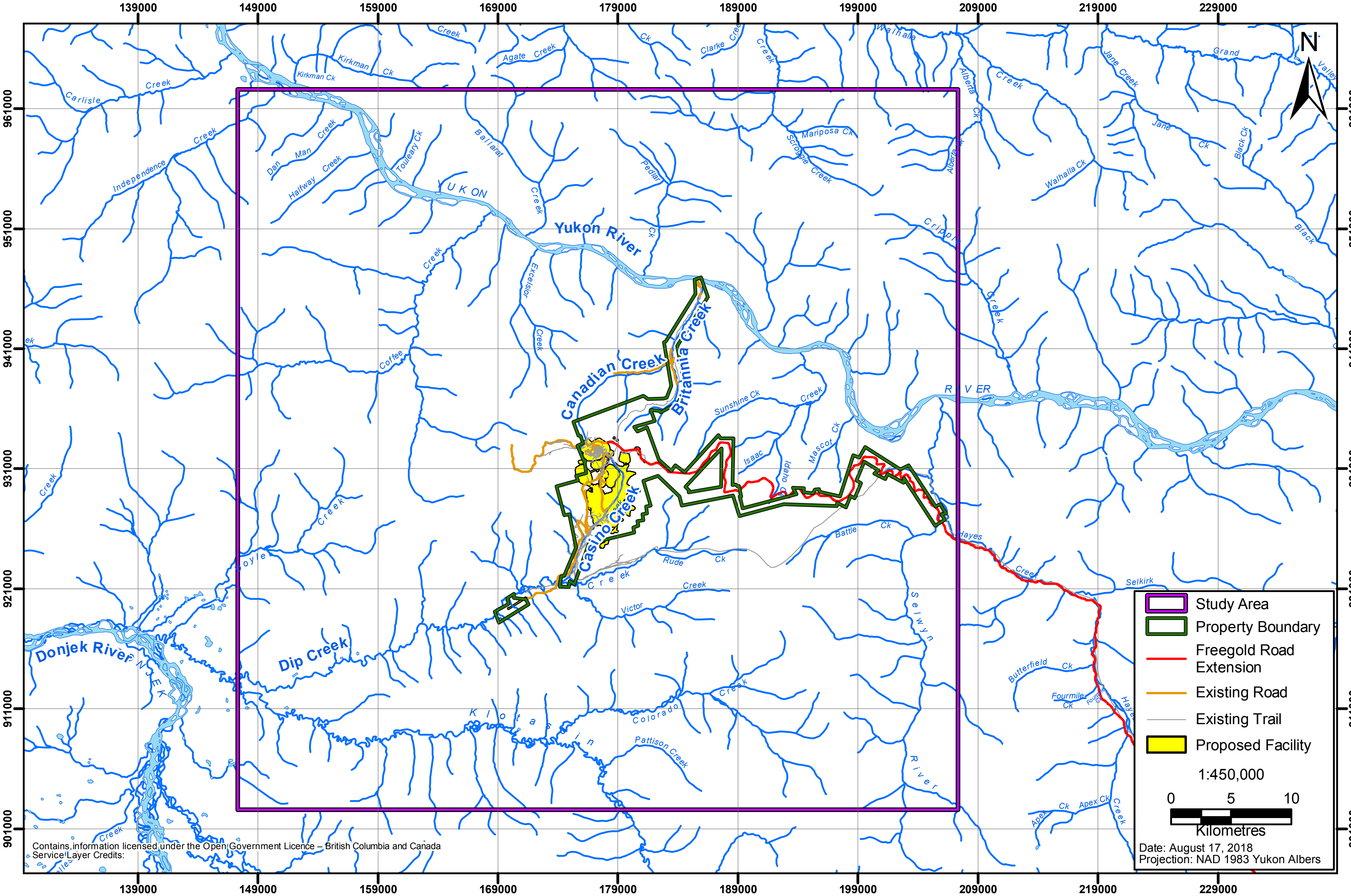
4.1.2 Topography and Physiography

Topography and physiography are important factors to consider in identifying preferred locations and technologies for mine waste storage. Their characterization facilitates selection of suitable sites to store the required volumes of mine waste, and also aids in identification of technologies that are more suitable for the available terrain and site characteristics.

The Project is located in the Dawson Range, which is located within the Klondike Plateau physiographic area of Yukon. The Dawson Range is a north-westerly trending belt of well-rounded ridges and hills that reach a maximum elevation of about 1,675 m and which are deeply incised by mature dendritic drainages. The Dawson range was not glaciated during the Pre-Reid, Reid or McConnell Glaciation events, which collectively represent the extent of North American continental glaciations in Yukon, however minor alpine glaciers were active in the area, resulting in a few small cirques and terminal moraines. The Dawson Range rises above the Yukon Plateau, which averages approximately 1,250 m in elevation.

[10] Casino Project Proposal for Executive Committee Review (Jan 2014). Available at https://casinomining.com/project/yesab-proposal

Figure 4-1
Casino Project Study Area (Project Proposal)



Regionally, the east-west trending major valleys in the North Dawson Range tend to be asymmetric, with shallower north-facing slopes being the result of enhanced sheetwash and solifluction processes on these more sheltered slopes.

On a local scale, the terrain around the mine site typically comprises broad summits, gentle upper slopes, moderate to moderately steep mid-slopes and gentle colluvial aprons at the slope toes. The mine site is located on the north slopes of the Dawson Mountain Range. The elevation of the terrain ranges from approximately 1,400 m above sea level (asl) in the northwest to approximately 700 m asl on the floor of the Casino Creek Valley in the south. The proposed open pit is located in the topographically-high northwest part of the study area. South-facing slopes in the area are generally steeper than the north-facing slopes. Exceptions found in the study area are the tributary catchments of Casino Creek where north-facing slopes are markedly steeper than the adjacent south-facing slopes.

The Project footprint is situated on a small drainage divide. The majority of the mine infrastructure is located in the Casino Creek Catchment where Casino Creek flows towards the south, joining Dip Creek, which drains to the Donjek River, which then flows northward to the Yukon River via the White River. The northwest part of the open pit lies within the Canadian Creek catchment. Canadian Creek flows in a northerly direction, joining to Britannia Creek, which flows north to the Yukon River.

4.1.3 Terrain Stability

Surficial geology and terrain features, including permafrost, are critical components to consider with respect to TMF design and siting. There is a general preference for less surficial cover, less permafrost, and stable terrain. As bedrock outcrop is sparse and limited to local hilltops, an understanding of surficial geology, and its associated vegetation cover, permafrost distribution and terrain stability will inform later parts of this study.

4.1.3.1 Surficial Geology and Terrain Mapping

Slopes in the study area are almost completely covered with surficial deposits with bedrock outcrops being restricted to the hill tops and ridgelines where they are present as tors and felsenmeer. The hill slopes are generally covered with a veneer or blanket of colluvium. Lobes of colluvial/eolian deposits are mapped along some of the ephemeral drainage lines. These deposits, referred to as ‘muck’, are indicated to be primary deposits of eolian fine sand and silt that were re-sedimented and interstratified with organic silts, colluvium and alluvial fans. These deposits are more prevalent on the north-facing slopes, where they can be up to approximately 20 m-thick and commonly contain segregated bodies of ice and buried ice wedges.

Geotechnical site investigations indicate that the bedrock at the Project is generally overlain by a veneer or blanket of colluvium on the hill slopes. The colluvium on the upper slopes predominantly comprises silty sand with trace to some gravel, cobbles and boulders. Ice-rich sandy silts with trace to some gravel, cobbles and boulders were encountered locally as were very coarse soils, predominantly comprising cobbles and boulders. The colluvium on the mid-slopes tends to be finer-grained, locally comprising sandy silts with trace gravel. The colluvial apron soils are silt-rich, contain organic material and tend to be ice-rich.

Coarse alluvium comprised of sand with some gravel, trace silt and trace cobbles was encountered adjacent to Casino Creek at the site of the proposed tailings embankment. The bedrock surface was generally encountered at depths of 1 to 4 m in the vicinity of the mine site. Bedrock was found at greater depths along drainage lines. The weathering profile also tended to be thicker along the drainage lines. The presence of a deeper weathering profile along the alignment of Canadian Creek is possibly associated with the presence of an east-northeast trending fault zone.

4.1.3.2 Permafrost

The permafrost table in the vicinity of the mine site is generally encountered at depths of approximately 0.5 to 2.5 m; however, permafrost in the colluvial slopes to the northwest of Casino Creek was found at a depth of greater than 4 m. Similarly, the depth of the permafrost table in the floor of the Casino Creek Valley increases markedly in a southerly direction on the downstream toe area of the TMF embankment in the original project proposal.

Extensive fine-grained loess deposits accumulated on some of the upland south-facing slopes in the north part of the mine site study area, and were reworked over time principally by sheetwash. The resulting colluvium in these areas tends to be silt-rich as it was derived principally from loess and is consequently susceptible to a shallow permafrost table with the possibility of massive ground ice. Ice-rich soils were encountered in trial trenches undertaken at the site of one of the proposed stockpiles. Ice-rich soils were also encountered in a drill hole to approximately 15 m deep and in a trial trench, undertaken at the site of the proposed open pit.

The regional occurrence of ice-rich soils in the colluvial aprons has been previously documented. Several test pits undertaken at the site of the proposed TMF embankment encountered ice-rich soils, with an approximately 0.5 m-thick band of massive ground ice being encountered at a depth of 4 m in a test pit.

Several test pits undertaken on colluvial aprons at the site of the proposed TMF embankment also encountered ice-rich soils/massive ground ice. A band of massive ground ice was encountered between 2.1 and 5.2 m depth in a drill hole. The site investigations undertaken at the site of the proposed TMF embankment have shown the permafrost table to generally be in the range of approximately 0.5 to 1.5 m below ground level within the colluvial aprons. However, there seems to be a marked variation in the depth of the permafrost table across the proposed downstream toe-line of the embankment. One test pit was terminated at a depth of 0.7 m in frozen silt, whereas, another, undertaken approximately 200 m to the southwest, was terminated at 4 m depth in unfrozen clay/silt with some sand.

A test pit adjacent to Casino Creek at the site of the proposed TMF embankment encountered un-frozen alluvium, comprising sand with some gravel, trace silt and trace cobbles to the full 5 m depth of the pit. It was interpreted that the permafrost table is depressed locally in the coarse alluvium in the vicinity of Casino Creek.

The nearest pingo is located approximately 4 km east of the proposed open pit.

4.1.3.3 Terrain Stability

Terrain characteristics and the stability of terrain are important considerations in the design of tailings storage facilities, and affects choices for both location and technology. Preference is typically given to stable terrain with low geohazard potential. The primary objective of the terrain stability mapping was to analyse the terrain stability in relation to the proposed development. Terrain stability refers to the likelihood of a landslide initiating in a terrain polygon following road construction activities and timber harvesting. Terrain stability was evaluated based on the slope angle, the slope aspect, the surficial geology, the permafrost conditions and the presence of gullied terrain.

Three terrain stability classes were used:

- Stable – identified as terrain with a 'negligible' to 'low' likelihood of landslide initiation following mine construction;
- Potentially unstable – expected to contain areas with a 'moderate' likelihood of landslide initiation following mine construction; and
- Unstable – expected to contain areas where there is a 'high' likelihood of landslide initiation following mine construction.

A terrain stability classification scheme was developed for the site, incorporating relatively low threshold slope angles for 'potentially unstable' terrain in areas of ice-rich soils – 35% for the Upper and Mid Colluvial Slopes and 20% for the Colluvial Aprons. The terrain stability mapping indicates approximately 13% of the study area (including the full upslope catchment areas from the proposed facilities) comprises 'potentially unstable' terrain and less than 0.5% 'unstable' terrain. The terrain stability mapping highlighted areas of 'potentially unstable' terrain and local areas of 'unstable' terrain at the site of the proposed tailings embankment, related to the interpreted presence of silt-rich and ice-rich soils. The mapping highlighted widespread areas of 'potentially unstable' terrain and local areas of 'unstable' terrain within the proposed storage area of the TMF. Areas of 'potentially unstable' terrain were identified, locally, at the sites of the proposed stockpiles and heap leach facility.

The slopes considered least susceptible to instability are generally those proposed in areas of bedrock exposure. The ice-rich colluvial slopes are considered most susceptible to landslides. The terrain attributes for 'potentially unstable' and 'unstable' terrain were established from observations of the conditions under which slope displacements and detachments were observed to have occurred within the study area, as well as in the surrounding area.

Geohazards

Geohazards in the area include erosion, avalanches, and permafrost disruption, as follows:

- **Erosion Potential:** The terrain mapping highlighted the widespread occurrence of silty and organic soils at the site. These soils occur within the colluvial aprons and also, locally, within the colluvial slopes. Silt and organic soils are especially prone to erosion. Thermal erosion gullies have developed on gentle colluvial aprons, in areas where the terrain was disturbed by the construction of access tracks. The erosion potential is possibly increased by the near surface presence of permafrost and ice-rich soils.

- **Snow avalanches:** Snow avalanches generally occur on terrain with slope angles of approximately 27 to 40 degrees. The predominant slope angle classes within the Study Area are gentle slopes (6 to 26%, 4° to 15°) and moderate slopes (27% to 49%, 16° to 26°). Nonetheless, a significant proportion of the annual precipitation falls as snow, and the study area includes some areas of moderately steep terrain that could be susceptible to snow avalanches.
- **Permafrost disruption:** The study area includes extensive areas of ice-rich soils, where the permafrost table is commonly within several metres of the ground surface. These areas include high elevation slopes, north-facing colluvial mid-slopes, and colluvial aprons. The occurrence of ice-rich soils yields a sensitive construction environment. Permafrost is susceptible to thermal disruption and may thaw surficial geology and terrain features, including permafrost are critical components to consider with respect to TMF design and siting. In regard to minimizing potential disruption of permafrost, there is a general preference for less surficial cover, less permafrost, and stable terrain. As bedrock outcrop is sparse and limited to local hilltops, it is important to understand the surficial geology and associated vegetation cover, permafrost distribution and terrain stability.

4.1.4 Geology and Mineralization

Geology and mineralization are related to many aspects considered in siting and designing TMFs, affecting choices relating to metal leaching (ML) and acid rock drainage (ARD), geotechnical conditions, hydrogeology and soils. Regional, local and deposit geology are summarized below. The geochemical and physical properties of the Project tailings and waste rock are presented in Section 5.

4.1.4.1 Regional Geology

Regional geological mapping indicates that the rocks in the region constitute a large portion of the Yukon-Tanana terrane, including former volcanic island arc and continental shelf depositional environments. Generally, metasedimentary rocks are intruded and overlapped by granitic and volcanic rocks.

The Casino Project is located within the Dawson Range, a west-central portion of the Yukon-Tanana terrane. The Yukon-Tanana terrane is composed dominantly of metamorphic rocks inferred to be Devonian to Mississippian in age that has been intruded by numerous Mesozoic granitic bodies and plutons hosting copper, molybdenum and gold mineralization.

In the deposit area, Yukon-Tanana terrane rocks are intruded by the mid-Cretaceous Dawson Range batholith, and subsequent Casino Intrusions. The Dawson batholith measures an approximately 300 km long by 60 km wide and extends northwest of Carmacks to the Alaskan border and dominates the geology of the Dawson Range. At the Casino deposit, the batholith consists of undeformed granodiorite.

The Dawson Range batholith is in turn intruded by the Casino Plutonic Suite, which is represented by fine- to medium-grained leucocratic granite, quartz monzonite and alaskite with associated aplite phases. The Casino Plutonic Suite is composed of stocks up to 18 km in diameter and is only exposed in the Colorado Creek (NTS 115 J/9) and Selwyn River (NTS 115 J/10) map areas. Late Cretaceous igneous activity produced a northwest-trending belt of small stocks including the host stock to the Casino deposit, referred to as the Patton Porphyry.

4.1.4.2 Local Geology

The Casino deposit is centered on the Patton Porphyry, an Upper Cretaceous (72-74 Ma), east-west elongated porphyry stock, which intrudes Mesozoic granitoids of the Dawson Range Batholith and Casino Plutonic Suite as well as the basement Paleozoic schists and gneisses of the Yukon Crystalline Complex. The Patton porphyry represents two or more episodes of high-level intrusion of porphyritic hypabyssal dacite to rhyodacite.

Intrusion of the Patton Porphyry into the older rocks caused brecciation of both the intrusive and the surrounding country rocks along the northern, southern and eastern contact of the stock. Brecciation is best developed in the eastern end of the stock where the breccia can be up to 400 metres wide in plan view. To the west, along the north and south contact, the breccias narrow gradually to less than 100 metres. The overall dimensions of the intrusive complex are approximately 1.8 by 1.0 kilometres.

The main body of the Patton Porphyry is a relatively small, locally mineralized, stock measuring approximately 300 by 800 metres and is surrounded by a potassically-altered Intrusion Breccia in contact with rocks of the Dawson Range. Elsewhere, the Patton Porphyry forms discontinuous dikes ranging from less than one to tens of metres wide, cutting both the Patton Porphyry Plug and the Dawson Range Batholith.

The Intrusion Breccia surrounding the main Patton Porphyry body consists of granodiorite, diorite, and metamorphic fragments in a fine-grained Patton Porphyry matrix. It may have formed along the margins, in part, by the stoping of blocks of wall rocks. An abundance of Dawson Range inclusions are prominent at the southern contact of the main plug, Wolverine Creek metamorphic rocks increase along the northern contact, and bleached diorite increases at the eastern contact of the main plug. Strong potassic alteration locally destroys primary textures.

4.1.4.3 Mineralization

Primary copper, gold and molybdenum mineralization was deposited from hydrothermal fluids that exploited the contact breccias and fractured wall rocks. Breccias are associated with higher grades, and grades decrease gradually with distance from the contact zone, either towards the centre of the stock or into the country rock granitoids and schists. Mineralization is grouped into four main types:

- **Leached Cap Mineralization (CAP):** an oxide gold zone which is gold-enriched and copper-depleted due to supergene alteration processes. This zone has a lower specific gravity relative to the other supergene zones. Weathering has replaced most minerals with clay. The weathering is most intense at the surface and decreases with depth.
- **Supergene Oxide Mineralization (SUP):** a discontinuous copper-enriched oxide zone with trace molybdenite. It generally occurs as a thin layer above the Supergene Sulphide zone. Where present, the supergene oxide zone averages 10 metres thick, and can contain chalcanthite, malachite and brocanthite, with minor azurite, tenorite, cuprite and neotocite.

- **Supergene Sulphide Mineralization (SUS):** a zone of supergene copper sulphide mineralization occurs in an up to 200 metre-deep weathered zone below the leached cap and above the hypogene mineralization (described below). SUS has an average thickness of 60 metres. Grades of the Supergene sulphide zone vary widely, but are highest in fractured and highly pyritic zones, due to their ability to promote leaching and chalcocite precipitation. The copper grades in the Supergene Sulphide zone are almost double the copper grades in the Hypogene (0.43% Cu versus 0.23% Cu).
- **Hypogene Mineralization:** is present as mineralized stock-work veins and breccias and occurs throughout the various alteration zones of the Casino Porphyry deposit. Significant Cu-Mo mineralization is related to the potassically-altered breccia surrounding the core Patton Porphyry, as well as in the adjacent phyllic-altered host rocks of the Dawson Range Batholith. The pyrite halo in the hypogene zone returns the highest Cu values on the property.

Native gold can occur as free grains in quartz (50 to 70 microns) and as inclusions in pyrite and/or chalcopyrite grains (1 to 15 microns). High grade smoky quartz veins with numerous specks of visible gold have also been logged.

4.1.5 Water Quality and Quantity

Activities associated with the construction, operation, and closure of the tailings management facility can alter surface water and groundwater quantity and quality with consequent effects on hydrological features (e.g., streams, lakes and wetlands) as well as terrestrial and aquatic species and habitat. The natural hydrological regime of a TMF's catchment affects the safe construction, operation and closure of the facility. Surface water factors such as catchment size, precipitation, and runoff affect the water flows in and out of a TMF site, influencing water quality, surplus water, and flood risks. These effects are key parameters for consideration in the tailings and waste rock management alternatives assessment.

4.1.5.1 Surface Water Hydrology

The Casino Project is located within the Yukon River regional watershed. Sub-basins in the project area include the Dip Creek and the Britannia Creek watersheds. The Britannia Creek watershed drains north directly into the Yukon River. The Dip Creek watershed drains southwest towards the Casino Creek tributary basin and the White River, which itself discharges in the Yukon River. Casino Creek is a tributary of Dip Creek. The mean annual runoff of watersheds in the area ranges from 2.8 $L/s/km^2$ and 9.2 $L/s/km^2$.

Surface water bodies in the region include multiple thaw lakes, streams, and rivers. Peak river discharges usually occur in May due to snow melting, with a second peak occurring mid-summer due to rainfall and permafrost melting. Annual precipitation is relatively low, between 300 mm and 450 mm per year, with some rain events between June and September. In the valleys, creeks also are sustained by groundwater that discharges to surface throughout the year, feeding the flows of the Casino Creek and Canadian Creek as they decrease in winter.

4.1.5.2 Surface Water Quality

Sampling of baseline surface water quality in the area identified ten parameters exceeding the Canadian Council of Ministers of the Environment (CCME) Canadian Environmental Water Quality Guidelines for the Protection of Aquatic Life: cadmium, copper, aluminum, iron, uranium, fluoride, zinc, lead, pH and silver. There were also many parameters with concentrations equal to or lower than detection limits, including beryllium, boron, bismuth, bromide, chloride, mercury, tin, silver, titanium, thallium, vanadium and zirconium.

Seasonal hydrological patterns result in varying water quality throughout the year. In winter, hardness, conductivity and nitrogen-based nutrients (ammonia, nitrite, nitrate, nitrate+nitrite-N) are higher; while total suspended solids, phosphorus-based nutrients (phosphate and orthophosphate), organic matter, and metal concentrations are elevated in summer months.

Surface water quality also varies geographically in the vicinity of the Project. Natural sources of ARD are present near the mineral deposit, affecting both groundwater quality and surface water quality. The Proctor Gulch tributary (which discharges to Casino Creek) had the highest concentrations of copper, aluminum, iron, acidity, hardness, conductivity, turbidity, and total dissolved solids; this characterization profile influences the quality of the Casino Creek watershed downstream. In general, concentrations of the water quality parameter concentrations were lower in Dip Creek, Canadian Creek, and Britannia Creek. Historic mining activities also impact the surface water quality at upper Meloy Creek, which had the highest concentrations of cadmium, lead, silver, and zinc in the Project area. This discharge also impacts water quality in Lower Casino Creek.

4.1.5.3 Groundwater Hydrology

Permafrost, topology, and geology in the region define two groundwater flow regimes in the vicinity of the Casino Project. The main flow system exists in the sub-permafrost layer throughout the year, while a second flow system is present in the supra-permafrost layer during the warm season. Both systems have limited hydraulic connectivity during the colder periods due to ice-bonded permafrost in winter.

Groundwater elevations vary geographically and seasonally. They are at their lowest just before spring and at their highest at the end of summer, in August, after the warm season rainfall and snow melting. Artesian pressures suggest faults in the region might limit groundwater flows. The different vertical hydraulic gradients found in the area also result in varying groundwater depths from six meters deep along the hillslope area to more than 100 meters deep in the open pit area.

4.1.5.4 Groundwater Quality

The quality of groundwater varies throughout the project area. Sampling results show three main types of groundwater. In the vicinity of the proposed open pit, groundwater shows higher concentrations of calcium and sulphate ions; while groundwater in the hillslope area is characterized by higher concentrations of calcium and bicarbonate ions. Groundwater from the Casino Creek valley varies along the valley but its overall quality is a mix of the former two, moving from a calcium-bicarbonate-sulphate type up the valley, towards a calcium-magnesium-bicarbonate-sulphate type in the middle of the valley, and a calcium-bicarbonate further down the valley.

Groundwater hardness and pH vary from low to high, and are highest in the Proctor Gulch area. As for hardness and pH, mean total dissolved solids (TDS) indicates that groundwater in the region is moderately to highly mineralized. In the Proctor Gulch area for instance, concentrations of cadmium and cobalt exceed the Yukon Contaminated Sites Regulation (YCSR)[11] standards, while arsenic, iron, uranium and zinc exceed the CCME guidelines. In other areas, copper and zinc concentrations also exceed the YCSR parameters while aluminium also exceeds those defined by CCME. Shallow groundwater samples demonstrated slightly higher mean TDS and higher concentrations of sulphate, sodium, fluoride, and chloride than deep groundwater samples.

4.1.5.5 Sediment Quality

Results of sediment sampling conducted in the mid-90s and between 2008 and 2012 show higher concentrations of antimony, arsenic, bismuth, cadmium, cobalt, copper, iron, lead, manganese, molybdenum, silver, thallium and zinc in the Upper Casino Creek area. In general, metal concentrations in stream sediments decrease with increased distance from Casino Creek. The Dip Creek tributaries have some of the lowest sediment metals concentrations of all creeks studied in the area.

The highest concentrations in stream sediments seem to be found on Patton Hill and below the Proctor Gulch confluence for cadmium, copper, and zinc. A shift in water pH might explain the precipitation of these metals. There are also natural sources of arsenic in the area, originating from weathered rocks and soils. Sampling shows concentrations exceeding the CCME Interim Sediment Quality Guideline (ISQG) and the Probable Effects Level (PEL) guideline in Upper Casino Creek and Canadian Creek, likely in relation to natural acidity of groundwater near the ore body.

4.2 BIOLOGICAL ENVIRONMENT

4.2.1 Fish and Aquatic Resources

Activities associated with construction, operation, and closure of the tailings management facility can cause alterations in the water chemistry, water quality, and hydrology of streams and lakes. In turn, these changes can impact fish and other aquatic organisms, including the aquatic food web resources upon which fish depend for growth and reproduction.

Slimy sculpin and Arctic grayling are the most dominant species found in the Project area, with low numbers of burbot and round whitefish also present in the lower watersheds. Juvenile Chinook salmon have been captured in lower Britannia Creek near the Yukon River confluence. Sampling of Dip Creek yielded no juvenile Chinook salmon; however, historical documentation of juveniles in the lower to mid reaches, and the more recent capture of a single juvenile in 2012, indicates that Dip Creek may provide occasional habitat for low abundances of juvenile Chinook. No Chinook salmon have been captured either recently or historically within Casino Creek. No Chinook salmon spawning was observed in either watershed despite multi-year surveying. No species at risk were caught within the fisheries local study area.

[11] Contaminated Sites Regulations. O.I.C. 2002/171 Environment Act. Schedule 3 – Generic Numerical Water Standards.

Statistical testing indicates that length-weight relationships of Arctic grayling does not vary among watersheds. The majority of Arctic grayling captured in the study area were greater than 125 mm in length, and thus represented age classes 1+. Sizes corresponding to probable young-of-the-year (<70 mm) were only observed in Dip Creek below its confluence with Casino Creek, and at a site on Britannia Creek. The lack of young-of-the year rearing in the majority of the study area suggests that Arctic grayling spawning activities are correspondingly minimal.

Habitat survey results are consistent with fish sampling results, and indicate that there is "no" to "poor" potential for spawning habitat throughout the Project area, although some moderate spawning potential has been identified in Dip and Britannia creeks, as well as in Casino Creek upstream of its confluence with Dip Creek. Similar habitat suitability maps produced by the Yukon Mining Secretariat[12] indicate that watercourses within the Project area do not support spawning activities or provide critical migratory corridors for spawning Chinook salmon.

Rearing habitat is the most common habitat type identified in the Project area, with most sites ranked from moderate to good. Poor rearing habitat quality was documented in upper Casino Creek and in Brynelson Creek, and was mainly attributed to a lack of potential fish resting or protective locations. In particular, upper Casino Creek has several long-medium gradient (5-11%) cascades comprised of a number of potential flow-regulated barriers hindering both juvenile and adult rearing activities. Fish habitat suitability maps from the Yukon Mining Secretariat[13] indicate similar habitat, with Casino, Canadian and Victor Creeks designated as low suitability areas unlikely to support juvenile Chinook rearing. Habitat supporting juvenile Chinook rearing activities was most probable in the lower Britannia Creek watershed, and in the lowest 10 km of Dip Creek.

Due to the lack of deep pools and the frequent occurrence of intermittent or ephemeral streams in the study area, the potential for overwintering habitat is generally sparse. This limits productivity in many small watercourses and suggests that many creeks in the study area may not provide critical habitat required for sustaining fish populations. Wider and deeper channels, including Dip Creek and Victor Creek, may provide some overwintering habitat.

Baseline metal concentrations in slimy sculpin tissues were compared among watersheds including Britannia Creek, Casino Creek, Victor Creek, and Dip Creek downstream of its confluence with Casino Creek. Metal concentrations were found to be the highest in Britannia Creek, and followed by Casino Creek. Tissue samples from samples collected from Casino Creek showed relatively high concentrations of arsenic, cadmium, copper, and lead; these results are consistent with the consistently poor water quality documented in Casino Creek.[14]

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[12] Yukon Placer Fish Habitat Suitability Map - White River Watershed (Map 1 of 3) (Category B).

[13] http://www.yukonplacersecretariat.ca/pdf/white_classification_2010_1of3.pdf

[14] The only guidelines currently available to determine safe metal concentrations in slimy sculpin tissue are for selenium and mercury. Baseline mean selenium concentrations in slimy sculpin tissues in Britannia and Victor Creeks were found to exceed the selenium guidelines for the protection of freshwater aquatic life; and mean estimated methylmercury concentrations exceeded the guideline for the protection of fish-eating (piscivorous) wildlife in all watersheds.

4.2.2 Terrestrial Ecosystems

The Project is located within the eastern edge of Beringia, a geographical area where rare vascular plants with Yukon, national, or global conservation status are known to occur, but there is limited information on the distribution and abundance.

Ecosystem Classification

The Casino Project is located within the Dawson Range of the Klondike Plateau Ecoregion, in the Boreal Cordillera Ecozone. The area is dominated by high mountain peaks and extensive plateaus. Lakes are largely absent, and open-water wetlands and ponds are mainly limited to slope toes and valley floors; these are generally infrequent and small in size, except in the vicinity of Dip Creek.

The study area includes alpine and sub-alpine habitat, transitioning to boreal forest. Alpine areas are typically characterized by un-vegetated and/or sparsely vegetated tundra, including mountain-avens, bryophytes and lichens, while sub-alpine areas are dominated by dense stands of scrub birch, willow, and low shrubs. Boreal forest includes white spruce and/or black spruce forests, and mixed forests with stands of aspen, balsam poplar, and/or birch found on warmer aspects, well-drained slopes, and valley bottoms. Understory vegetation varies across aspect and slope position with nutrient-rich sites supporting willows, alders, and a variety of other shrubs, grasses, horsetails and forbs, while poorly drained depressions and upland sites include sphagnum mosses, tussock grass, sedges, shrubs, and lichens.

Rare Plants

Nine species listed as having conservation concern[15] have been identified at the Project Site: *Artemisia laciniata*, *Botrychium alaskense*, *Cypripedium guttatum*, *Koenigia islandica*, *Phacelia mollis*, *Silene williamsii*, *Minuartia yukonensis*, *Erigeron purpuratus* and *Helictotrichon hookeri*. Of these nine species, *Botrychium alaskense*, *Artemisia laciniata*, and *Silene williamsii* are on the Yukon Conservation Data Centre[16] (YCDC) Track list and the remainders are on the YCDC Watch list.

Vegetation Health

Although there are no specific guidelines or thresholds for metal levels in vegetation, metals levels can be compared over time to monitor increases in metals from fugitive dust. Baseline samples of vegetation were collected for metals analyses in June 2013. Sampling sites were chosen based on terrain, soil type, potential to support at least two focal species, predominant wind direction, and distance from the mine site. Results showed elevated metal levels in vegetation samples; however, since the area has been subject to mineral exploration and is known to be mineral rich, higher baseline levels were expected. Interpretation of the vegetation analysis results suggests that there is little to no relationship between metal concentration in plant tissue and proximity to the mine site.

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[15] *Scirpus hudsonianus* was also found during the 2010 survey, but has since been removed altogether from the YCDC Watch list and is no longer considered rare in Yukon.

[16] Yukon Rare Plant Information Sheet. March, 2017. http://www.env.gov.yk.ca/animals-habitat/documents/RarePlantIndex_21March2017.pdf

4.2.3 Wildlife

Terrestrial wildlife are characterized and considered in the tailings and waste management alternatives assessment process. In particular, the presence of rare and endangered wildlife is a significant factor to consider in the BAT candidate selection process.

4.2.3.1 Terrestrial Wildlife

Caribou and moose dominate the landscape in this region and also play an integral role in the region's culture by providing sustenance and resource opportunities. Species of conservation concern include woodland caribou (Special Concern), wood bison (Threatened), grizzly bear (Special Concern), wolverine (Special Concern) and collared pika (Special Concern).

The primary caribou herd is the Klaza herd, although the Aishihik and Forty Mile herds are also present in the region. Woodland caribou from the Klaza herd are present year-round, with parts of the herd's annual range overlapping with the proposed Freegold Road Upgrade and extension. The population of the Klaza herd has increased since the early 1990s; once numbering approximately 440 animals, the herd is now estimated at around 1,180 animals.

Moose are the largest ungulate in the area and are the primary harvest species for Yukon hunters. Moose are unevenly distributed throughout the area, likely selecting available burned and treed riparian areas. Moose densities in the vicinity of the Project are considered low for Yukon. Other ungulates include Dall's sheep, wood bison (Aishihik herd), and mule deer. Dall's sheep are known to use traditional seasonal ranges southeast of the mine site, including Apex Mountain, Klaza Mountain, and Mount Langham. Wood bison are only sporadically present in the very southern section of the study area (near the Nisling River), and mule deer are occasionally observed on south-facing slopes near the Yukon River.

The dominant carnivores in the RSA include grizzly and black bears, wolves, and wolverine, all of which occur at relatively low densities. Lynx, marten, coyote, and red fox are also present. Collared pika are known to inhabit alpine areas close to the Project. No amphibian surveys were conducted as part of the Casino baseline surveys. However, both tadpoles and adult frogs were observed along the Freegold Road near Big Creek, during the rare plants survey conducted in 2012.

4.2.3.2 Birds

The Project area contains a wide variety of bird habitats ranging from alpine peaks to forested valley bottoms and as a result there is a diverse assemblage of bird species present. Field studies for birds were conducted in 2010, 2011 and 2013, and included point-count surveys for songbirds and other upland bird species, encounter transects, aerial surveys for cliff-nesting raptors, a stand-watch survey for short-eared owl, and collection of incidental sightings. In total, 116 bird species have the potential to occur within the study area, 82 of which were confirmed present. The diversity of birds in the area is generally reflective of the avian community in this portion of the central Yukon. The only primary bird habitat type not present within the study area is lakes or other large water bodies; as such, species associated with those habitats are generally not present.

Raptors found in the area include cliff-nesting raptors such as peregrine falcon, golden eagle and gyrfalcon, and forest-dwelling species like northern goshawk, sharp-shinned hawk, red-tailed hawk, northern hawk-owl and boreal owl. Tors (rock outcrops), cliffs, and rocky outcrops on steep slopes are essential to cliff-nesting species, while forest-dwelling raptors inhabit a variety of forested habitats.

A diverse assemblage of upland bird species are found throughout the area including grouse, ptarmigan, kingfisher, woodpeckers, and passerines (songbirds). Passerine species include the following general groups: flycatchers, shrikes and vireos, jays and crows, swallows, chickadees, kinglets, thrushes, waxwings, warblers, sparrows, blackbirds and finches. Virtually all habitats in the vicinity of the mine site provide breeding habitat for songbirds and other upland bird species, but bird density and species diversity vary greatly. In general, higher elevation habitats show lower bird densities and lower species diversity compared to valley bottom habitats. Forested habitats have some of the highest bird density and diversity, but the richest habitats are usually associated with riparian features (e.g., riparian forest and riparian shrub habitats).

Waterfowl (i.e., ducks, swans and geese) and other waterbirds (e.g., loons, grebes, gulls) are relatively uncommon due to the limited availability of suitable habitats. In addition to the lack of lakes in the region, open water wetland and pond habitats are infrequent and generally small in size. However, species such as mallard, American green-winged teal and bufflehead can be found in certain areas including the Dip Creek drainage. The most common shorebirds are spotted sandpiper, which are found regularly along the large streams and rivers, and solitary sandpiper, which are typically found at small ponds and wetlands.

A number of bird species-at-risk, or species of conservation concern, have been documented in the study area or are likely to occur based on regional survey data or known distributions within Yukon. Eight species—horned grebe, peregrine falcon, common nighthawk, short-eared owl, olive-sided flycatcher, bank swallow, barn swallow, and rusty blackbird—are listed as species-at-risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and four of these— peregrine falcon, common nighthawk, short-eared owl, and olive-sided flycatcher—are also listed under Schedule 1 of the federal Species at Risk Act. Additionally, 14 of the bird species found in the Project area are on the YCDC's Track list.

4.3 HUMAN ENVIRONMENT

The Project has the potential to impact the human environment including land use, and health and cultural effects tied to the environment and natural resources. Development may conflict with land tenure and related commercial and non-commercial land uses. The Project may also influence with human health by affecting water and air quality. Heritage may also be impacted due to ground disturbance, potentially impacting sites of archaeological, or historical significance.

4.3.1 First Nations' Interests

First Nations actively use the area around the Project for traditional hunting, gathering, fishing, and trapping. Other traditional land uses include collection of plants for food, medicine and materials for crafts (e.g., basket weaving). Yukon First Nations rely on traditional activities, including hunting, for an important part of their food supply.

SFN has two parcels of Category A settlement lands approximately 15 km southeast of the mine site. No other settlement lands or First Nations special management areas are identified in the vicinity of the Project.

4.3.2 Land and Resource Use

The mine site is located in Yukon Game Management Area 509, and adjacent to Game Management Area 510 (south of Dip Creek). There are no parks or protected areas in the vicinity of the mine site; the nearest protected area is the Nordenskold (*Tsâwnjik Chu*) Habitat Protection Area, located on the west side of the Klondike Highway south of Carmacks.

Hunting is both a subsistence and recreation activity in the area, with cultural and traditional significance in addition to economic value for First Nations and others households. Big game hunting in Yukon includes caribou, sheep, goat, bison, bear, deer, elk, wolf, wolverine, coyote, and muskox. Harvest statistics (aggregated for Yukon) show that moose and caribou are the most-harvested species. Hunters who are not residents of Yukon must utilize the services of a guide outfitter; the mine site lies entirely within Outfitting Concession No. 11, at the north end of the area. This concession area covers more than 22,000 km^2 and is accessible by floatplane, horseback, by boat, and on foot. Species hunted in this concession area include Dall sheep, mountain caribou, moose, and grizzly bear.

The mine site is located within Trapping Concession No. 121, and south of the boundary with Trapping Concession No. 116. The most common species trapped in the vicinity of the Project is marten, followed by lynx, beaver, wolverine, and wolf. Fishing (angling) is also a popular recreational sport in Yukon, and is also an important subsistence and traditional activity for First Nations. Species of interest include Chinook salmon, Arctic grayling, Northern Pike, burbot, and inconnu. Fish drying racks have been constructed and used at Britannia Creek on the Yukon River riverbank. Downstream, at Coffee Creek on the Yukon River, is a culturally important fish camp and camp site.

Recreation opportunities are abundant throughout Yukon. No campgrounds, picnic areas, or recreational trails are identified in the vicinity of the mine site, although the Project area is generally known to be used for a variety of recreational land uses including backcountry activities.

There are a number of quartz (hard rock) and placer claims in the Project area, including mineral leases and claims of various status. In 2017, there were placer prospecting leases at Excelsior Creek and Coffee Creek, and placer claims staked along Lower Britannia Creek, Canadian Creek, Casino Creek, Sunshine Creek, and Rude Creek. There were also placer mining land use permits authorizing up to ten years of placer mining operations at Canadian Creek, Lower Britannia Creek, and Upper Dip Creek. In addition to quartz mining permits held by CMC, permits for quartz exploration in the area were held by Cariboo Rose Resources, Centerra Gold, and Kaminak (Goldcorp).

4.3.3 Health

Human health data in the area is available at the regional level. There is data available on causes of death, levels of mental and physical health, and drug and alcohol consumption. Overall, most health survey results for Yukon are similar to those found at the national level.

In 2008, the leading causes of death in Yukon were the same as the national leading causes of death, although in slightly different proportions. The five leading causes of death were cancer, heart disease, cerebrovascular disease, chronic lower respiratory diseases, and unintentional injuries, with cancer and heart disease occupying first and second rank of the causes for both Yukon and Canada, respectively. Accidents ranked higher for Yukon (third cause of death) than for Canada (fifth cause of death).

Whitehorse is the center for obtaining medical services in Yukon. Yet the Yukon population is dispersed and made of numerous small communities. Thus, two of the main challenges identified for Yukoners is the access to medical treatment for physical and mental health problems and for addictions due to the physical distance of services and length of transportation.

Subsistence and recreational harvesting is a potential pathway for health effects through consumption of wild foods (game, fish, berries, and other products). Although specific locations of First Nations land use are not identified, it is generally assumed to occur throughout the Project area, including activities in pursuit of harvesting activities, or simply being on the land as a means to promote cultural or spiritual well-being.

4.3.4 Heritage Resources

The Project area has a recorded history of access for mining purposes dating back to 1917. Places of historical, cultural, and archaeological value have been identified through archaeological and heritage investigations of the Project area, engagement with Aboriginal communities, and public and government consultation efforts, and are considered an indicator of cultural continuity.

Studies conducted in the Project area have identified historical and archaeological sites at Britannia Creek, Patton Gulch, and Patton Hill. Within the mine footprint area, there are a total of 11 archaeological sites and 19 historic sites. Historic sites include log cabins, caches, and pit features. There are also remnants of ethno-historic trails in the vicinity of the Project. No paleontological remains, grave sites, or human remains were identified in the study area.

5. CASINO PROJECT MINE WASTE CHARACTERIZATION

Selection of BAT for mine waste storage is dependent on the quantities, physical properties, and geochemistry of the mine waste generated by the Project and the implications of each for a potential storage location and technology. Aside from the geochemical characterization, environmental and safety risks are also important considerations.

The geochemical characteristics of geological materials proposed to be disturbed by the Project were assessed as part of the waste and water management planning for the Project (Lorax 2013a). The ML and ARD characteristics were used to define the geochemical characterization of mine waste generated at the Project, which consists primarily of waste rock from the open pit and tailings generated from the flotation process. ARD refers specifically to leaching of these materials under acidic (low pH) conditions arising from sulphide mineral oxidation in the absence of acid neutralizing minerals, whereas ML refers more generally to leaching regardless of pH (i.e., including pH neutral and non-acidic conditions).

The assessment of mine waste management for the Project was initiated in 2008, and refinement of the mine waste management strategy continued through to completion of the Feasibility Study in 2013, as well as during further optimization studies through 2016. Mine waste volumes are summarized from M3 (2013). Geochemical characterization is summarized from the various geochemical characterization programs that were published in 2013 and 2014 (Lorax, 2013a; Lorax, 2013b; Lorax, 2013c; Lorax, 2014).

The geochemical characterization indicates that of the 956 million tonnes of tailings that will be produced over the 22 year mine life, approximately 80% is considered NAG material, while the remaining 20% is classified as PAG. The 658 million tonnes of waste rock and overburden material has also been characterized as either PAG and/or ML. Volumes and ARD classification of waste rock and tailings are summarized in Table 5-1.

Table 5-1. Mine Waste Types and Quantities

Mine Waste	Type	Quantity
Waste Rock	NAG	-
	PAG / ML	658 Mt
	Total	658 Mt
Tailings	NAG	764 Mt
	PAG	191 Mt
	Total	955 Mt

5.1 TAILINGS PROPERTIES

A laboratory testing program was conducted in 2012 to determine the geotechnical characteristics of the tailings materials. A NAG tailings sample was collected for physical properties testing. This sample was used to generate representative samples of tailings cyclone overflow (fine tailings) and cyclone underflow (sand) materials. The particle size distribution of the whole tailings sample comprises approximately 58% fine sand, 35% silt and 7% clay.

Geochemical laboratory testing and chemical analysis of the tailings (solids and process solutions) was conducted by Lorax to determine their geochemical characteristics under saturated and unsaturated conditions. Testwork indicates that approximately 20% of the total tailings is classified as PAG material. Additional geotechnical and geochemical testing were completed on NAG and PAG tailings after being separated through the pyrite rougher circuit, and are summarized in the following sections.

5.1.1 Depyritized Whole NAG Tailings

A pyrite rougher circuit will be operated to produce a stream of depyritized tailings, which can in turn be cycloned to create a cyclone sand for embankment construction. The process of operating the pyrite rougher circuit thus creates the NAG tailings stream that accounts for approximately 80% of the overall tailings mass. The cyclone overflow, as a result of the pyrite rougher circuit, will also be NAG, thus not requiring to be managed in a saturated or sub-aqueous manner to prevent the onset of ARD.

Depyritized tailings produced from supergene (SUP) ore has a higher metal leaching potential under unsaturated conditions compared to depyritized hypogene (HYP) tailings. To minimize the final surface exposure of supergene tailings, low grade ore (LGO) processing can be staged so that SUP LGO piles are processed before HYP LGO stockpile material. This staging plan will allow for the final surface layer of tailings to be composed primarily of the less reactive HYP tailings.

Source terms from both the beach and embankment are predicted to be pH-neutral during operations and closure. Metal leaching rates are generally predicted to be lower during closure than operations due to the greater influence of hypogene. Due to the greater depth of oxidation expected in the tailings embankment, source term concentrations are predicted to be slightly higher than the exposed tailings beach.

5.1.1.1 Overflow Tailings (Tailings Slimes)

The cyclone overflow sample was generated to a target particle size distribution with approximately 75% fines (silt and clay fractions). The resulting cyclone overflow material comprised approximately 23% sand, 69% silt and 8% clay (77% total fines).

5.1.1.2 Underflow Tailings (Cyclone Sand)

Compaction, shear strength and permeability tests were carried out on laboratory manufactured cyclone underflow (cyclone sand) samples. The test samples used for shear strength and permeability testing were prepared to target density and moisture content conditions representative of compacted cyclone sand fill material used for embankment construction. The shear strength and permeability tests were carried out over a large range of confining stresses to examine the influence of a large dam height (and corresponding high confining stress) on the strength and permeability values.

The cyclone underflow sample was generated for a target particle size distribution with a maximum of 15% fines. The resulting cyclone underflow material comprised approximately 85% sand, 13% silt and 2% clay (15% total fines). The specific gravity of the tailings solids was measured to be 2.80 for the sample. The cyclone underflow material is described as a non-plastic sand with some silt and a trace clay, and classifies as SM (sand with non-plastic fines).

The maximum dry density and optimum moisture content of the cyclone underflow sample were determined from a standard proctor test. The optimum moisture content was determined to be 16.7% and the maximum (ultimate) dry density was 1.56 t/m^3.

Consolidated undrained triaxial compression tests were carried out on the cyclone underflow sample to determine the shear strength of the material over a range of confining stresses. The test results indicate an average effective friction angle of 36 degrees with zero cohesion. The potential strength characteristics of the cyclone sand over a large stress range has also been examined, including estimation of the shear strength (effective friction angle) at low and very high stresses.

The shear strength test results for the cyclone underflow have been compared to published information on the strength characteristics of granular materials (rockfill and angular sands) provided by Leps[17]. Specifically, a relationship between friction angle and effective stress provided for angular sands has been used for comparison to the cyclone underflow test results. This relationship suggests that the effective friction angle of the cyclone sand will be greater than 36 degrees at low confining stresses (approximately 40 degrees for a normal effective stress of 100 kilopascal (kPa), but potentially lower at very high stresses (about 30 degrees for very high effective stresses of about 4,000 to 5,000 kPa). However, it is noted that the laboratory test results for the cyclone underflow sample suggest that there is no apparent loss of strength at the higher stresses, over the stress range tested.

Flexible wall permeability tests were carried out for the cyclone underflow sample, and shows a general trend of reducing permeability with increasing confining stress. This decrease is the result of the decrease in material density and potentially from the generation of finer particles due to particle crushing. However, the results do not appear to indicate a dramatic decrease in permeability at high stresses, which would be indicative of significant particle crushing and changes to the fines content of the material. The permeability of the cyclone underflow material will generally range from 2×10^{-3} cm/sec at lower stresses to about 5×10^{-4} cm/sec at higher stresses (approximately 3,000 kPa).

5.1.2 PAG Tailings

PAG tailings includes the pyrite that was separated from the whole tailings stream via the pyrite rougher circuit. Given that the PAG tailings are planned to be managed at closure using either a water table cover or a ponded water cover, testwork was developed with this concept in mind. Saturated column testwork indicates that metal leaching is minimal from saturated pyrite concentrate and PAG tailings. At the end of mine life, a layer of depyritized (NAG) tailings produced from HYP LGO will be placed as a cover over the PAG tailings and pyrite concentrate. Tailings porewater concentrations from the saturated portion of the TMF reflect the low metal leaching potential from all forms of sub-aqueous tailings due to the stability of sulphide minerals in a saturated condition. Saturated source terms from both the PAG and NAG tailings are predicted to be pH-neutral, with relatively low

[17] *Review of Shearing Strength of Rockfill*. Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 96, No. SM4, July 1970

metal concentrations. Potential parameters of concern from saturated tailings include SO_4, Mo, Fe, Mn, Cd, Cu and Zn. Similar to flows from saturated waste rock, Fe and Mn can be expected to oxidize and precipitate when seepage from saturated tailings interacts with oxygenated surface waters.

A specific gravity value for the PAG tailings material is 3.0, based on test results conducted for laboratory metallurgical testing.

5.2 WASTE ROCK PROPERTIES

5.2.1 Unsaturated Waste Rock

Waste rock placed in the TMF will remain unsaturated for an average of three years prior to being flooded by the rising water table in the TMF. In the early years of mine life (year -3 to year 4) waste rock mined from the Casino pit will predominantly be composed of oxide cap (CAP) rock. Oxide CAP waste rock will produce a mildly acidic drainage pH (pH 4.7) and metal leaching characteristics similar to the Gold Ore stockpile. Between year 5 and 14, similar quantities of HYP, SUP and CAP waste rock will be produced.

Hypogene waste rock has sufficient neutralizing potential to remain neutral during the relatively brief exposure time period. However, a portion of the SUP has little or no neutralizing potential and may become acidic. To mitigate this, supergene waste rock can be mixed with hypogene waste rock in the TMF. During this time period metals associated with HYP and SUP waste rock will increase in concentration (i.e., SO_4, Cd, U, Zn). Potential parameters of concern include Cu, Cd, Se, Ni, U and Zn. In the final years of active mine life (year 15 to 19), waste rock production will be dominated by HYP. Hypogene waste rock is expected to produce neutral pH drainage and have metal leaching characteristics similar to the HYP LGO stockpile.

At the end of mine life all waste rock in the TMF will be submerged beneath a layer of depyritized (NAG) tailings and/or a water pond to prevent sulphide oxidation and associated metal leaching from Casino waste rock.

5.2.2 Saturated Waste Rock

All waste rock produced at the Casino mine will be placed in the TMF and fully saturated at the end of mine life. This will inhibit sulphide oxidation preventing further release of metals and acidity associated with the sulphide mine waste. Long-term drainage chemistry from saturated mine waste is expected to be better than unsaturated rock piles, however, drainage from the saturated TMF will not be entirely benign due to the abundance of water soluble weathering products associated with CAP and SUP mineralization zones.

Oxide waste rock kinetic tests have indicated that the ML potential for oxide waste rock is reduced under saturated conditions (Lorax 2013b). This is attributed to upper limits on metal concentrations due to secondary mineral solubility and kinetic controls, limited water flux rates and the inhibition of sulphide oxidation under subaqueous conditions from trace quantities of pyrite. Under saturated conditions some metal leaching will continue, albeit at reduced rates, owing to the presence of oxide minerals and the mildly acidic pH.

Subaqueous disposal of PAG supergene waste rock in the TMF will prevent further acid generation by inhibiting sulphide oxidation. A portion of SUP waste rock is expected to have little or no available neutralizing potential, and may become acidic prior to sub-aqueous disposal. Similar to the oxide CAP waste rock, SUP waste rock contains water soluble oxide minerals which may continue to release metals and acidity under saturated conditions, albeit at a reduced rate compared to an unsaturated pile.

Under saturated conditions the hypogene waste rock is predicted to have low leaching rates of most metals compared to either oxide or supergene waste rock. The majority of hypogene waste rock will be mined in the final years (year 15-19) of mine life. As such, it will form a cap of carbonate-containing material over the SUP and CAP waste rock in the TMF. A majority of seepage through the waste rock zone will move upwards, interacting with the carbonates contained in the hypogene material before seeping into the water table and/or ponded water. This will ensure that any acidity associated with SUP waste rock in the TMF will be neutralized prior to discharge into surface water of the TMF.

Potential parameters of concern from saturated waste rock include SO_4, Cu, Fe, Mn, Mo, Se, Cd and U. Concentrations of Mn and Fe are predicted to be high in TMF seepage owing to the reducing conditions expected in TMF porewater. Once porewater seeps from the TMF and discharges to surface waters, it will come into contact with the atmosphere and/or mix with oxygenated water. Under these conditions, dissolved Fe and Mn will oxidize and precipitate from solution.

5.3 OVERBURDEN/BORROW SOURCE PROPERTIES

Site investigations within the TMF area show that overburden is generally shallow along the ridges and upper slopes of Casino Creek valley. The overburden depth in this area varies from 0.5 to 7.5 m, with an average thickness between 2 and 3 m. The overburden consists of residual soil and colluvial veneer, overlain by approximately 0.3 m of silty, mossy topsoil.

Residual soils are mainly present along ridges at higher elevations and along the upper parts of slopes. The residual soil is generally comprised of loose to compact silty sand and gravel with some cobbles and trace clay. The material is derived from *in situ* weathering of host bedrock. Weathering is dominated by frost action rather than chemical weathering, and as a result little clay is present.

The material is locally silt-rich due to windblown loess enrichment. The residual soils coarsen with depth to fractured rock as the influence of frost action decreases. The ridges and upper slopes are characterized by well drained colluvial and residual sandy soils, supporting stands of tall spruce and poplar. The colluvial veneer is locally overlying residual soils near the top of the slopes. The colluvial soils have been transported down-slope by gravity, causing variations in composition and intermixing of organic material. The colluvium is relatively thin along the upper part of particularly south facing slopes, and generally absent on ridges where residual soils predominate.

The colluvial veneer along the slopes of Casino Creek valley is comprised of a fine to medium grained sand with some silt, supporting coarse gravel and cobble sized broken rock fragments. The thickness and organic content generally increase down-slope. On north-facing slopes, the colluvial veneer is mostly frozen.

The depth to bedrock is considerably larger near the valley bottom, where slopes are gentler. The overburden thickness in the Casino Creek valley bottom varies from approximately 2 to 23 m. This material is classified as colluvial apron, which has a higher fines and organic content than the colluvial veneer. The colluvial apron is underlain by alluvium close to Casino Creek and is mostly frozen, with excess ice and massive ice layers. The alluvium is coarse grained and comprised of interbedded sands and gravelly sands with cobbles. It is typically overlain by frozen, organic-rich colluvial apron, except near the creek where the alluvium is non-frozen and at surface. The alluvium is generally at surface in tributary valleys, and consists of highly saturated, ice rich, fine grained sands and clayey silts.

6. MINE WASTE MANAGEMENT TECHNOLOGIES

This section provides an overview of tailings and waste rock management approaches and available technologies. The approaches and technologies described below will be further evaluated through the BAT study in Sections 7 through 12.

6.1 DESIGN STORAGE REQUIREMENTS

Based on the current design information, the Project will generate an estimated 960 Mt of total tailings, and approximately 660 Mt of mine waste rock and overburden, over the life of the mine. Of the 955 Mt of total tailings, approximately 20% (191 Mt) are expected to be PAG tailings, and the remainder (764 Mt) will be NAG tailings.

The TMF dam classification will be developed during the next level of design, according to Canadian Dam Association (CDA) Dam Safety Guidelines[18]. Once the dam classification for the TMF is established, the following criteria will be established so that the TMF can:

- manage the Inflow Design Flood (IDF) during operations;
- manage an IDF equivalent to the PMF event for closure; and
- withstand the design earthquake.

The TMF is designed to be a zero discharge facility during operations. A spillway will be constructed at closure, designed to safely manage the PMF.

6.2 TAILINGS TECHNOLOGY

Tailings can be processed and managed in a number of ways, resulting in tailings product with varying levels of solids and moisture content. Tailings technologies may include conventional slurry, thickened slurry, paste, and filtered (dry stack) tailings.

The characteristics of the tailings and the surrounding environment are factors in how tailings can be stored, and how water and geochemical effects can be managed. There is no generic "best approach" to tailings management. All factors must be considered on the basis of the proposed project, location, and geochemical characteristics of the ore and waste rock. Landscape, climate, and other environmental factors also influence tailings management.

Table 6.2-1 compares the key factors for each category of tailings technology, which are described in more detail below.

[18] Canadian Dam Association (CDA). *Dam Safety Guidelines*. Published 2007; Revised 2013. Available at: www.cda.ca

Table 6.2-1. Comparison of Tailings Technology

Parameter	Conventional Slurry	Thickened Slurry	Paste	Filtered
Solids content	20% to 35%	50% to 60%	60% to 75%	75% to 80%
Placement method	Pipeline	Pipeline	Pipeline	Transported by truck or conveyor and placed in lifts using dozers
Retaining structures	Yes	Yes	Yes	Maybe
Back-up facilities	Not required	Not required	Back-up tailings production and placement required	Back-up tailings production and placement required
Spatial extent	→ → → In general, decreasing spatial footprint with increased solids concentration → →			
Operational costs and complexity	→ → → Increasing complexity, cost, and power requirements → → →			

6.2.1 Conventional Slurry Tailings

Conventional slurry tailings have a solids content of approximately 20 to 35% by weight. The tailings are typically transported via pipeline through gravity, but can also be pumped, although thickening of the slurry would often occur if pumping were required, so as to minimize the volume of solids and liquids that would required pumping.

6.2.2 Thickened Slurry Tailings

Thickened slurry tailings have a solids content of approximately 50 to 60% by weight. In a typical tailings storage facility, water is removed from the conventional slurry tailings in a thickener, and either pumped or gravity fed via pipeline to the tailings facility for deposition. Thickening is often undertaken if there are water shortages, where less water is lost if it is recovered in the process plant. Additionally, thickening may be conducted if there are advantages to having less water in the slurry, such as if pumping of the tailings stream is required. Furthermore, for sites were there is a large head difference between the tailings facility and the process plant, it can often be less costly to dewater (thicken) the tailings and the process plant rather than pump larger quantities of water from the lower elevation facility to the higher elevation process plant.

6.2.3 Paste Tailings

The paste (or ultra-thickened) tailings technology requires additional thickening or additives to increase the solids content to about 60 to 75% by weight. Ultra-thickened tailings are commonly referred to as paste tailings; however the term paste is only relevant if certain yield stress criteria are met.

Ultra-thickening results in greater water recovery at the mill and less water delivered to the TMF. The tailings flowrate is less and therefore conveyed in smaller pipeline sizes, however greater pumping pressures may be required and positive displacement pumps are typically used. Reclaim pumping requirements are usually low because less water is delivered to the TMF with the tailings. A separate water management pond may be required for a paste tailings facility for management of stormwater from the TMF.

Capital costs for tailings pipelines may be lower than for thickened or conventional tailings; however, the cost of additional thickening/flocculants and tailings pumps must be considered. Positive displacement pumps are significantly more expensive than centrifugal pumps. Operating costs are typically higher for a paste tailings system when compared to thickened or conventional tailings disposal.

Paste tailings are generally more appropriate for sites that operate in a significant water deficit and require a high level of water conservation, i.e. where water supply is significantly limited or prohibitively expensive.

6.2.4 Filtered (Dry Stack) Tailings

Mechanical dewatering of tailings can be used to remove process water to a point at which the tailings behave like a soil. A partially saturated filter cake is developed for disposal as filtered tailings. Mechanical dewatering of the tailings can be achieved through a variety of technologies including vacuum and pressure filtration processes. Filtered tailings are dewatered to a solids content of approximately 75 to 80%, then placed and compacted in thin lifts. Filtering and transport of dewatered tailings by conveyor or haul truck can be costly in comparison to pipeline disposal of tailings slurry. In addition, a contingency alternative method for tailings discharge is required (i.e., pipeline system and/or emergency dump pond in the event of a filter system failure).

Confining berms and buttresses may be required to support the filtered tailings stack. In some cases, full TMF embankments may be required to contain the filtered tailings.

A separate water management pond is required to store process water and storm water runoff from the surface of the TMF as the water cannot be stored on the filtered tailings, which should be maintained in an unsaturated condition. The water management pond must be large enough to manage storm water runoff and to provide a buffering volume for fluctuations in process water requirements and periods of low rainfall and/or runoff, such as during winter operations.

A key requirement for filtered tailings is maintaining the stack in a relatively dry (unsaturated) condition, which is a challenge in wet environments. Continued snow removal is required during the winter months to allow for on-going tailings placement and to reduce the impacts of snowmelt during the freshet period. Excessive moisture may be present in the stack and can result in high pore pressures with stability problems. The operational complexity and high capital and operating costs, coupled with the risks of reactive tailings management, are critical issues that may require additional design measures.

6.3 EMBANKMENTS

The embankments will be designed in accordance to the CDA's Dam Safety Guidelines. They will be constructed as a solids retaining cyclone sand structure. The starter dam is designed to store runoff as a source for mill start-up water and accommodate tailings and potentially reactive waste rock and overburden production for approximately one year of initial operations. The embankment shell zones for the starter dam will be constructed with random fill comprising suitable rockfill from local borrow sources, supplemented by available non-reactive (leach cap) waste rock material from pre-production stripping.

Cyclone sand production in Year 1 of operations will be used to extend the downstream shell of the embankment, allowing the dam crest to be raised after about 1 year. Cyclone sand will be produced from bulk NAG tailings at the cyclone plant and discharged into the cyclone sand shell zones where it will be spread in cells and compacted using bulldozers. Bulk tailings that bypass the cyclone plant and cyclone overflow (fines) produced during cycloning operations will be discharged into the impoundment.

6.3.1 Materials

6.3.1.1 Local Borrow Source

Local borrow sources are required to provide the following materials for embankment construction:

- Starter Embankment Fill - locally sourced low permeability overburden.
- Rockfill Shell Zones – partly sourced from non-reactive open pit waste, the remainder will be sourced from local borrow (quarries).

All embankment construction materials will need to be non-reactive. Rockfill is expected to be sourced relatively easily on site, including use of excavated material from preparation of the plant site foundations. The borrow sources for the filter and transition zones have not been identified at this stage as this depends on the gradation of the core zone material. An effort has been made to identify potential borrow sources for low permeability core zone material for the starter embankment, as well as the upstream blanket.

The criteria that have been used to determine suitability of the material for use as low permeability core zone borrow material for the starter embankment are:

- ≥ 20 % fines. Material with ≥ 20% fines is expected to have a sufficiently low permeability for use as core zone material, based on available laboratory testing and experience with other projects.
- No organic content. Where the presence of organic material is indicated by laboratory testing or geotechnical logging, the material is considered unsuitable for use as core material. Organic material can oxidize over time, potentially causing settlements and leading to preferential seepage paths.
- Non frost susceptible. Ice rich soils are considered unsuitable as these are difficult to excavate when frozen. Thawing of ice rich soils will cause excess water to be released, which causes the soil to flow and makes it very difficult to handle and compact.

The residual soil and colluvial veneer materials identified at the site are potentially suitable starter embankment core zone borrow materials. The colluvial apron in Casino Valley is typically organic-rich, saturated and frozen, and is not suitable for use as core zone construction material. Residual soils are locally silt rich due to windblown loess enrichment. Residual soils at the site are mainly present along ridges at higher elevations and along the upper parts of some slopes. In the open pit area, residual soils are locally thick due to the presence of alteration zones and preferential weathering along shear and fault structures.

6.3.1.2 *Cyclone Sand*

The particle size distribution of the Casino mill tailings is a key consideration for determining the suitability of the bulk NAG tailings to provide cyclone sand of suitable quality and in sufficient quantity. Coarser tailings are preferred, as a higher sand fraction or 'split' can be realized. Clean sand with sufficiently low fines content (% passing a #200 sieve) will be required for placement, in order to facilitate rapid drainage and subsequent compaction. The anticipated particle size distribution of the Casino tailings is well within the range of tailings particle size distributions that have been successfully cycloned at other tailings operations.

Laboratory testing of tailings samples, correlated with experience from existing cyclone sand dams, indicates that the sand fill should have an *in situ* permeability equal to or greater than 2×10^{-4} cm/s. This will ensure the rapid drainage of construction water (following cyclone sand placement), seepage water and direct precipitation. It is typical to present specifications limiting the fines content of the cyclone sand. For copper tailings, a fines content in the range of 15 and 20 percent typically provides sufficient permeability for sand drainage. This criterion continues to be valid provided the sand grain size is not significantly changed by particle crushing, due to very large confining pressures imposed by dams of large height. Chilean experience for large copper cyclone sand tailings dams indicates that large confining pressures do not significantly affect the sand grain size. However, this may not be valid for tailings with a different mineralogy. Therefore, for large cyclone sand dams it is prudent to conduct permeability tests at large confining pressures to simulate the behavior of the material.

Considering the large height and size of the confining embankment, it is recommended that the fines content of the cyclone sand be less than 15%, in order to maximize fill placement rates and to ensure adequate compaction, strength and drainage. CMC has adopted a maximum fines content of 12%. There may be an opportunity to increase the fines content a few percent to allow increased sand quantities, based on actual performance during operations and material characteristics (permeability and strength) of the cyclone sand. The potential to provide more sand fill material will allow increased operating flexibility related to construction activities.

6.3.2 Foundation Preparation

The embankment footprint area that covers colluvial apron or other ice-rich overburden will be excavated to competent foundation, absent of frost susceptible soil. The removed material will be replaced with core, filter or shell zone material, depending on the location relative to the embankment. The average thickness of the colluvial apron is expected to be approximately 10 metres based on the findings of the site investigations.

A low permeability cut-off is required beneath the starter embankment at locations where no colluvial apron or other ice rich soil is present, to provide an effective seepage control barrier. The seepage cut-off trench will extend through the foundation soils and key into competent bedrock.

6.4 WASTE ROCK DISPOSAL TECHNOLOGY

Methods for waste rock disposal can be broadly categorized in two way, sub-aerial placement, and sub-aqueous deposition. Sub-aqueous deposition of waste rock can be achieved in several manners, such as having a water cover above the waste rock, or cover the waste rock with a solid cover that provides saturated conditions of the underlying waste rock.

6.4.1 Sub-aqueous

Sub-aqueous deposition of waste rock involves the placement of waste in a confined space, followed by submergence of the waste rock with water and/or tailings. This method is commonly utilized for sites where the waste rock is subject to ML/ARD if left exposed.

Waste rock co-disposal with tailings in the TMF involves placement of the waste within the impoundment, and allowing tailings and/or process water to flood over the waste rock. Waste rock can be used to create cells for segregated tailings placement within the TMF utilizing this approach

Alternatively, waste rock can be mixed, or co-mingled, with the tailings during placement. This provides better coverage of the waste rock, and can also improve the stability of the tailings mass (if required).

6.4.2 Sub-aerial

Sub-aerial waste rock placement is the most common storage method for non-PAG waste rock. And typically takes the form of waste rock stockpiles or dumps.

PAG waste rock can be placed in temporary LGO stockpiles if there is potential to mill the waste at the end of the mine life. Temporary storage of PAG waste requires that contact water and sediment controls be in place to prevent contamination of downstream environments.

7. STEP 1: IDENTIFICATION OF BAT CANDIDATES

7.1 OVERVIEW

The first step in the BAT study process is the identification of alternative tailings and waste rock management locations and technologies. Each "BAT candidate" comprises a specific combination of location, tailings management concept, waste rock management concept, and embankment design.

The output of Step 1 is a long-list of BAT candidates. To be considered in the long-list of candidates, a candidate must meet basic "threshold criteria" specified for the Project. The ECCC Guidelines state that candidates should be reasonable, conceivable, and realistic. Threshold criteria are primarily related to site selection and are used to establish geographic and other parameters for selecting candidate alternatives (ECCC 2016). Identified sites may each be conducive to hosting facilities constructed using different types of tailings technology and/or design configurations and unsuccessful combinations are also determined at this step.

7.2 THRESHOLD CRITERIA

Threshold criteria establish the minimum standard that must be met for a potential candidate to be considered in the BAT study. CMC identified three threshold criteria, based on distance, storage capacity, and general site characteristics (Table 7.2-1). On this basis, any proposed candidate that meets these criteria can be included in the long-list of candidates, to be further evaluated in Step 2.

Table 7.2-1. Threshold Criteria

Criteria	Definition
Distance	Be located within a 20 km radius centering on the deposit, and south of the Yukon River.
Storage Capacity	Provide sufficient storage capacity, in a single or combination of locations, for the anticipated volume of tailings and waste rock produced over the life of the mine.
Site Characteristics	Mitigation must be achievable for potential issues related to topography, foundation conditions, terrain stability/geo-hazards, water management, and accessibility characteristics.

The distance and storage capacity criteria were included in the previous alternatives assessment for the Casino Project (CMC 2015), which also included an additional criterion specifying the type of tailings technology. The 2015 study "only considered conventional tailings slurry deposition" because filtered (dry stack) alternatives are not proven at the scale of anticipated production. In the interest of facilitating a broader assessment of tailings technology alternatives, the type of technology is not considered to be a threshold criterion for the BAT study.

7.2.1 Distance

The distance criterion of 20 km radius centering on the deposit (Figure 7.2-1) represents the maximum potential distance for transporting mine waste, considering both economic costs and environmental and social effects associated with longer transport distances. Further, in the interest of minimizing environmental impacts, transporting waste materials across the Yukon River was not considered a viable option, hence the 20 km radius is truncated at the Yukon River on the northern edge.

TWG Highlights 7-1. Threshold Criteria

CMC provided the draft threshold criteria to the TWG for review and comment prior to identifying potential candidates. As a result of TWG comments on the Threshold Criteria, the criterion for **storage capacity** was revised to specify that storage capacity could be achieved through a single or combination of facilities or locations.

7.2.2 Storage Capacity

The ability to store the volume of mine waste (tailings and waste rock) produced over the life of the project (comprising approximately 955 Mt of total tailings, of which 20% is potentially acid generating (PAG), and 658 Mt of mine waste rock and overburden) is a fundamental requirement to ensure that waste can be safely disposed in the long term. If a candidate is unable to store the required volume, it is not a viable option. However, storage capacity does not need to be constrained to a single facility; candidates that provide sufficient storage through a combination of sites and/or technologies will satisfy this threshold criterion.

7.2.3 Site Characteristics

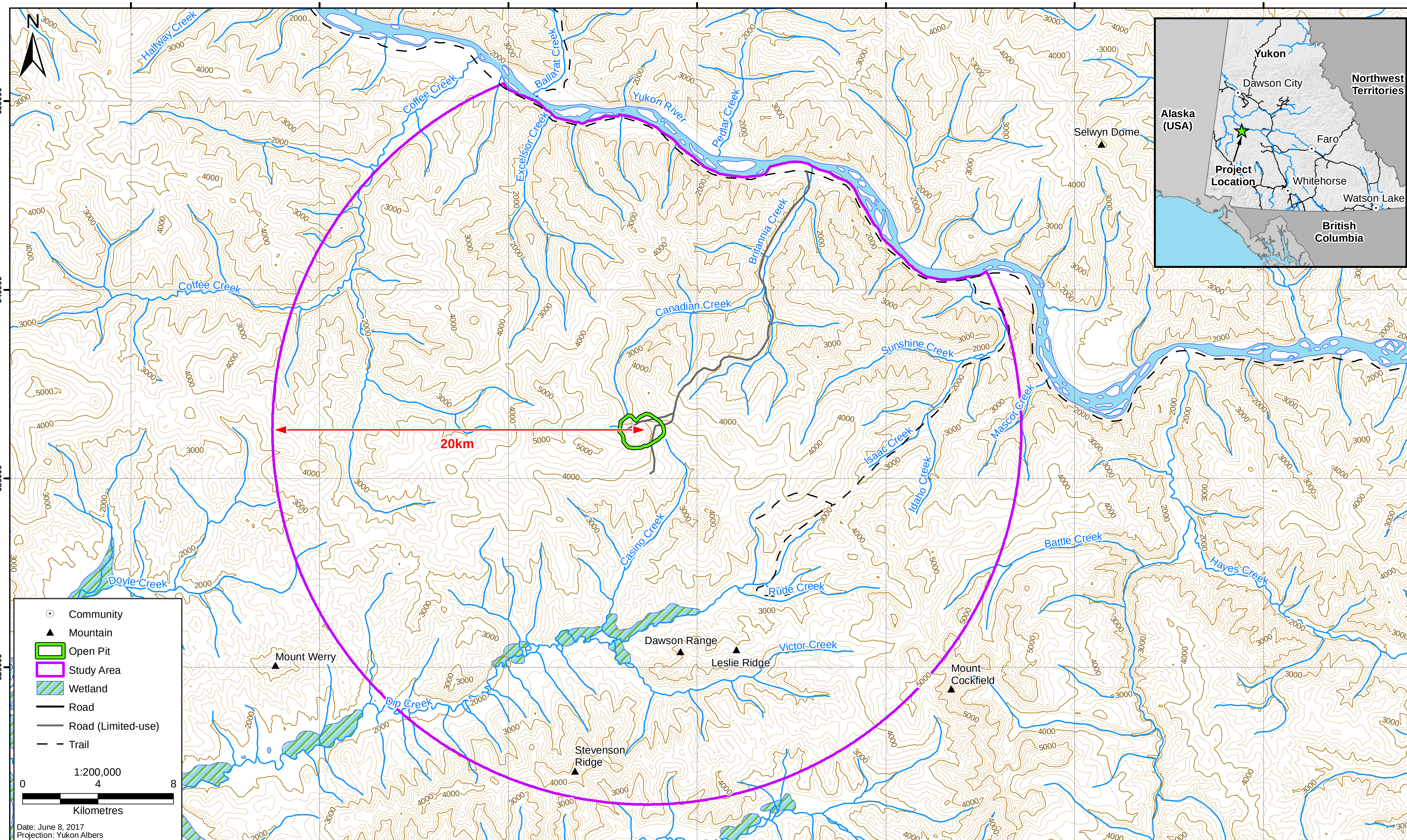
The third criterion addresses the need for the natural environment to support (naturally or through engineered mitigation) the safe construction, operation and closure of a tailings and waste rock facility. For example:

- The topography of the site, such as the size of valley, steepness of the valley walls, and location of the facility within the catchment, are important considerations for the different possible designs for tailings and waste rock storage.
- The foundation conditions must be amenable to support the confining embankments and waste materials, as well as effectively manage seepage from the facility.
- Terrain stability is important as sites with un-mitigatable high risk of slope instability or avalanche have unacceptable safety and environmental risks.
- Access constraints created by landscape features (e.g., mountains, waterways) and topography (e.g., steep slopes) can also result in the exclusion of a site due to the technological and environmental challenges of transporting materials across the landscape.
- The local climate must be suitable for the proposed approach to mine waste management.

7.3 Candidate Development

The identification of candidates involved three steps. First, prospective sites were identified within the study area (Section 7.3.1). Next, conceptual configurations were identified based on the available approaches to tailings and waste rock management (Section 7.3.2). Finally, the sites and configurations were combined to provide a list of conceptual candidates (Section 7.3.3), which were then evaluated against the threshold criteria to produce the long-list of candidates for the BAT study (Section 7.4).

Figure 7.2-1
BAT Study Threshold Criteria - Study Area for Potential BAT Candidates



7.3.1 Sites

Eleven potential sites for tailings and waste rock disposal were identified within the study area specified by the "distance" threshold criteria. Sites were identified based on a desktop review of landscape and topographical information with the goal of identifying sites with sufficient storage capacity. Identification of the sites began with reference to previous alternatives assessments conducted by CMC (2015), which examined ten sites. Eight of the previously examined sites were re-considered in this BAT study[19], with three additional sites: Lower Dip Creek, Lower Britannia Creek, and Sunshine Creek. Sites are listed in Table 7.3-1 and shown in Figure 7.3-1. For each site, the distance to the open pit (km) was calculated to present the relative distance waste rock and tailings would need to be transported for each site. The catchment area (km^2) that report to each site was also calculated to provide an indication of the relative level of effort required to manage water. Location maps for all sites are provided in **Appendix C**.

Table 7.3-1. Locations for Tailings and Waste Rock Management

Site Name	Code	Included in previous studies?	Distance to Open Pit (km)	Catchment Area* (km^2)
Upper Casino Creek	UC	Yes	5	29
Middle Casino Creek	MC	Yes	6	36
Canadian Creek	CA	Yes	8	55
Upper Britannia Creek	UB	Yes	10	42
Excelsior Creek	EX	Yes	14	68
Coffee Creek	CO	Yes	17	78
Upper Dip Creek	UD	Yes	10	93
Lower Dip Creek	LD	No	18	365
Lower Britannia Creek	LB	No	12	120
Sunshine Creek	SU	No	18	84
Lower Casino Creek	LC	Yes	8	79

Note: (*) Catchment area measured as the area that reports to each site. The larger the value generally require greater effort to manage water.

7.3.2 Tailings and Waste Rock Management Technologies and Configurations

The BAT study considered alternative technologies for NAG tailings, PAG tailings and waste rock; as well as alternative configuration types (e.g., co-disposal or separated impoundments, in five possible combinations as shown in Figure 7.3-2). Conceptual configurations were identified independently from sites, with a generalized assumption that each configuration could be applied at each site.

[19] A "multiple sites" option was evaluated in CMC 2015 and included three separate locations in the Upper Casino, Upper Brynelson and Upper Meloy drainages. This option is not included in the BAT study.

Technologies and approaches for tailings and waste rock management are described in detail in Section 1. Tailings technologies considered in the BAT study include thickened slurry[20], paste, and filtered stack. Sub-aqueous (submerged) and sub-aerial (not submerged) waste rock storage was considered. Different configurations for waste rock were also considered, such as storage in a segregated waste rock facility, or combined (co-disposed) with PAG and/or NAG tailings.

In total, based on the three technologies for tailings management and the two waste rock storage options, 45 conceptual configurations were identified based on five general configuration types (Table 7.3-2). For some candidates, the same tailings technology is proposed for both NAG and PAG tailings (i.e. both filtered stacks), whilst other candidates use a combination of technologies (i.e., NAG tailings as a filtered stack and PAG tailings as thickened slurry).

7.3.3 Preliminary List of Conceptual Candidates

Considering 11 sites and 45 conceptual configurations for each site, CMC identified a preliminary list of 495 conceptual BAT candidates. Table 7.3-3 describes the 45 configurations, all of which are applied to each of the 11 sites. The combination of the site code and configuration number provides a unique identifier for each of the 495 candidates. For example, candidates in the Upper Casino Creek (UC) location are numbered UC-1 to UC-45, candidates in the Canadian Creek (CA) location are numbered CA-1 to CA-45, etc.

7.3.4 Evaluation of Threshold Criteria

The preliminary list of 495 conceptual candidates was evaluated against the threshold criteria provided in Section 7.2. All candidates satisfactorily meet the threshold criteria for distance and storage capacity. However, one site (Lower Dip Creek) and one tailings technology (paste) were excluded on the basis of site characteristics, as described below.

7.3.4.1 Distance

All candidates are located within the study area shown in Figure 7.2-1. Thus, all candidates meet the threshold criteria for distance.

7.3.4.2 Storage Capacity

All candidates provide sufficient potential storage capacity for the expected volume of tailings and waste rock. Thus, all candidates meet the threshold criteria for storage capacity.

7.3.4.3 Site Characteristics

The size of a site's catchment area and the prevailing climate were identified as limiting factors to the success of some candidates.

[20] Given that the mill design for Casino will generate a thickened tailings at the process plant, unthickened tailings slurry technology was not considered.

Figure 7.3-1
BAT Study – Location of BAT Candidates (Long-list)

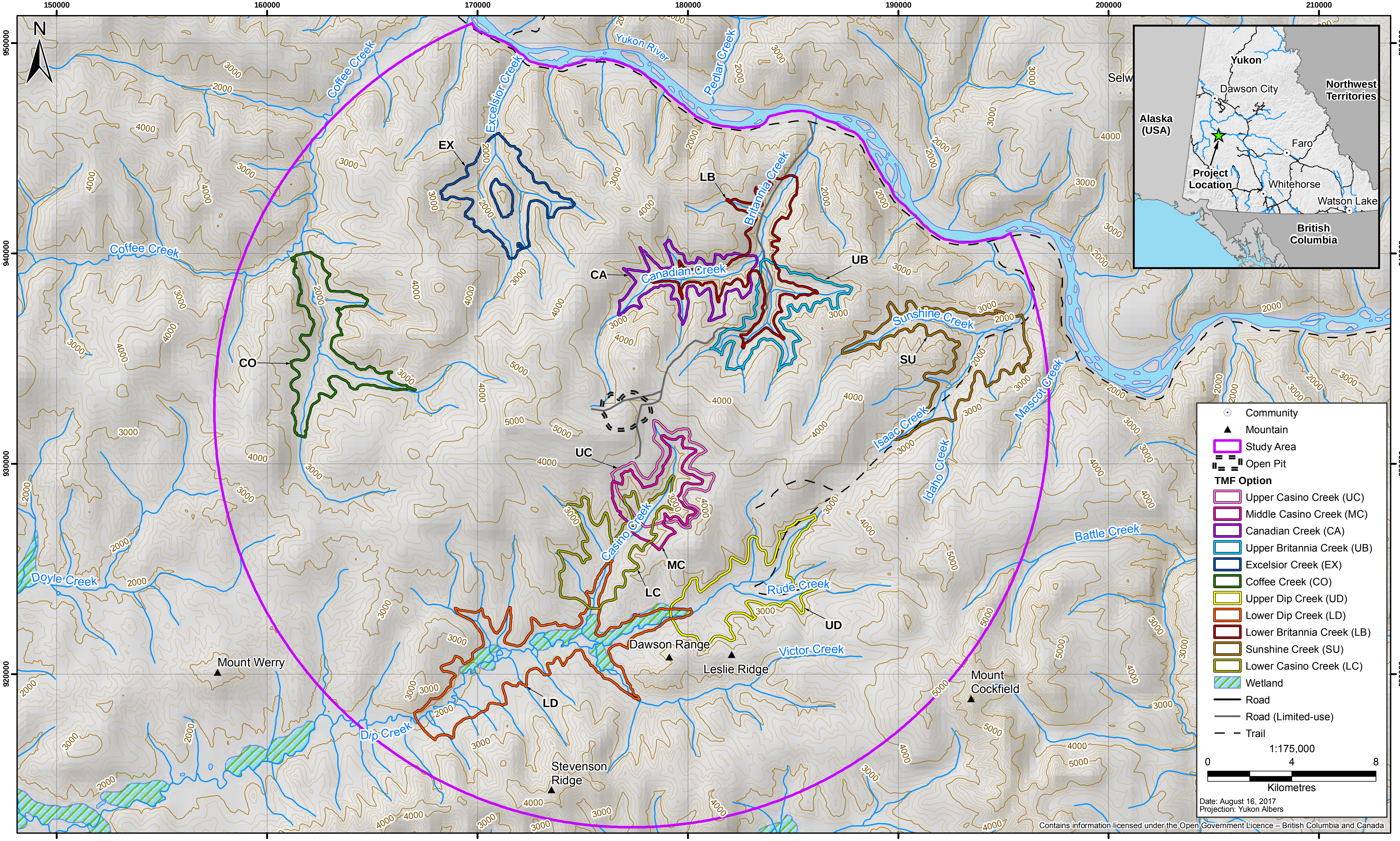


Figure 7.3-2
Conceptual Configuration Types

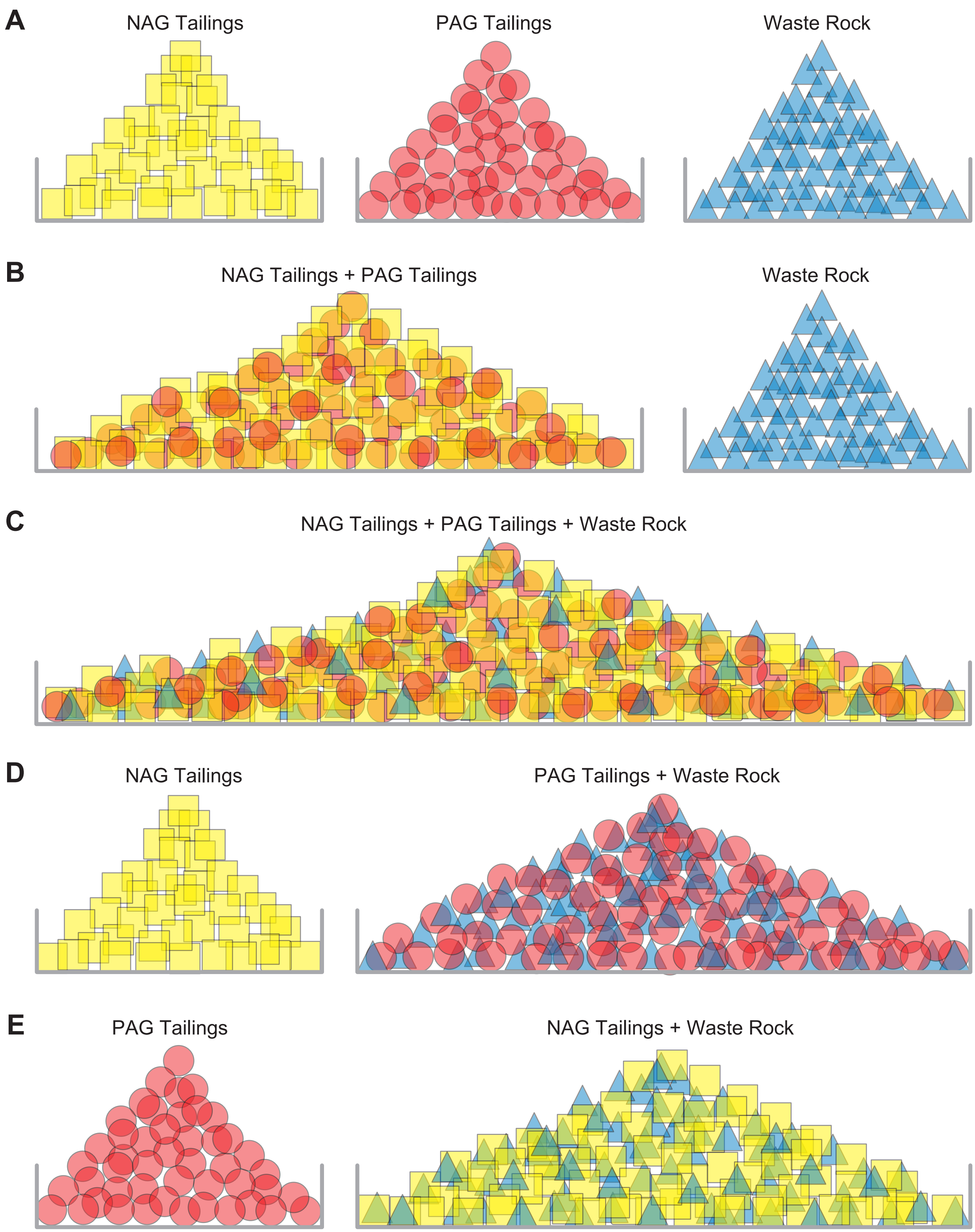


Table 7.3-2. Conceptual Configurations for Tailings and Waste Rock Management

Configuration Type	Mine Waste Type	Tailings: Thick. Slurry	Tailings: Paste	Tailings: Filtered	Waste Rock: Sub-Aerial	Waste Rock: Sub-Aqueous	# of Configurations
A. Separate disposal of NAG, PAG, and waste rock	NAG Tailings	X	X	X			18
	PAG Tailings	X	X	X			
	Waste Rock				X	X	
B. Combined storage of NAG and PAG tailings, with separate storage of waste rock	NAG/PAG Tailings	X	X	X			6
	Waste Rock				X	X	
C. Combined storage of NAG tailings, PAG tailings and waste rock	NAG/PAG Tailings + Waste Rock	X	X	X	*	*	3
D. Combined storage of PAG tailings and waste rock, with separate storage of NAG tailings	NAG Tailings	X	X	X			9
	PAG Tailings + Waste Rock	X	X	X	*	*	
E. Combined storage of NAG tailings and waste rock, with separate storage of PAG tailings	PAG Tailings	X	X	X			9
	NAG Tailings + Waste Rock	X	X	X	*	*	
Total Conceptual Combinations							**45**

Note: (*) waste rock storage is dependent on tailings technology; sub-aerial storage is used for filtered tailings, and sub-aqueous storage is used for thickened and paste tailings.

Table 7.3-3. Conceptual Configurations

No.	BAT Factor: NAG Tailings	BAT Factor: PAG Tailings	BAT Factor: Waste Rock Management	Description of Candidate	Config. Type
1	Thickened slurry	Thickened slurry	Sub-aerial	Separate storage of NAG and PAG tailings as thickened slurries, with waste rock stored separately in sub-aerial facility	A
2	Thickened slurry	Thickened slurry	Sub-aqueous	Separate storage of NAG and PAG tailings as thickened slurries, with waste rock stored separately in sub-aqueous facility	A
3	Thickened slurry	Paste	Sub-aerial	Separate storage of NAG tailings as thickened slurry and PAG tailings as paste, with waste rock stored separately in sub-aerial facility	A

(continued)

Table 7.3-3. Conceptual Configurations (continued)

No.	BAT Factor			Description of Candidate	Config. Type
	NAG Tailings	PAG Tailings	Waste Rock Management		
4	Thickened slurry	Paste	Sub-aqueous	Separate storage of NAG tailings as thickened slurry and PAG tailings as paste, with waste rock stored separately in a sub-aqueous facility	A
5	Thickened slurry	Filtered Stack	Sub-aerial	Separate storage of NAG tailings as thickened slurry and PAG tailings as filtered stack, with waste rock stored separately in sub-aerial facility	A
6	Thickened slurry	Filtered Stack	Sub-aqueous	Separate storage of NAG tailings as thickened slurry and PAG tailings as filtered stack, with waste rock stored separately in sub-aqueous facility	A
7	Paste	Thickened Slurry	Sub-aerial	Separate storage of NAG tailings as paste and PAG tailings as thickened slurry, with waste rock stored separately in sub-aerial facility	A
8	Paste	Thickened Slurry	Sub-aqueous	Separate storage of NAG tailings as paste and PAG tailings as thickened slurry, with waste rock stored separately in sub-aqueous facility	A
9	Paste	Paste	Sub-aerial	Separate storage of NAG and PAG tailings as pastes, with waste rock stored separately in sub-aerial facility	A
10	Paste	Paste	Sub-aqueous	Separate storage of NAG and PAG tailings as pastes, with waste rock stored separately in sub-aqueous facility	A
11	Paste	Filtered Stack	Sub-aerial	Separate storage of NAG tailings as paste and PAG tailings as filtered stack, with waste rock stored separately in sub-aerial facility	A
12	Paste	Filtered Stack	Sub-aqueous	Separate storage of NAG tailings as paste and PAG tailings as filtered stack, with waste rock stored separately in sub-aqueous facility	A
13	Filtered Stack	Thickened Slurry	Sub-aerial	Separate storage of NAG tailings as filtered stack and PAG tailings as thickened slurry, with waste rock stored separately in sub-aerial facility	A
14	Filtered Stack	Thickened Slurry	Sub-aqueous	Separate storage of NAG tailings as filtered stack and PAG tailings as thickened slurry, with waste rock stored separately in sub-aqueous facility	A
15	Filtered Stack	Paste	Sub-aerial	Separate storage of NAG tailings as filtered stack and PAG tailings as paste, with waste rock stored separately in sub-aerial facility	A
16	Filtered Stack	Paste	Sub-aqueous	Separate storage of NAG tailings as filtered stack and PAG tailings as paste, with waste rock stored separately in sub-aqueous facility	A
17	Filtered Stack	Filtered Stack	Sub-aerial	Separate storage of NAG and PAG tailings as filtered stack, with waste rock stored separately in sub-aerial facility	A

(continued)

Table 7.3-3. Conceptual Configurations (continued)

No.	BAT Factor			Description of Candidate	Config. Type
	NAG Tailings	PAG Tailings	Waste Rock Management		
18	Filtered Stack	Filtered Stack	Sub-aqueous	Separate storage of NAG and PAG tailings as filtered stack, with waste rock stored separately in sub-aqueous facility	A
19	Thickened slurry	Thickened slurry	Sub-aerial	Combined storage of NAG and PAG tailings as thickened slurry, with separate storage of waste rock in a sub-aerial facility	B
20	Thickened slurry	Thickened slurry	Sub-aqueous	Combined storage of NAG and PAG tailings as thickened slurry, with separate storage of waste rock in a sub-aqueous facility	B
21	Paste	Paste	Sub-aerial	Combined storage of NAG and PAG tailings as paste, with waste rock stored separately in sub-aerial facility	B
22	Paste	Paste	Sub-aqueous	Combined storage of NAG and PAG tailings as paste, with waste rock stored separately in sub-aqueous facility	B
23	Filtered Stack	Filtered Stack	Sub-aerial	Combined storage of NAG and PAG tailings as filtered stack, with waste rock stored separately in sub-aerial facility	B
24	Filtered Stack	Filtered Stack	Sub-aqueous	Combined storage of NAG and PAG tailings as filtered stack, with waste rock stored separately in sub-aqueous facility	B
25	Thickened slurry	Thickened slurry	Sub-aqueous	Co-disposal of NAG and PAG tailings as thickened slurry with waste rock (sub-aqueous)	C
26	Paste	Paste	Sub-aqueous	Co-disposal of NAG and PAG tailings as paste with waste rock (sub-aqueous)	C
27	Filtered Stack	Filtered Stack	Sub-aerial	Co-disposal of NAG and PAG tailings as filtered stack with waste rock (sub-aerial)	C
28	Thickened slurry	Thickened slurry	Sub-aqueous	Combined storage of PAG tailings as thickened slurry with waste rock (sub-aqueous), with separate storage of NAG tailings as thickened slurry	D
29	Thickened slurry	Paste	Sub-aqueous	Combined storage of PAG tailings as paste with waste rock (sub-aqueous), with separate storage of NAG tailings as thickened slurry	D
30	Thickened slurry	Filtered Stack	Sub-aerial	Combined storage of filtered PAG tailings with waste rock (sub-aerial) in a stack, with separate storage of NAG tailings as thickened slurry	D
31	Paste	Thickened slurry	Sub-aqueous	Combined storage of PAG tailings as thickened slurry with waste rock (sub-aqueous), with separate storage of NAG tailings as paste	D
32	Paste	Paste	Sub-aqueous	Combined storage of PAG tailings as paste with waste rock (sub-aqueous), with separate storage of NAG tailings as paste	D

(continued)

Table 7.3-3. Conceptual Configurations (completed)

No.	BAT Factor			Description of Candidate	Config. Type
	NAG Tailings	PAG Tailings	Waste Rock Management		
33	Paste	Filtered Stack	Sub-aerial	Combined storage of filtered PAG tailings with waste rock (sub-aerial) in a stack, with separate storage of NAG tailings as paste	D
34	Filtered Stack	Thickened slurry	Sub-aqueous	Combined storage of PAG tailings as thickened slurry with waste rock (sub-aqueous), with separate storage of NAG tailings as filtered stack	D
35	Filtered Stack	Paste	Sub-aqueous	Combined storage of PAG tailings as paste with waste rock (sub-aqueous), with separate storage of NAG tailings in filtered stack	D
36	Filtered Stack	Filtered Stack	Sub-aerial	Combined storage of filtered PAG tailings with waste rock (sub-aerial) in a stack, with separate storage of NAG tailings in filtered stack	D
37	Thickened slurry	Thickened slurry	Sub-aqueous	Combined storage of NAG tailings as thickened slurry with waste rock (sub-aqueous), with separate storage of PAG tailings as thickened slurry	E
38	Thickened slurry	Paste	Sub-aqueous	Combined storage of NAG tailings as thickened slurry with waste rock (sub-aqueous), with separate storage of PAG tailings as paste	E
39	Thickened slurry	Filtered Stack	Sub-aqueous	Combined storage of NAG tailings as thickened slurry with waste rock (sub-aqueous), with separate storage of PAG tailings in filtered stack	E
40	Paste	Thickened slurry	Sub-aqueous	Combined storage of NAG tailings as paste with waste rock (sub-aqueous), with separate storage of PAG tailings as thickened slurry	E
41	Paste	Paste	Sub-aqueous	Combined storage of NAG tailings as paste with waste rock (sub-aqueous), with separate storage of PAG tailings as paste	E
42	Paste	Filtered Stack	Sub-aqueous	Combined storage of NAG tailings as paste with waste rock (sub-aqueous), with separate storage of PAG tailings in filtered stack	E
43	Filtered Stack	Thickened slurry	Sub-aerial	Combined storage of filtered NAG tailings with waste rock (sub-aerial) in a stack, with separate storage of PAG tailings as thickened slurry	E
44	Filtered Stack	Paste	Sub-aerial	Combined storage of filtered NAG tailings with waste rock (sub-aerial) in a stack, with separate storage of PAG tailings as paste	E
45	Filtered Stack	Filtered Stack	Sub-aerial	Combined storage of filtered NAG tailings with waste rock (sub-aerial) in a stack, with separate storage of PAG tailings in filtered stack	E

Catchment Area

The catchment areas for the sites range from 29 km^2 to 365 km^2. With the largest catchment area—at more than three times the size of the next largest area—the Lower Dip Creek site was determined to be unsuitable. Although the location of the site in Lower Dip Creek could store the all of the tailings and waste rock, the site is situated such that it has a substantial upstream catchment. The extreme catchment size would require an extensive network of diversions to keep water away from the facility. Additionally, when preparing a design for a facility, the diversions are assumed to not function during the Inflow Design Flood (IDF), thereby requiring each of the configurations to either contain or pass through the IDF for this very large upstream catchment. Hence, the Lower Dip Creek site is considered unsuitable given the size of the upstream catchment.

As a result, all 45 candidates at the Lower Dip Creek site were excluded from further assessment.

Climate

For all sites, local climate characteristics—specifically, precipitation levels—are not acceptable for paste tailings technology. Paste tailings are better suited to facilities located in dry climates; elsewhere, they are more common at smaller, underground operations when structural backfill is required. For surface operations in temperate climates, the experience from paste facilities shows difficulty in consistently achieving the intended solids content, and therefore the solids content of tailings ends up being closer to ultra-thickened tailings.

Given the annual precipitation in the study area, configurations utilizing paste technology do not meet the site characteristics threshold criteria. Compared to thickened tailings, paste tailings would require additional energy and effort to produce and transport, yet would offer little additional benefit with respect to retaining extracted water at the process plant. Further, if the paste tailings were deposited in the facility, given the local precipitation, the water content of the paste tailings would likely increase and migrate towards that of a thickened slurry.

As a result, 23 configurations[21] are excluded on the basis of paste tailings technology being incompatible with the site characteristics. This includes any candidate that proposed to manage PAG and/or NAG tailings as paste.

7.4 LONG-LIST OF BAT CANDIDATES

A total of 275 conceptual candidates did not meet the threshold criteria and were not assessed further, including those at the Lower Dip Creek site, and the configurations that utilized paste tailings. The remaining 220 candidates (based on 10 sites and 22 configurations) met the threshold criteria and proceed to the critical flaw assessment in Step 2; these candidates are summarized in Table 7.4-1.

[21] With reference to the conceptual configurations presented in Table 7.3-, configuration numbers 3, 4, 7-12, 15, 16, 21, 22, 26, 29, 31-33, 35, 38, 40- 42, and 44 are excluded for all sites.

Table 7.4-1. Long List of BAT Candidates

Site	Configuration Type	Configuration No.	Description of Candidate
Ten sites: 1. Upper Casino Creek (UC) 2. Middle Casino Creek (MC) 3. Canadian Creek (CC) 4. Upper Britannia Creek (UB) 5. Excelsior Creek (EX) 6. Coffee Creek (CO) 7. Upper Dip Creek (UD) 8. Lower Britannia Creek (LB) 9. Sunshine Creek (SU) 10. Lower Casino Creek (LC)	A	1	Separate storage of NAG and PAG tailings as thickened slurries, with waste rock stored separately in sub-aerial facility
		2	Separate storage of NAG and PAG tailings as thickened slurries, with waste rock stored separately in sub-aqueous facility
		5	Separate storage of NAG tailings as thickened slurry and PAG tailings as filtered stack, with waste rock stored separately in sub-aerial facility
		6	Separate storage of NAG tailings as thickened slurry and PAG tailings as filtered stack, with waste rock stored separately in sub-aqueous facility
		13	Separate storage of NAG tailings as filtered stack and PAG tailings as thickened slurry, with waste rock stored separately in sub-aerial facility
		14	Separate storage of NAG tailings as filtered stack and PAG tailings as thickened slurry, with waste rock stored separately in sub-aqueous facility
		17	Separate storage of NAG and PAG tailings as filtered stack, with waste rock stored separately in sub-aerial facility
		18	Separate storage of NAG and PAG tailings as filtered stack, with waste rock stored separately in sub-aqueous facility
	B	19	Combined storage of NAG and PAG tailings as thickened slurry, with separate storage of waste rock in a sub-aerial facility
		20	Combined storage of NAG and PAG tailings as thickened slurry, with separate storage of waste rock in a sub-aqueous facility
		23	Combined storage of NAG and PAG tailings as filtered stack, with waste rock stored separately in sub-aerial facility
		24	Combined storage of NAG and PAG tailings as filtered stack, with waste rock stored separately in sub-aqueous facility
	C	25	Co-disposal of NAG and PAG tailings as thickened slurry with waste rock (sub-aqueous)
		27	Co-disposal of NAG and PAG tailings as filtered stack with waste rock (sub-aerial)
	D	28	Combined storage of PAG tailings as thickened slurry with waste rock (sub-aqueous), with separate storage of NAG tailings as thickened slurry
		30	Combined storage of filtered PAG tailings with waste rock (sub-aerial) in a stack, with separate storage of NAG tailings as thickened slurry
		34	Combined storage of PAG tailings as thickened slurry with waste rock (sub-aqueous), with separate storage of NAG tailings as filtered stack
		36	Combined storage of filtered PAG tailings with waste rock (sub-aerial) in a stack, with separate storage of NAG tailings in filtered stack
	E	37	Combined storage of NAG tailings as thickened slurry with waste rock (sub-aqueous), with separate storage of PAG tailings as thickened slurry
		39	Combined storage of NAG tailings as thickened slurry with waste rock (sub-aqueous), with separate storage of PAG tailings in filtered stack
		43	Combined storage of filtered NAG tailings with waste rock (sub-aerial) in a stack, with separate storage of PAG tailings as thickened slurry
		45	Combined storage of filtered NAG tailings with waste rock (sub-aerial) in a stack, with separate storage of PAG tailings in filtered stack

TWG Highlights 7-2. Consideration of Additional Candidates

After reviewing the long-list of candidates and critical flaw assessment, the TWG requested that additional "distributed storage" candidates be developed for consideration. In addition, the TWG requested that further study examine the potential use of pit backfilling to reduce the volume of mine waste stored outside the pit, and the use of the uppermost segment of Canadian Creek (as the development of the open pit will isolate this segment from the rest of the Canadian Creek catchment). CMC has conducted supplemental analysis of these factors, as discussed in Section 8.4. Ultimately, the distributed storage candidate was excluded because it did not offer any benefits over a single-impoundment storage, and had a number of downsides.

8. STEP 2: CRITICAL FLAW ASSESSMENT

8.1 OVERVIEW

The critical flaw assessment screens the long-list of BAT candidates (as described in Section 7.4) to identify alternatives that have obvious deficiencies, and remove these alternatives from further analysis. This step ensures that the decision-making process is optimized so that the study is focused on realistic and sufficiently detailed alternatives. Candidates with “critical flaws”, i.e., a characteristic so unfavourable or immitigable as to eliminate it as a viable alternative—are not considered further.

The screening criteria comprise a list of yes-or-no questions designed to identify critical flaws (i.e., unavoidable or immitigable flaws). Critical flaws may be associated with design limitations, the ability of the candidate to obtain the necessary permits, CMC’s environmental objectives, or other factors. A candidate with one or more critical flaws (i.e., answering “yes” to any of the screening criteria) is not considered further in the BAT study; candidates with no critical flaws proceed to the HLRA in Step 3.

8.2 SCREENING CRITERIA

The screening criteria were developed specifically for the Casino Project, considering the local context, environment, and CMC’s commitments. The screening criteria are presented in Table 8.2-1.

TWG Highlights 8-1. Screening Criteria

CMC provided the draft screening criteria to the TWG for review and comment. The following adjustments to the criteria were made as a result of TWG comments.

- Criterion “i” was adjusted to focus on the ability to obtain permission for mine waste storage, rather than listing examples of excluded land designations.
- Criterion “ii” originally referred to the practicality of collection and treatment of surface discharges, and comments noted that there would not be sufficient detail available for each candidate in order to use this criterion as a differentiator. This criterion was adjusted to focus on sites and their relative proximity to the Yukon River.
- The original wording of criterion “iii” asked whether long-term active water treatment would be required. The working group questioned the availability of information to support this analysis for each candidate at this point in the process, although the intention of the criterion was supported. Given CMC’s understanding of the geochemical characteristics of the Project’s tailings and waste rock, and the associated management strategy that best addresses these characteristics, this criterion was adjusted to focus on the use of BAT to manage the risks associated with the mine waste.

Table 8.2-1. Screening Criteria

Screening Criteria	Rationale
i. Will the candidate overlap with lands for which the proponent is precluded from reasonably obtaining permissions for long-term mine waste storage?	A candidate that is located in areas or lands that preclude mining is not acceptable. These areas may include First Nations settlement lands (categories A and B), and protected areas including Yukon and federal parks. In accordance with the exceptions identified in the *Yukon Quartz Mining Act*, it may also include residential properties; land valuable for water power purposes; agricultural land under active cultivation; land on which a cemetery, burial ground or church is situated; and land that may be required for settlement of Aboriginal land claims, park, historic site, or public infrastructure.
ii. Is the candidate located in a first-order or second-order tributary of the Yukon River?	A candidate that is situated in a catchment that drains directly into the Yukon River (i.e., a first- or second-order tributary) is not acceptable. Given the regional environmental and cultural importance of the Yukon River, CMC is committed to minimizing risk to this waterway. The potential environmental consequences of unplanned discharges or a dam failure varies depending upon the technology chosen and, importantly, the characteristics of the downstream environment. As such, candidates that are located in close proximity to the Yukon River will result in a significantly greater potential environmental effect as a consequence of an unplanned discharge or a dam failure compared to those candidates that are not.
iii. Will the candidate exclude the application of best available technology for management of metal leaching and acid rock drainage?	A candidate that proposes sub-aerial storage of waste rock and/or unsaturated storage of PAG tailings will promote the onset of ARD conditions, given the geochemical characteristics of these materials. Such configurations disregard the BAT to act as source control and prevent the onset of ML and ARD. Such candidates will clearly require active water treatment in the long-term and are therefore not acceptable.
iv. Will the candidate result in deposition of tailings into a fish-bearing lake?	A candidate that deposits tailings or waste rock in a fish-bearing lake is not acceptable due to impacts on fish and fish habitat, aquatic resources, cultural use, and public perception.
v. Will the candidate preclude future exploration and development of subsurface resources?	A candidate that precludes future subsurface exploration and development is not acceptable as it prevents the Crown from receiving economic and social benefits from mineral development.
vi. Will the candidate rely on mine waste technologies that have not been proven effective, in practice, at an operating mine?	A candidate that relies on unproven mine waste technologies is not acceptable. This criterion requires the technology to be proven effective at an operating mine regardless of scale (i.e., eliminating purely conceptual or academic technology).

8.3 CRITICAL FLAW ASSESSMENT

The long-list of candidates from Step 1 includes ten sites and 22 possible configurations (based on two tailings technologies (thickened slurry and filtered stack) and two waste rock storage alternatives (sub-aerial and sub-aqueous), for a total of 220 candidates (Table 7.3-1). The following sections evaluate the locations and configurations as relevant to each screening criteria.

<u>i. Will the candidate overlap with lands for which the proponent is precluded from reasonably obtaining permissions for long-term mine waste storage?</u>

This criterion is dependent only on the location of a given candidate. None of the ten remaining locations overlap with First Nations settlement lands (categories A and B), parks or protected areas, or other lands for which the proponent may be precluded from obtaining the necessary permissions.

Conclusion: No candidates are excluded on the basis of this criterion.

ii. Is the candidate located in a first-order or second-order tributary of the Yukon River?

This criterion focuses on the location of each candidate as it relates to the Yukon River. Sites that drain directly to the Yukon River are viewed to pose an unnecessary risk in the event of unplanned discharges or potential facility failure scenarios and potential effects on the receiving environment. While all candidates are situated in the Yukon River drainage, some candidates are located in a first- or second-order tributary of the Yukon River, where the candidate is only a few kilometers upstream from the river.

Conclusion: The Coffee Creek (CO), Excelsior Creek (EX), Canadian Creek (CA), Upper Britannia Creek (UB), Lower Britannia Creek (LB), and Sunshine Creek (SU) sites are situated in first- or second-order tributaries to the Yukon River (Figure 7.3-1), and are excluded from further assessment.

iii. Will the candidate exclude the application of best available technology for management of metal leaching and acid rock drainage?

The specific geochemical characteristics of the Casino Project tailings and waste rock are understood sufficiently well to determine the BAT that will lead to effective source control and therefore the prevention of ML/ARD conditions. In accordance with industry guidance and the 2016 review of the TMF design by the Independent Engineering Review Panel (IERP), and subsequent optimization of the design, CMC has confirmed that the best available technology for managing waste rock and PAG tailings at the Casino site is in a sub-aqueous environment. Therefore, those candidates that propose sub-aerial storage of waste rock and/or unsaturated storage of PAG tailings do not meet the BAT for this deposit. On this basis, a candidate that proposes filtered disposal of PAG tailings and/or sub-aerial waste rock placement is not acceptable.

Conclusion: Candidates with configurations 5, 6, 17, 18, 23, 24, 27, 30, 36, 39 and 45, that were not previously eliminated in Step 1, involve filtered PAG tailings, and are excluded from further assessment. Candidates with sub-aerial waste rock storage, that were not previously eliminated in Step 1, which includes candidates with configurations 1, 5, 13, 17, 19, 23, 27, 30, 36, 43 and 45, are also eliminated.

TWG Highlights 8-2. Elimination of Filtered PAG

In response to the TWG's request for further information supporting the elimination of filtered PAG tailings, CMC commissioned a geochemical memorandum detailing the challenges of filtered PAG tailings, including ARD-generating potential, for the Casino deposit. This memorandum (Geochemical Implications of Unsaturated Tailings Storage) is provided in **Appendix E**.

iv. Will the candidate result in deposition of tailings into a fish-bearing lake?

This criterion is dependent primarily on the location of a given candidate. None of the ten remaining locations overlap with fish-bearing lakes.

Conclusion: No candidates are excluded on the basis of this criterion.

v. Will the candidate preclude future exploration and development of subsurface resources?

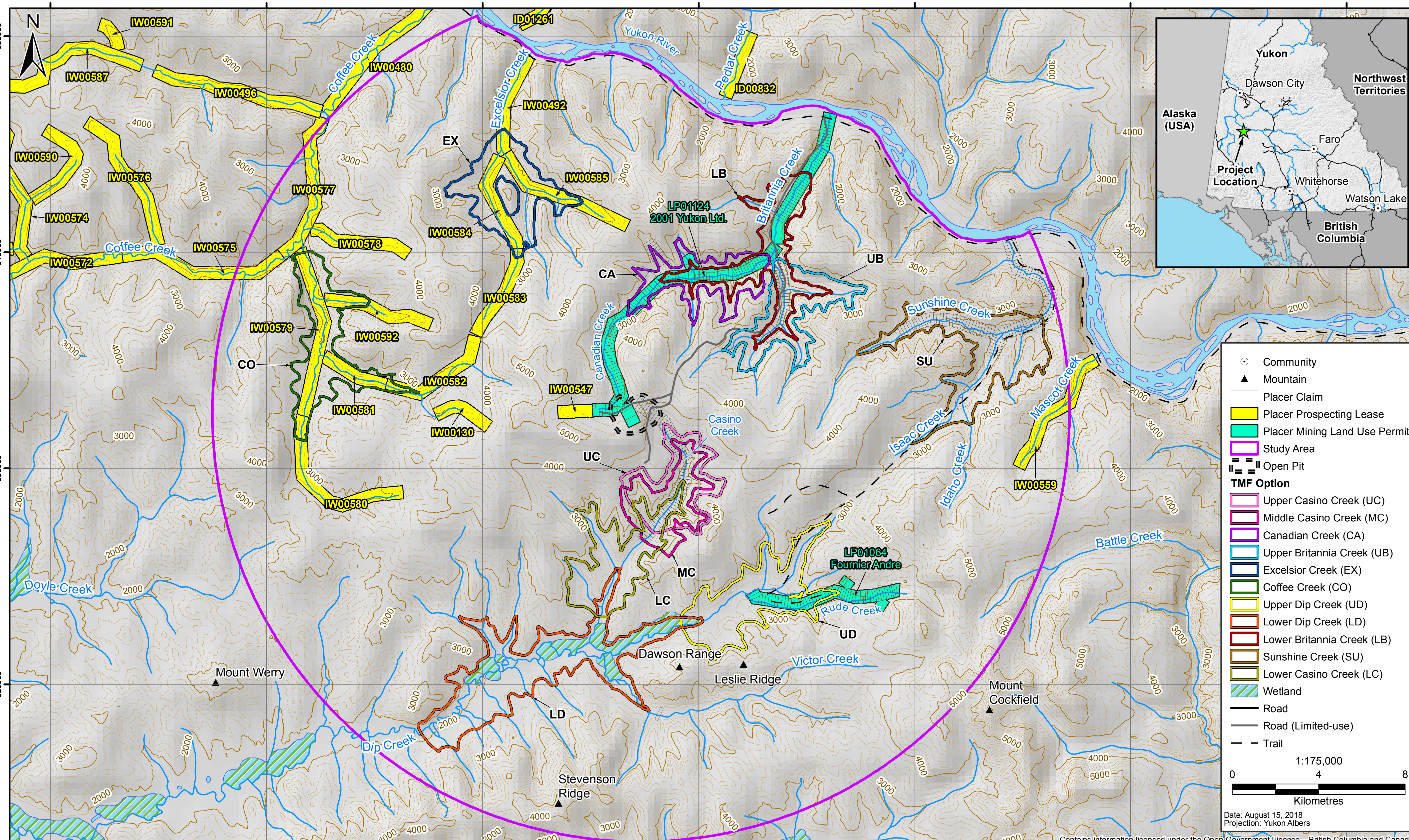
This criterion is dependent primarily on the location of a given candidate. There are no known oil-and-gas, coal, or other subsurface resource tenures in the study area. However, there are numerous overlapping mineral tenures in the study area, including quartz and placer claims, leases, and mining land use permits. The presence of mineral claims and leases is not indicative of a proven and economically viable resource and does not preclude development of surface facilities and infrastructure, although active mining land use permits for the exploitation of these resources offers a greater level of certainty about the viability of these resources.

Table 8.3-1 describes the placer and hard rock (quartz) mining tenures that overlap with the proposed sites. Placer tenures are illustrated in Figure 8.3-1.

Table 8.3-1. Mineral Tenures

Type of Tenure	Description
Placer prospecting leases	The Excelsior Creek (EX) and Coffee Creek (CO) sites overlap active placer prospecting leases. A prospecting lease allows the holder to prospect and test a large area and gain exclusive rights to stake and claim that area; prospecting leases are not indicative of a commercially viable resource, and do not preclude the development of surface facilities.
Placer claims	Placer claims have been staked along Lower Britannia Creek, Canadian Creek, Casino Creek, Sunshine Creek, and Rude Creek. CMC holds the placer claims along Casino Creek including the proposed mine site. Claims along Canadian Creek also overlap with the proposed mine site and are included under a placer mining land use permit held by Yukon 2001 Ltd. (discussed below). Placer claims at Sunshine Creek overlap with the Sunshine Creek (SU) site. Claims at Rude Creek overlap with the Upper Dip Creek (UD) site and are also covered by a placer mining land use permit held by Andre Fournier (discussed below). The presence of placer claims is not indicative of commercially viable resources, and do not preclude the development of surface infrastructure.
Placer mining land use permits	The Canadian Creek (CA), Lower Britannia Creek (LB), and Upper Dip Creek (UD) sites overlap with active placer mining land use permits. These permits (LP01124 and LP01064, both valid 2016 to 2026) allow the holders to develop placer mines, each permitted for ten years of mining operations. The placer mining land use permits represent commercially viable mineral resources for which the development of surface infrastructure could preclude development. However, the duration of these operations is typically short (i.e., permits are valid for 10 years) and financial investments are small compared to the scale of the Casino Project. It is reasonable to expect that CMC could negotiate an agreement with these tenure holders to acquire their tenures; thus, this is not considered to be a critical flaw.
Quartz mining land use permits	In addition to the permits held by CMC, there are three permits for quartz exploration in the study area, held by Cariboo Rose Resources, Centerra Gold, and Kaminak (Goldcorp). Permits for quartz exploration do not preclude development. The nearest proposed hard rock mining project is the Coffee Gold Project. Based on a review of the Coffee Project Proposal, it does not appear that the proposed mine site overlaps with, or is downstream of, any of the candidates. However, associated infrastructure includes roads and barge landings around the confluence of Coffee Creek and the Yukon River, which is downstream of the Coffee Creek (CO) site (which has been eliminated by criterion ii).

Figure 8.3-1
Placer Tenures



TWG Highlights 8-3. Elimination Based on Mineral Tenures

An early draft of the critical flaw assessment eliminated sites at Canadian Creek, Lower Britannia Creek, and Upper Dip Creek due to their overlap with active placer mining land use permits. However, based on discussion with the TWG in October 2017, this was no longer classified as a critical flaw as it is reasonable to expect that CMC could negotiate an agreement with the permit holders. Thus, Upper Dip Creek was reinstated as a viable candidate at this stage; however, Canadian Creek and Lower Britannia Creek remained eliminated on the basis of being first- or second-order tributaries of the Yukon River.

vi. Will the candidate rely on mine waste technologies that have not been proven effective, in practice, at an operating mine?

This criterion is dependent primarily on the choice of tailings technology, which may include thickened slurry and filtered stack technologies. Each candidate includes one or more of these technologies to manage PAG and NAG tailings, which may be stored separately or together, and/or co-disposed with waste rock.

All candidates utilise tailings technologies and waste rock management approaches that have been proven, in practice, at operating mines. Not all have been proven in Yukon and/or at the scale of the Casino Project. Project-specific considerations (including technical feasibility, safety, scalability, etc.) will be addressed in later steps of the BAT study.

Conclusion: No candidates are excluded on the basis of this criterion.

TWG Highlights 8-4. Distributed Storage, Backfilling, and Isolated Canadian Creek

After reviewing the long-list of candidates and critical flaw assessment results, the TWG requested that CMC provide additional information or analysis in the following areas:

- Consideration of potential "distributed storage" candidate(s) utilizing multiple smaller sites, in order to understand whether such an option could provide advantages over candidates constrained to a single location. In particular, the TWG expressed interest in determining whether a distributed storage candidate could be developed to include multiple water-retaining embankments with lower embankment heights.
- Calculation of the volume of mine waste that could be backfilled into the pit, and the implications this might have on dam height and catchment areas through reduction in the volume of mine waste stored outside the pit.
- Potential use of the uppermost segment of Canadian Creek, as the development of the open pit will eventually isolate this segment from the rest of the Canadian Creek catchment.

Specifically, the TWG requested that distributed storage candidate(s) be considered within the Casino Creek and Upper Dip Creek valleys, and with consideration for backfilling of the pit and the use of the isolated Canadian Creek catchment. CMC has conducted additional analysis to respond to these questions, as summarized in the memoranda relating to the use of multiple sites (**Appendix D**) and unsaturated storage of PAG tailings (**Appendix E**).

8.4 SUPPLEMENTAL STUDIES

8.4.1 Multiple Sites ("Distributed Storage") Assessment

In response to questions from the TWG, CMC provided a supplemental analysis of potential candidates utilizing a "distributed storage" approach. This analysis is described in the *Multiple Sites Assessment*[22] (**Appendix D**), and considered the use of multiple sites within the remaining catchment areas following the critical flaw assessment. This analysis included calculation of the volume that could be backfilled in the final years of mine operations, and this backfill is accounted for in the assessment. The storage capacity of the isolated portion of the Canadian Creek valley was also calculated and considered in the assessment.

The multiple sites assessment was undertaken to identify if there is a combination of locations within the Casino Creek catchment—and along with the isolated Canadian Creek catchment, and open pit backfill in the last years of operations, and Upper Dip Creek catchment—that would result in:

- Smaller embankments;
- Smaller reporting catchment areas for each facility; and
- Lesser stored volumes in any one facility.

The multiple sites assessment considered a total of seven prospective sites for distributed storage, including five sites in the Casino Creek catchment, plus Upper Dip Creek, the isolated branch of Canadian Creek, and included in-pit backfill opportunities. Results showed that at least four embankments of at least 200 m each would be required to provide the total required storage volume. Based on these results, no significant advantage is identified in regard to a distributed storage approach, and a distributed storage candidate is not considered further.

8.4.2 PAG Tailings Assessment

As noted in TWG Highlight 7-2, a supplemental geochemical summary was prepared to describe the ARD-generating potential of the Project's PAG tailings. The resulting technical memorandum, *Geochemical Implications of Unsaturated Tailings Storage*[23] (**Appendix E**) concluded that the PAG tailings will generate ARD if stored in an unsaturated environment where oxygen ingress can occur. Depyritized tailings are not PAG and can be safely stored in an unsaturated environment without posing an ARD risk. However, the production of depyritized tailings results in the production of a pyrite concentrate which will have a greater acid-generating potential due to its higher sulphide content. If tailings solids are exposed to oxygen, the time until onset of ARD is expected to be a matter of decades; however, this period will be much shorter for the pyrite concentrate. Prior to the onset of acid generation, neutral metal leaching will occur leading to the release of metals that are relatively soluble at a neutral pH. Metal leaching rates are expected to increase dramatically upon the onset of ARD from the PAG tailings and pyrite concentrate.

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[22] Knight Piésold. Memorandum dated December 2017; updated and re-issued April 2018 to include potential use of sites in the Dip Creek catchment.

[23] Lorax Environmental. Memorandum dated December 27, 2017.

This assessment confirmed that the storage of filtered PAG tailings is not a viable option for the Project.

8.5 SUMMARY OF REMAINING CANDIDATES

The critical flaw assessment identified flaws for candidates using sub-aerial waste rock storage and/or storage of PAG tailings as a filtered stack. This resulted in the elimination of 15 of the 22 conceptual configurations (Table 8.5-1), equalling 150 of the 220 remaining candidates. Flaws were also identified for six of the remaining ten sites due to their location within first- or second-order tributaries of the Yukon River (Table 8.5-2). Thus, four sites and seven configurations remain at the end of the critical flaw assessment, for a total of 28 candidates, as summarized in Table 8.5-3.).

Table 8.5-1. Critical Flaw Assessment Results (Configurations)

Configuration			
Type	No.	Description of Candidate	Critical flaw(s) identified?
A	1	Separate storage of NAG and PAG tailings as thickened slurries, with waste rock stored separately in sub-aerial facility	• Sub-aerial waste rock storage
	2	Separate storage of NAG and PAG tailings as thickened slurries, with waste rock stored separately in sub-aqueous facility	No critical flaws
	5	Separate storage of NAG tailings as thickened slurry and PAG tailings as filtered stack, with waste rock stored separately in sub-aerial facility	• Sub-aerial waste rock storage • PAG filtered stack
	6	Separate storage of NAG tailings as thickened slurry and PAG tailings as filtered stack, with waste rock stored separately in sub-aqueous facility	• PAG filtered stack
	13	Separate storage of NAG tailings as filtered stack and PAG tailings as thickened slurry, with waste rock stored separately in sub-aerial facility	• Sub-aerial waste rock storage
	14	Separate storage of NAG tailings as filtered stack and PAG tailings as thickened slurry, with waste rock stored separately in sub-aqueous facility	No critical flaws
	17	Separate storage of NAG and PAG tailings as filtered stack, with waste rock stored separately in sub-aerial facility	• Sub-aerial waste rock storage • PAG filtered stack
	18	Separate storage of NAG and PAG tailings as filtered stack, with waste rock stored separately in sub-aqueous facility	• PAG filtered stack
B	19	Combined storage of NAG and PAG tailings as thickened slurry, with separate storage of waste rock in a sub-aerial facility	• Sub-aerial waste rock storage
	20	Combined storage of NAG and PAG tailings as thickened slurry, with separate storage of waste rock in a sub-aqueous facility	No critical flaws
	23	Combined storage of NAG and PAG tailings as filtered stack, with waste rock stored separately in sub-aerial facility	• Sub-aerial waste rock storage • PAG filtered stack
	24	Combined storage of NAG and PAG tailings as filtered stack, with waste rock stored separately in sub-aqueous facility	• PAG filtered stack

(continued)

Table 8.5-1. Critical Flaw Assessment Results (Configurations; completed)

Configuration			
Type	No.	Description of Candidate	Critical flaw(s) identified?
C	25	Co-disposal of NAG and PAG tailings as thickened slurry with waste rock (sub-aqueous)	No critical flaws
	27	Co-disposal of NAG and PAG tailings as filtered stack with waste rock (sub-aerial)	• Sub-aerial waste rock storage • PAG filtered stack
D	28	Combined storage of PAG tailings as thickened slurry with waste rock (sub-aqueous), with separate storage of NAG tailings as thickened slurry	No critical flaws
	30	Combined storage of filtered PAG tailings with waste rock (sub-aerial) in a stack, with separate storage of NAG tailings as thickened slurry	• Sub-aerial waste rock storage • PAG filtered stack
	34	Combined storage of PAG tailings as thickened slurry with waste rock (sub-aqueous), with separate storage of NAG tailings as filtered stack	No critical flaws
	36	Combined storage of filtered PAG tailings with waste rock (sub-aerial) in a stack, with separate storage of NAG tailings in filtered stack	• Sub-aerial waste rock storage • PAG filtered stack
E	37	Combined storage of NAG tailings as thickened slurry with waste rock (sub-aqueous), with separate storage of PAG tailings as thickened slurry	No critical flaws
	39	Combined storage of NAG tailings as thickened slurry with waste rock (sub-aqueous), with separate storage of PAG tailings in filtered stack	• PAG filtered stack
	43	Combined storage of filtered NAG tailings with waste rock (sub-aerial) in a stack, with separate storage of PAG tailings as thickened slurry	• Sub-aerial waste rock storage
	45	Combined storage of filtered NAG tailings with waste rock (sub-aerial) in a stack, with separate storage of PAG tailings in filtered stack	• Sub-aerial waste rock storage • PAG filtered stack

Table 8.5-2. Critical Flaw Assessment Results (Sites)

Site		Critical flaw(s) identified?
UC	Upper Casino Creek	No critical flaws
MC	Middle Casino Creek	No critical flaws
CA	Canadian Creek	• Second-order tributary of Yukon River
UB	Upper Britannia Creek	• First-order tributary of Yukon River
EX	Excelsior Creek	• First-order tributary of Yukon River
CO	Coffee Creek	• First-order tributary of Yukon River
UD	Upper Dip Creek	No critical flaws
LB	Lower Britannia Creek	• First-order tributary of Yukon River
SU	Sunshine Creek	• First-order tributary of Yukon River
LC	Lower Casino Creek	No critical flaws

Table 8.5-3. Remaining Candidates at End of Step 2

Site	Configuration		Description of Candidate
	Type	No.	
Four sites: 1. Upper Casino Creek (UC) 2. Middle Casino Creek (MC) 3. Lower Casino Creek (LC) 4. Upper Dip Creek (UD)	A	2	Separate storage of NAG and PAG tailings as thickened slurries, with waste rock stored separately in sub-aqueous facility
		14	Separate storage of NAG tailings as filtered stack and PAG tailings as thickened slurry, with waste rock stored separately in sub-aqueous facility
	B	20	Combined storage of NAG and PAG tailings as thickened slurry, with separate storage of waste rock in a sub-aqueous facility
	C	25	Co-disposal of NAG and PAG tailings as thickened slurry with waste rock (sub-aqueous)
	D	28	Combined storage of PAG tailings as thickened slurry with waste rock (sub-aqueous), with separate storage of NAG tailings as thickened slurry
		34	Combined storage of PAG tailings as thickened slurry with waste rock (sub-aqueous), with separate storage of NAG tailings as filtered stack
	E	37	Combined storage of NAG tailings as thickened slurry with waste rock (sub-aqueous), with separate storage of PAG tailings as thickened slurry
Total:	**4 sites x 7 configurations = 28 candidates**		

9. STEP 3: HIGH-LEVEL RISK ASSESSMENT

9.1 OVERVIEW

The relative risks of the 28 remaining candidates were evaluated in a HLRA, with the objective of identifying candidates with relatively lower risks, and carrying these candidates into the MAA in Step 5.

The HLRA was conducted in consultation with the TWG as follows:

- At an initial workshop with the TWG in October 2017, CMC provided an overview of the remaining candidates, including their safety, environmental and technical execution hazards. Based on the discussion in the workshop (described in Section 9.2), sites and configurations with higher levels of risk were eliminated by consensus.
- CMC then developed the remaining candidates in further detail, including maps, design, and closure concepts. The TWG reconvened in January and February 2018 and conducted a relative risk assessment of the remaining candidates (Section 9.3).

9.2 HIGH-LEVEL COMPARISON OF SITES AND CONFIGURATIONS

9.2.1 Comparison of Sites

The comparison of sites focused on the predicted dam heights, footprint areas, and catchment areas at Upper Casino Creek, Middle Casino Creek, Lower Casino Creek, and Upper Dip Creek (Table 9.2-1). Total estimated volumes of mine waste include 140 Mm^3 of PAG tailings, 558 Mm^3 of NAG tailings, 329 Mm^3 of waste rock, for a total combined volume of 1,026 Mm^3.

Table 9.2-1. Comparison of Candidates in the HLRA

Site	Dam Height (m)	Impoundment Footprint Area (km^2)	Catchment Area (km^2)
Upper Casino	323	10	29
Middle Casino	280	10	36
Lower Casino	185	12	79
Upper Dip	144	15	93

<u>Casino Creek Catchment</u>

Comparing the three sites in the Casino catchment, the TWG concluded that there was no discernable advantage to Upper Casino Creek compared to the Middle Casino Creek site. However, compared to Middle Casino, Upper Casino was identified to be disadvantageous due to a higher dam and less available area for potential expansion or adjustment.

In the event of a dam failure, Upper Casino and Middle Casino was considered to be similar in terms of how far material would travel; Lower Casino could be better or worse depending on whether it is a sunny-day or rainy-day scenario (i.e., larger reporting catchment means greater IDF, and therefore more energy, during a storm event).

In the Casino Creek valley, there is generally more overburden in lower levels of the valley compared to the upper elevations. Thus, it was reasonably assumed that there would be greater construction challenges for a starter facility in the Lower Casino Creek site. However, the Lower Casino site offers advantages in terms of lower dam height.

The TWG considered potential advantages associated with the Upper Casino location. Upper Casino would have a slightly smaller upstream catchment, and therefore a lower IDF, but it would also require a much higher dam. Some members of the group expressed concern that a higher dam height could result in a higher risk of dam failure compared to Middle or Lower Casino sites.

Ultimately, the TWG saw no strong advantage to the Upper Casino site relative to the Middle Casino and Lower Casino sites, as the disadvantages largely related to a higher dam height. On the basis of this discussion, the TWG supported eliminating the Upper Casino Creek site and associated candidates (UC-2, UC-14, UC-20, UC-25, UC-28, UC-34, and UC-37).

Upper Dip Creek Catchment

The TWG noted that the Dip Creek valley has permafrost conditions which could be challenging for the construction and operation of an impoundment facility. Compared to Lower Casino Creek (another “down-valley” candidate), Upper Dip Creek would require a smaller dam, but has a larger catchment area. It is also further away from the open pit, leading to increased risks related to transporting tailings and waste rock over longer distances. Therefore, compared to Lower Casino Creek, Upper Dip Creek offers the benefit of a modestly lower dam height (approximately 40 m less). But it would require a longer transport distance for pipeline, trucking and/or conveyor.

The biggest disadvantage of the Upper Dip Creek site is that it would disturb a new catchment area that would not otherwise be affected by the Project. The Dip Creek watershed also has different environmental values; based on the available maps, baseline studies, and TWG knowledge, Dip Creek was expected to have higher values with respect to fish habitat and wetlands.

Ultimately, the TWG saw no significant advantage when comparing Upper Dip Creek to Lower Casino Creek, as the benefit of having a lower dam was outweighed by disadvantages in terms of distance and potential environmental impact. The TWG supported eliminating the Upper Dip Creek site and associated candidates (UD-2, UD-14, UD-20, UD-25, UD-28, UD-34, and UD-37).

Conclusion

Upper Casino Creek and Upper Dip Creek sites were eliminated, as the disadvantages for these sites clearly outweighed any advantages. Overall, the TWG agreed that the preferred “upper valley” site is Middle Casino Creek, while the preferred “lower valley” site is Lower Casino Creek.

TWG Highlights 9-1. Elimination of Upper Casino Creek and Upper Dip Creek

On the basis of comparing high-level risks between Upper Casino, Middle Casino, Lower Casino, and Upper Dip sites, the TWG determined that Upper Casino and Upper Dip offered no discernable advantages over the other sites. The working group noted that the higher dam height required for the Upper Casino candidates presented a greater risk that could be avoided with the elimination of this site. Upper Dip was disadvantaged by longer transport distances and potential environmental impacts in a watershed that would not be affected by the Project.

The TWG noted that there could be an opportunity to incorporate the Upper Casino and/or Upper Dip sites through the development of a distributed storage (multiple sites) candidate. CMC subsequently considered the development of a multiple sites candidate, as described in Section 8.4.

9.2.2 Comparison of Configurations

At this stage of the BAT study, seven configurations remained, including at least one of each of the configuration types (A through E) illustrated in Figure 7.3-2. Configurations included various combinations of co-disposal and/or separate storage, which involved the physical separation of waste materials, either in distinct facilities or partitioned within a facility using an independent material (e.g., cyclone sand or borrow material) as a confining embankment.

The TWG discussed the advantages of comingling waste rock with NAG and/or PAG tailings given the advantage of managing waste work and PAG tailings together to prevent ARD. However, given the effort to segregate NAG and PAG waste streams in order to depyritize NAG tailings for use in cyclone sand production, the TWG determined there was no notable benefit to co-mingling NAG and PAG tailings.

Integrated Mitigation

The TWG recognized that configuration types C and D allow for integrated mitigation of dam failure by strategically placing waste rock to contain PAG tailings in case of dam failure, whereas configuration types A, B and E do not provide for this strategic mitigation.

Configuration Type B

Configuration type B (candidates MC-20 and LC-20) involves co-mingling of NAG and PAG tailings. In this configuration, waste rock is stored separately and therefore tailings would not have secondary containment of PAG tailings upstream of waste rock, such that, in the event of a dam failure, the PAG tailings will be released from the TMF area. As indicated above, comingling of NAG and PAG tailings offers no benefit, and configuration type B offers less robust tailings management compared to type A.

Configuration type B also results in two impoundments containing materials that require management of ML/ARD. This has no advantage over configuration type D, which only has one such impoundment, as PAG tailings and waste rock are impounded together. In the event of dam failure, configuration type D also allows for the downstream environment to be protected from PAG tailings dispersal though the strategic placement of waste rock within the impoundment, whereas type B does not allow for this protection.

The TWG also discussed the importance of relative volumes. Configuration type B requires storage of 700 Mm^3 of combined PAG and NAG material, while type D requires combined storage of only 470 Mm^3 of PAG and waste rock. Thus, configuration type B represents a higher risk related to dam failure, compared to configuration type D, simply based on the stored volume. The TWG concluded that, when comparing configuration types B and D, there are disadvantages with type B.

Configuration Type A

An advantage of configuration type A could be the use of waste management strategies tailored to the specific needs of each material, as each material is stored separately. Also, while there are three separate embankments, the consequence of any one embankment failure would be diminished. However, configuration type A was seen to have a number of disadvantages, including two impoundments containing materials that require management of ML/ARD, separate embankments for each material, and an inability to use the waste materials to manage each other. There is also no feasible option for closure that doesn't include a ponded water cover.

Candidates MC-2 and LC-2 were discussed, as these candidates involve storage of NAG and PAG tailings as thickened slurries in separate impoundments. Considering spatial constraints at Middle Casino Creek, the TWG concluded it was not feasible to develop the MC-2 configuration at this location, although the down-valley LC-2 candidate would provide more space for the required facilities.

Configuration Type E

As for types A and B, configuration type E also provides no integrated protection of PAG tailings, as PAG tailings would be isolated in a separate impoundment. The TWG considered that this could provide an opportunity for robust treatment of PAG on its own, possibly in a lined impoundment, but the feasibility of storing 140 Mm^3 PAG in a lined impoundment was questioned.

The TWG compared configuration type E (MC-37 and LC-37) with type C (MC-25 and LC-25). Participants noted that there was no advantage to the E configuration as it would result in two impoundments containing materials that require management of ML/ARD.

Conclusion

Based on the above discussion, the TWG supported eliminating configuration types B and E, which included the elimination of candidates MC-20, LC-20, MC-37, and LC-37.[24] Despite the disadvantages identified for configuration type A, the TWG agreed that these candidates should be investigated further before determining whether they should be eliminated. However, candidate MC-2 was eliminated as it was determined to be inappropriate for the Middle Casino Creek location due to spatial constraints, although the comparable candidate at Lower Casino Creek (LC-2) was retained.

[24] Configuration type E was noted to be considered for inclusion as a possible 'multiple sites' candidate; however, as described in Section 8.4.1, a subsequent evaluation failed to identify feasible multiple sites candidates within the study area.

TWG Highlights 9-2. Elimination of Configuration Types B and E

On the basis of comparing high-level risks of the various configuration types, the TWG concluded that types B and E offered no advantages over the other configurations. Configuration type B was typified by the combined storage of NAG and PAG tailings as thickened slurries, with separate storage of waste rock. The disadvantage of this configuration included the management of two facilities containing materials that require management of ML/ARD, and the inability to use waste rock to protect PAG tailings in the event of dam failure. Based on this increased risk, the TWG decided, by consensus, to eliminate this configuration. Configuration type E posed similar disadvantages and was also eliminated.

9.3 RELATIVE RISK ASSESSMENT

Risks associated with the remaining nine candidates were compared, with the goal of determining which candidates had higher or lower levels of risk. The risk assessment considered the greatest risks, rather than all possible risks. The approach and methods for the comparative risk assessment were developed in consultation with the TWG, and based on standard risk assessment practice, which considered the following factors:

- **Hazard**: a condition, event or circumstance that could lead to, or contribute to, an unplanned or undesirable event.
- **Likelihood**: the probability that the hazard will occur.
- **Consequence**: the expected outcome (worst-case scenario) if the hazard does occur.
- **Risk = likelihood x consequence**.

<u>The Base Case</u>

The relative risk assessment was conducted with comparison to CMC's optimized design (i.e., the base case), represented by candidate MC-25. This candidate has undergone the most detailed level of engineering by CMC, and it has been reviewed and optimized based on IERP comments.

<u>Types of Hazards</u>

The following three hazards were considered:

- **Safety hazard:** The primary safety hazard is a physical failure of a tailings dam or waste pile, leading to the loss of containment of tailings, waste rock, and/or mine water. This hazard considers downstream impacts and the consequences that could result from a failure. The loss of containment could result from a flood-induced (i.e., rainy day) scenario, or a fair weather (i.e., sunny day) scenario, depending on the candidate.
- **Environmental hazard:** The primary environmental hazard is the failure to manage ML/ARD in the long term, leading to the onset of ML/ARD conditions post-closure. This hazard considers the expected ability to effectively manage ML/ARD post-closure, including adaptability to potential environmental changes (e.g., climate change).

- **Technical execution hazard:** The primary technical execution hazard is the failure to meet design criteria for managing tailings, waste rock, and/or mine water. This hazard considers the proven reliability of the technology to operate at the desired scale, as well as the overall complexity of the waste management system (i.e., simpler systems are generally more reliable).

Risk Rating

The scales of likelihood and consequence, relative to the base case, are shown in Table 9.3-1. The relative likelihoods and consequences were rated for each candidate for each of the hazard categories.

Table 9.3-1. Likelihood and Consequence Rating Scales

Likelihood	Consequence
(1) Least likely	(1) Least serious
(2) Less likely	(2) Less serious
(3) Neutral	(3) Neutral
(4) More likely	(4) More serious
(5) Most likely	(5) Most serious

For each candidate, the total risk rating was calculated for each hazard (*Risk = Likelihood x Consequence*) which provided a risk rating for each candidate on a scale of 1 to 25. The ratings for the three hazards were then summed to provide a total risk rating for the candidate. Higher risk ratings represented higher levels of risk.

Safety Risk (scale of 1 to 25)	+	Environmental Risk (scale of 1 to 25)	+	Technical Execution Risk (scale of 1 to 25)	=	Total Risk (scale of 3 to 75)

TWG Highlights 9-3. Relative Risk Assessment

To narrow down the list of candidates, the TWG compared the relative risks of the remaining candidates by considering whether a given candidate offered advantages and/or disadvantage with respect to risk. The approach was developed in consultation with the TWG in October 2017, and was modified from a methodology originally proposed by CMC to more objectively quantify safety, environmental, and technical execution risks for each candidate. The objective quantification was revised based on concerns that the high-level estimates of the likelihood and consequence of hazards would not strongly differentiate the candidates due to similarities in location and configuration amongst the remaining candidates. Thus, a relative comparison of candidates was proposed as a means to better differentiate the candidates and identify those with lower levels of risk.

9.4 DESCRIPTION OF CANDIDATES

After the high-level comparison described in Section 9.2, nine candidates remained, with all candidates in either Middle Casino Creek (MC) or Lower Casino Creek (LC), as follows:

- LC-2 — Separate storage of NAG and PAG tailings as thickened slurries, with waste rock stored separately in a sub-aqueous facility.
- MC-14, LC-14 — Separate storage of NAG tailings in a filtered stack and PAG tailings as thickened slurry, with waste rock stored separately in a sub-aqueous facility.
- MC-25, LC-25 — Co-disposal of NAG and PAG tailings as thickened slurry with waste rock (sub-aqueous).
- MC-28, LC-28 — Combined storage of PAG tailings as thickened slurry with waste rock (sub-aqueous), with separate storage of NAG tailings as thickened slurry.
- MC-34, LC-34 — Combined storage of PAG tailings as thickened slurry with waste rock (sub-aqueous), with separate storage of NAG tailings in a filtered stack.

The remaining candidates included storage of PAG tailings as thickened slurry, NAG tailings as thickened slurry or filtered in a stack, and waste rock stored sub-aqueously. The following sections describe the design concept of each remaining candidate, as it relates to the relative risk assessment. Comparative figures are provided in Table 9.4-1. Concept sheets for each candidate were developed and provided to the TWG (**Appendix G**), including detailed descriptions and illustrations of each candidate, and discussion of water management, technical precedent and limitations, and closure concepts.

Table 9.4-1. Comparison of TMF Metrics for Remaining Candidates

Design characteristics	LC-02	MC-14	LC-14	MC-25	LC-25	MC-28	LC-28	MC-34	LC-34
Maximum embankment height (m)	200	285	185	285	200	285	200	245	185
Embankment crest length (m)	1,920	2,380	2,050	2,500	1,920	2,470	1,830	2,160	2,040
Upstream catchment area (km^2)	77	64	77	36	77	36	77	64	77
TIA footprint (km^2)	16	14	16	12	16	12	16	15	17
Distance to open pit (km)	8	6	8	6	8	6	8	6	8
Annual inflows (Mm^3)	16	13	16	7	16	7	16	13	16
Closure PMF (Mm^3)	29	24	29	13	29	13	29	24	29
Closure Pond Area (km^2)	9	8.5	9.5	0.0	0.0	5.9	8.4	6.9	9.9
No. of water retaining embankments (operations phase)	3	2	2	1	1	2	2	1	1
No. of water retaining embankments (post-closure)	2	2	2	0	0	1	1	1	1

At this stage, the following concepts applied to all candidates:

- **Cyclone sand and depyritization circuit:** Cyclone sand production and NAG depyritization will operate nine months of the year.
- **Centreline dam construction**: Centreline dam construction will be employed for the construction of the downstream embankment.
- **Disposal in open pit:** In the final three years of operations (i.e. Years 20 to 22), the PAG tailings pipeline to the TMF will be decommissioned and relocated to convey PAG tailings to the open pit (approximately 16 Mm^3 of PAG tailings). Additionally, the final three years of waste rock production (i.e., Years 17 to 19) will be placed in the open pit (approximately 12 Mm^3 of waste rock).

9.4.1 LC-02

Location	Storage Concept	NAG Tailings	Closure Concept
Lower Casino Creek (LC-02)	Separate impoundments for NAG tailings, PAG tailings, and waste rock, divided by internal embankments	Thickened slurry	Ponded water cover

<u>Storage Concept</u>

LC-02 provides for separated storage of thickened slurry PAG tailings, thickened slurry NAG tailings, and sub-aqueous waste rock. The PAG tailings and waste rock impoundments will be located upstream from the NAG tailings impoundment, and each impoundment will be separated by internal embankments.

For nine months of the year, NAG tailings will be cycloned to supply cyclone sand for the embankment. The overflow of NAG tailings (and full NAG tailings stream when cyclones are not operational) will be deposited adjacent to the embankment to develop and maintain above-water beaches while the tailings slimes segregate and settle further away from the embankment. A confined process water pond will be developed at the most upstream end of the TMF; this will be the largest and primary location for contact water for the process plant, and it will be functional throughout the majority of tailings and waste rock deposition in the TMF.

<u>Embankments</u>

The starter embankments will be water-retaining and constructed from local borrow material with supplement from non-reactive waste rock. Ongoing raises to the embankments will be constructed from cyclone sand sourced from the underflow of the NAG tailings and will utilize the centerline method of construction. Permafrost in the embankment foundations for the life-of-mine will be removed prior to construction. Ongoing raises of the waste rock and PAG tailings embankments will be water-retaining to facilitate closure requirements. Ongoing raises of the NAG tailings embankment will not include a low-permeable core zone, which will assist the NAG tailings to drain and consolidate during and after closure.

Technical Precedent and Reliability

There are numerous examples of mining projects utilizing thickened slurry tailings with ore processing throughputs at the scale of the Project, and in similar climate conditions as the Project site. Thus, the NAG and PAG tailings distribution and discharge strategy is considered proven and is unlikely to be subject to any major implementation challenges or weather conditions. Extreme wet conditions can impact available storage capacity; however, this consideration is accommodated for in this concept. This tailings technology is the most flexible from an operational standpoint.

Availability of Materials

This configuration is inherently more complex as it requires the simultaneous construction of three cyclone sand embankments, and as such will be more sensitive to interruptions in the availability of cyclone sand. The availability of cyclone sand for embankment construction will be limited due to freezing temperatures preventing direct placement of sand during winter conditions. Reliable and consistent operation of the cyclone sand will be necessary to construct the waste rock embankment as well as the internal embankment in pace with the production schedule. There will not be a sufficient volume of cyclone sand available to construct three separate embankments simultaneously throughout the life of the mine, and interruptions in the availability of cyclone sand will have significant impacts on the ability to store tailings and waste rock effectively. Approximately 14 Mm^3 of local borrow and/or waste rock will be required to make up the shortfall in the internal embankments.

Closure Concept

This candidate includes a ponded water closure cover concept. The PAG tailings and waste rock impoundments will have a ponded water closure cover that will act to prevent oxidization of the underlying materials under a wide range of precipitation conditions. The closure pond will have an overall surface area of 9.0 Mm^2 and volume of 13.5 Mm^3. Water from the open pit, once it has reached the maximum elevation within the pit, will begin to spill towards the PAG impoundment. Spillway channels will be constructed for the PAG and waste rock impoundments to drain off excess water and prevent overtopping of each of the confining embankments.

The NAG tailings surface will be graded to promote drainage. The NAG tailings, and downstream cyclone sand embankment (an area of approximately 7.3 Mm^2), will be revegetated.

9.4.2 MC-14 and LC-14

Location	Storage Concept	NAG Tailings	Closure Concept
Middle Casino Creek (MC-14) Lower Casino Creek (LC-14)	Separate impoundments for NAG tailings, PAG tailings, and waste rock, divided by internal embankments	Filtered stack	Ponded water cover

Storage Concept

MC-14 and LC-14 provide for separated storage of thickened slurry PAG tailings, mechanically dewatered NAG tailings in a stack, and waste rock in a sub-aqueous facility. The PAG tailings and waste rock impoundments will be located upstream from the NAG tailings stack, and each impoundment will be separated by internal embankments.

For nine months of the year, NAG tailings will be cycloned to supply cyclone sand for the embankments. The overflow of NAG tailings (and full NAG tailings stream when cyclones are not operational) will be mechanically dewatered to a filter cake consistency (80-85% solids content) and stacked downstream of the waste rock embankment. An internal embankment will be constructed upstream of the NAG tailings stack, with waste rock placed immediately upstream of this embankment. Another internal embankment will be constructed upstream of the waste rock to impound the PAG tailings as a thickened slurry. A process water pond will be located at the most upstream end of the TMF; this will be the largest and primary location for contact water for the process plant, and it will be functional throughout the majority of tailings deposition in the TMF.

Embankments

The starter embankments will be water-retaining and will be constructed from local borrow material with supplement from non-reactive waste rock. Ongoing raises to the embankments will be constructed from cyclone sand sourced from the underflow of the NAG tailings and will utilize the centerline method of construction. Permafrost in the embankment foundations for the life-of-mine will be removed prior to construction. Ongoing raises of the waste rock and PAG tailings embankments will be water-retaining to facilitate closure requirements.

Technical Precedent and Reliability

There are numerous examples of mining projects utilizing thickened slurry tailings with ore processing throughputs at the scale of the proposed Casino Project, and in similar climate conditions as the project site. Thus, the PAG tailings distribution and discharge strategy is considered proven and is unlikely to be subject to any major implementation challenges or weather conditions. Extreme wet conditions can impact available storage capacity; however, this consideration was accounted for in this concept. This tailings technology is the most flexible from an operational standpoint.

In regard to the mechanical dewatering of NAG tailings, existing large-scale filtered tailings facilities have not been in operation long enough to verify the long-term performance of such operations. Existing smaller scale operations in the region have exhibited issues with maintaining mechanically dewatered tailings production rates and tailings stack stability. There will be challenges inherent in maintaining a consistent solids product throughout the mine life, which will impact the production and filling schedules for all waste management facilities on site. Placement and compaction of mechanically dewatered tailings will also be subject to restrictions caused by cold weather and precipitation.

Availability of Materials

This configuration is inherently more complex as it requires the simultaneous construction of two cyclone sand embankments, and as such will be more sensitive to interruptions in the availability of cyclone sand. The availability of cyclone sand for embankment construction will be limited due to freezing temperatures preventing direct placement of sand during winter conditions. Reliable and consistent operation of the cyclone sand will be necessary to construct the waste rock embankment as well as the internal embankment in pace with the production schedule. For MC-14, sufficient volume of cyclone sand will not be available to construct both embankments, and approximately 40 Mm^3 of local borrow and/or waste rock will be required to make up the shortfall in the upstream zone of the waste rock embankment, as well as the earlier stages of the internal PAG tailings embankment. For LC-14, sufficient volume of cyclone sand will be available to construct both embankments.

Closure Concept

This candidate includes a ponded water closure cover concept. The PAG tailings and waste rock impoundments will have a ponded water closure cover to prevent oxidization of the underlying materials under a wide range of precipitation conditions. The closure pond for MC-14 will have an overall surface area of 8.5 Mm^2 and a volume of 12.8 Mm^3., while the closure pond for LC-14 will have an overall surface area of 9.5 Mm^2 and a volume of 14.3 Mm^3. Water from the open pit, once it has reached the maximum elevation within the pit, will begin to spill towards the PAG impoundment. Spillway channels will be constructed for the PAG and waste rock impoundments to drain off excess water and prevent overtopping of each of the confining embankments.

The mechanically dewatered NAG tailings surface will be contoured and graded to promote drainage and reduce erosion. The NAG tailings and all exposed cyclone sand embankments (an area of approximately 5.5 Mm^2 for MC-14 and 6.5 Mm^2 for LC-14), will be revegetated.

9.4.3 MC-25 and LC-25

Location	Storage Concept	NAG Tailings	Closure Concept
Middle Casino Creek (MC-25) Lower Casino Creek (LC-25)	Zoned facility, no internal embankments	Thickened slurry	Drained facility with NAG tailings water table cover

Storage Concept

MC-25 and LC-25 provide for zoned storage of thickened PAG tailings, a combination of thickened NAG whole tailings plus unthickened NAG overflow tailings, and waste rock, behind a main embankment. NAG tailings are located directly upstream of the embankment; waste rock is located upstream of NAG tailings, and PAG tailings are located within a defined cell within the waste rock storage area. No internal embankments separate tailings and waste rock. A process water pond will be located at the most upstream (north) end of the TMF; each of the PAG and NAG tailings areas will have small supernatant ponds.

For nine months of the year, NAG tailings will be cycloned to supply cyclone sand for the embankment. The overflow of NAG tailings (and full NAG tailings stream when cyclones are not operational) will be deposited adjacent to the embankment to develop and maintain above-water beaches.

In the final three years of operations, as PAG tailings are directed to the open pit, NAG tailings will continue to be deposited in the TMF so as to create a NAG cover over the waste rock and PAG tailings. The cover will range in thickness, from 2 m over the waste rock to as much as 10 m over the PAG tailings. This NAG cover will create a capping layer sufficient to minimize oxygen infiltration of the underlying materials over a wide range of precipitation conditions.

Embankment

The starter embankment will be water-retaining and will be constructed from local borrow material with supplement from non-reactive waste rock. Ongoing raises to the embankment will be constructed from cyclone sand sourced from the underflow of the NAG tailings and will utilize the centerline method of construction. Permafrost in the embankment foundations for the life-of-mine will be removed prior to construction. Ongoing raises will not include a low-permeable core zone, which will assist the tailings mass above the starter embankment to drain and consolidate during and after closure, while maintaining a sufficiently low level of oxygen infiltration to prevent the onset of ARD in the waste rock and PAG tailings.

Technical Precedent and Reliability

There are numerous examples of mining projects utilizing thickened slurry tailings with ore processing throughputs at the scale of the proposed Casino Project. The proposed tailings technology is considered proven and not subject to any major implementation challenges. Additionally, thickened slurry tailings have a proven history of application in similar climate conditions as the project site. The tailings distribution and discharge strategy is unlikely to be affected in a significant way by any weather conditions. Extreme wet conditions can impact available storage capacity; however, this consideration was addressed in this concept. This tailings technology is the most flexible from an operational standpoint. Tailings discharge will not be the limiting factor for operational reliability.

Availability of Materials

There will be limitations in the availability of cyclone sand for embankment construction due to freezing temperatures preventing direct placement of sand during winter conditions. However, as there is one main embankment, there is operational flexibility to accommodate interruptions in the cyclone stream that are not available to other configurations.

Closure Concept

These candidates include a drained closure concept of the NAG tailings mass, as well as a water table cover of NAG tailings over the PAG tailings and waste rock. At closure, a spillway channel will be excavated back to the low point of the NAG beach to drain off any supernatant water build-up. All tailings surfaces will be amended with a growth medium and revegetated, including the downstream face of the TMF embankment. The NAG tailings cover across the waste rock and PAG tailings within the TMF will act to minimize oxygen infiltration of the underlying materials under a wide range of precipitation conditions.

Consolidation of the NAG and PAG tailings deposits will occur throughout operations and during the closure phase of the project, which will result in localized depressions within the TMF. Preferential deposition of NAG tailings in the final three years of operations, in addition to covering the PAG tailings and waste rock, will occur to prevent ponding on the tailings surface in closure and post-closure, and enhance shedding of runoff water. Water from the open pit, once it has reached the maximum elevation within the pit, will begin to drain towards the upper end of the TMF. It will drain through constructed wetlands located at the upstream end of the TMF prior to exiting the TMF through the closure spillway.

9.4.4 MC-28 and LC-28

Location	Storage Concept	NAG Tailings	Closure Concept
Middle Casino Creek (MC-28) Lower Casino Creek (LC-28)	Zoned facility, one internal embankment	Thickened slurry	Ponded water cover

Storage Concept

MC-28 and LC-28 provide for zoned storage of thickened PAG tailings, a combination of thickened NAG whole tailings plus unthickened NAG overflow tailings, and waste rock, with one internal embankment. NAG tailings are located directly upstream of the main embankment; waste rock is stored behind an internal embankment upstream of NAG tailings, and PAG tailings are located within a defined cell within the waste rock storage area. A process water pond will be located at the most upstream (north) end of the TMF; each of the PAG and NAG tailings areas will have small supernatant ponds.

For nine months of the year, NAG tailings will be cycloned to supply cyclone sand for the embankment. The overflow of NAG tailings (and full NAG tailings stream when cyclones are not operational) will be deposited adjacent to the downstream embankment to develop and maintain above-water beaches.

In the final three years of operations, as PAG tailings are directed to the open pit, NAG tailings will continue to be deposited in the TMF so as to create a NAG cover over the waste rock and PAG tailings. The cover will range in thickness, from 2 m over the waste rock to as much as 10 m over the PAG tailings. This NAG cover will create a capping layer sufficient to minimize oxygen infiltration of the underlying materials over a wide range of precipitation conditions. Additionally, a ponded water cover over the PAG tailings and waste rock will be developed as further redundancy to minimize oxygen infiltration.

Embankments

The starter embankment will be water-retaining and will be constructed from local borrow material with supplement from non-reactive waste rock. Ongoing raises to the embankment will be constructed from cyclone sand sourced from the underflow of the NAG tailings and will utilize the centerline method of construction. Permafrost in the embankment foundations for the life-of-mine will be removed prior to construction. Ongoing raises of the waste rock and PAG tailings embankment will be water retaining to facilitate closure requirements. Ongoing raises of the NAG tailings embankment will not include a low-permeable core zone, which will assist the tailings mass above the starter embankment to drain and consolidate during and after closure.

Technical Precedent and Reliability

There are numerous examples of mining projects utilizing thickened slurry tailings with ore processing throughputs at the scale of the proposed Casino Project. The proposed tailings technology is considered proven and not subject to any major implementation challenges. Additionally, thickened slurry tailings have a proven history of application in similar climate conditions as the project site. The tailings distribution and discharge strategy is unlikely to be affected in a significant way by any weather conditions. Extreme wet conditions can impact available storage capacity; however, this consideration was addressed in this concept. This tailings technology is the most flexible from an operational standpoint. Tailings discharge will not be the limiting factor for operational reliability.

Availability of Materials

This configuration is inherently more complex as it requires the simultaneous construction of two cyclone sand embankments, and as such will be more sensitive to interruptions in the availability of cyclone sand. The availability of cyclone sand for embankment construction will be limited due to freezing temperatures preventing placement of sand during winter conditions. Sufficient volume of cyclone sand will be available to construct both embankments for LC-28, but will not be available to construct both embankments for MC-28 (approximately 48 Mm^3 of local borrow and/or waste rock will be required to make up the shortfall).

Closure Concept

These candidates include a drained closure concept of the NAG tailings mass, as well as a cover of NAG tailings over the PAG tailings and waste rock. Additionally, a ponded water cover will exist over the PAG tailings and waste rock areas, which will act to minimize oxygen infiltration of the underlying materials. At closure, a spillway channel will be excavated back to the low point of the NAG tailings to drain off any supernatant water build-up, but with the invert situated to allow for approximately 1.5 m of water to remain in the ponded water cover above the PAG tailings and waste rock areas. The closure pond will have an overall surface area of 5.9 Mm^2 and volume of 8.9 Mm^3.

Water from the open pit, once it has reached the maximum elevation within the pit, will begin to drain towards the upper end of the TMF. It will drain through constructed wetlands located at the upstream end of the TMF prior to exiting the TMF through the closure spillway. The NAG tailings surface will be graded to promote drainage and reduce erosion. The NAG tailings and downstream embankment (an area of approximately 4.8 Mm^2), will be amended with a growth medium and re-vegetated.

9.4.5 MC-34 and LC-34

Location	Storage Concept	NAG Tailings	Closure Concept
Middle Casino Creek (MC-34) Lower Casino Creek (LC-34)	Storage of PAG tailings and waste rock behind an embankment, with separate storage of NAG tailings as a filtered stack	Filtered stack	Ponded water cover

Storage Concept

MC-34 and LC-34 provide for storage of NAG tailings as mechanically dewatered stack, with storage of thickened slurry PAG tailings and waste rock behind an embankment located upstream from the NAG tailings stack.

For nine months of the year, NAG tailings will be cycloned to supply cyclone sand for the embankment. The overflow of NAG tailings (and full NAG tailings stream when cyclones are not operational) will be mechanically dewatered to a filter cake consistency (80-85% solids content) and stacked downstream of the waste rock and PAG tailings embankment. An embankment will be constructed upstream of the NAG stack, with waste rock placed immediately upstream of this embankment, and PAG tailings placed as thickened slurry upstream of the waste rock. A process water pond will be located at the most upstream end of the TMF; this will be the largest and primary location for contact water for the process plant, and it will be functional throughout the majority of tailings deposition in the TMF.

Embankments

The starter embankments will be water-retaining and will be constructed from local borrow material with supplement from non-reactive waste rock. Ongoing raises to the embankment will be constructed from cyclone sand sourced from the underflow of the NAG tailings and will utilize the centerline method of construction. Permafrost in the embankment foundations for the life-of-mine will be removed prior to construction. Ongoing raises of the waste rock and PAG tailings embankments will be water-retaining to facilitate closure requirements.

Technical Precedent and Reliability

There are numerous examples of mining projects utilizing thickened slurry tailings with ore processing throughputs at the scale of the proposed Casino Project, and in similar climate conditions as the project site. Thus, the PAG tailings distribution and discharge strategy is considered proven and is unlikely to be subject to any major implementation challenges or weather conditions. Extreme wet conditions can impact available storage capacity; however, this consideration was addressed in this concept. This tailings technology is the most flexible from an operational standpoint.

In regard to the mechanical dewatering of NAG tailings, existing large-scale filtered tailings facilities have not been in operation long enough to verify the long-term performance of such operations. Existing smaller scale operations in the region have exhibited issues with maintaining mechanically dewatered tailings production rates and tailings stack stability. There will be challenges inherent in maintaining a consistent solids product throughout the mine life, which will impact the production and filling schedules for all waste management facilities on site. Placement and compaction of mechanically dewatered tailings will also be subject to restrictions caused by cold weather and precipitation.

Availability of Materials

There will be limitations in the availability of cyclone sand for embankment construction due to freezing temperatures preventing placement of sand during winter conditions. However, this is a single embankment facility, and there will be sufficient volume of cyclone sand available for construction.

Closure Concept

This candidate includes a ponded water cover closure concept. The PAG tailings and waste rock impoundment will have a ponded water cover at closure that will act to prevent oxidization of the underlying materials under a wide range of precipitation conditions. The closure pond will have an overall surface area of 6.9 Mm^2 and volume of 10.4 Mm^3. Water from the open pit, once it has reached the maximum elevation within the pit, will begin to spill towards the PAG impoundment. A spillway channel will be constructed in the PAG and waste rock embankment to drain off excess supernatant water build-up and prevent overtopping of the downstream embankment.

The mechanically dewatered NAG tailings surface will be contoured and graded to promote drainage and reduce erosion. The NAG tailings, and all exposed cyclone sand embankments (an area of approximately 5.0 Mm^2), will be revegetated.

9.5 RISK ASSESSMENT RESULTS

The results of the risk assessment are provided in Table 9.5-1, and the following principles guided the comparison of risks between candidates:

- **Safety**: In regard to safety hazards, likelihood was not considered to be differentiating as all candidates would be built in accordance with the relevant engineering and design standards. Thus, the likelihood that a dam failure would occur was considered to be comparable (i.e., unlikely) in all cases. However, the consequence of such a failure was determined to be differentiating. Candidates located at Lower Casino Creek have a larger upstream catchment area, and therefore would likely have a larger consequence in the event of a storm-induced event; and candidates with a ponded water closure cover (as opposed to a water table closure cover) would also have a larger consequence under certain circumstances.
- **Environment**: Considering that the geochemical characteristics of waste materials are the same for all candidates, the consequence of failure was not determined to be differentiating. However, the likelihood that ML/ARD would be effectively managed would vary depending on the type of closure cover, as well as location. Compared to a facility with a water table closure cover, candidates with a ponded water closure cover were determined to be more likely to prevent the onset of ML/ARD in the long-term because a water cover is a proven management strategy to minimize oxygen infiltration. In addition, candidates at Lower Casino Creek would be more protected from future changes in the availability of water due to climate change, as they have a larger upstream catchment area compared to candidates at Middle Casino Creek.
- **Technical Execution**: Technical execution hazards (i.e., inability to operate as designed) were determined to be more likely for candidates with filtered stack tailings, as this technology has not been proven at the scale of the Casino Project, and/or in the climate typical in Yukon (as there would be limitations in placing the filtered tailings in cold weather). In addition, candidates with more than one embankment inherently have greater construction complexity as interruptions in the production of cyclone sand (such as plant downtime, changes in production, unavailability of NAG tailings, etc.) could affect the availability of material for embankment construction. Candidates at the Lower Casino Creek site were also determined to have higher technical execution risks than those at Middle Casino Creek due to the increased distance between the pit and the TMF.

Table 9.5-1. High-Level Risk Assessment Results

Candidate	Safety Hazard			Environmental Hazard			Technical Execution Hazard			Total
Base Case										
MC-25	The primary safety hazard is a loss of containment during operations leading to release of NAG tailings and/or water. PAG tailings will not be released to the downstream environment as they are sequestered behind the waste rock within the TMF. Furthermore, the process water pond is sequestered upstream of waste rock, and the NAG and PAG supernatant ponds are actively managed to remain small.			The primary environmental hazard is an inability to manage ML/ARD in the long-term, should the drained facility with NAG tailings cover not sufficiently minimize oxygen infiltration. The likelihood of occurrence is considered greater than if a water cover is utilized over the PAG tailings and waste rock. However, the NAG cover would still inhibit oxygenation of these materials even if it underperforms, and contingency mitigation measures could be implemented.			With a single embankment, there is operational flexibility to accommodate interruptions in the cyclone stream that are not available to other configurations. Thickened slurry tailings are considered proven and not subject to any major implementation challenges.			
	Likelihood: 3	Consequence: 3	Safety Risk: 9	Likelihood: 3	Consequence: 3	Environmental Risk: 9	Likelihood: 3	Consequence: 3	Technical Execution Risk: 9	**27**
Other Candidates										
LC-02	The primary safety hazard is a loss of containment in closure leading to release of NAG tailings and/or water to the downstream environment, likely caused by flooding and overtopping of the NAG embankment. PAG tailings and waste rock are at a lesser risk of loss of containment as they are sequestered behind the NAG impoundment. The Lower Casino location has a large upstream catchment area, and as such the volume of water and tailings carried downstream in the event of a breach is expected to be greater than if a breach occurred at a Middle Casino location.			The primary environmental hazard is an inability to manage ML/ARD in the long-term due to a loss of the water cover. A loss of the pond may be caused by long-term variations in climatic conditions allowing a net evaporation state, and/or higher than anticipated seepages rates from the impoundment. This hazard is less of a concern compared to those options in the Middle Casino locations, as the larger catchment area will temper long-term climatic variability.			This option requires three individual embankments, and inherently has a greater construction complexity than MC-25. Interruptions in the production of cyclone sand (such as plant downtime, changes in production, unavailability of NAG tailings, etc.) may have severe impacts on the ability to maintain the construction schedule required for three separate impoundments. Delays in the construction schedule will likely result in an inability to manage the volume of tailings and waste rock produced.			
	Likelihood: 3	Consequence: 5	Safety Risk: 15	Likelihood: 1	Consequence: 3	Environmental Risk: 3	Likelihood: 4	Consequence: 5	Technical Execution Risk: 20	**38**
MC-14	The primary safety hazard is a loss of containment during closure, leading to release of water and subsequent erosion of the downstream NAG tailings, likely caused by flooding and overtopping of the waste rock embankment. PAG tailings are at a lesser risk of loss of containment as they are sequestered behind the waste rock impoundment. In addition to water flooding the impoundment, run-off from Brynelson creek will need to be managed to prevent saturation of the NAG tailings stack. Compared to similar concepts at the Lower Casino Creek site, Middle Casino Creek has less upstream catchment area.			The primary environmental hazard is an inability to manage ML/ARD in the long-term due to a loss of the water cover. A loss of the pond may be caused by long-term variations in climatic conditions allowing a net evaporation state, and/or higher than anticipated seepages rates from the impoundment.			This option involves producing mechanically dewatered NAG tailings, as well as constructing two cyclone sand embankments to sequester PAG tailings and waste rock. This configuration inherently has a greater construction complexity than MC-25. Interruptions in the production of mechanically dewatered NAG tailings (such as filter press downtime, inability to achieve a consistent product, placement challenges, unavailability of NAG tailings, etc.) may have severe impacts on the ability to maintain the construction schedule required for two separate impoundments. Delays in the construction schedule will likely result in an inability to manage the volume of tailings and waste rock produced as excess NAG tailings would have to be rerouted to the PAG impoundment.			
	Likelihood: 3	Consequence: 4	Safety Risk: 12	Likelihood: 2	Consequence: 3	Environmental Risk: 6	Likelihood: 5	Consequence: 5	Technical Execution Risk: 25	**43**
LC-14	The primary safety hazard is a loss of containment during closure leading to release of water and subsequent erosion of the downstream NAG tailings, likely caused by flooding and overtopping of the waste rock embankment. PAG tailings are at a lesser risk of loss of containment as they are sequestered behind the waste rock impoundment. The Lower Casino location has a large upstream catchment area, and as such the volume of water and tailings carried downstream in the event of a breach is expected to be greater than if a breach occurred at the Middle Casino location.			The primary environmental hazard is an inability to manage ML/ARD in the long-term due to a loss of the water cover. A loss of the pond may be caused by long-term variations in climatic conditions allowing a net evaporation state, and/or higher than anticipated seepages rates from the impoundment. This hazard is less of a concern compared to those options in the Middle Casino locations, as the larger catchment area will temper long-term climatic variability.			This option involves producing mechanically dewatered NAG tailings, as well as constructing two cyclone sand embankments to sequester PAG tailings and waste rock. This configuration inherently has a greater construction complexity than MC-25. Interruptions in the production of mechanically dewatered NAG tailings (such as filter press downtime, inability to achieve a consistent product, placement challenges, unavailability of NAG tailings, etc.) may have severe impacts on the ability to maintain the construction schedule required for two separate impoundments. Delays in the construction schedule will likely result in an inability to manage the volume of tailings and waste rock produced as excess NAG tailings would have to be rerouted to the PAG impoundment.			
	Likelihood: 3	Consequence: 4 0	Safety Risk: 12	Likelihood: 1	Consequence: 3	Environmental Risk: 3	Likelihood: 5	Consequence: 5	Technical Execution Risk: 25	**40**
LC-25	The primary safety hazard is a loss of containment during operations leading to release of NAG tailings and/or water. PAG tailings will not be released to the downstream environment as they are sequestered behind the waste rock within the TMF. Furthermore, the process water pond is sequestered upstream of waste rock, and the NAG and PAG supernatant ponds are actively managed to remain small. The Lower Casino location has a large upstream catchment area, and as such the volume of water and tailings carried downstream in the event of a breach is expected to be greater than if a breach occurred at a Middle Casino location.			The primary environmental hazard is an inability to manage ML/ARD in the long-term, should the drained facility with NAG tailings cover not sufficiently minimize oxygen infiltration. The likelihood of occurrence is considered greater than if a water cover is utilized over the PAG tailings and waste rock. However, the NAG cover would still inhibit oxygenation of these materials even if it underperforms, and contingency mitigation measures could be implemented.			With a single embankment, there is operational flexibility to accommodate interruptions in the cyclone stream that are not available to other configurations. Thickened slurry tailings are considered proven and not subject to any major implementation challenges. Greater distance to the stack will increase complexity somewhat compared to locations in the Middle Casino site.			
	Likelihood: 3	Consequence: 4 0	Safety Risk: 12	Likelihood: 3	Consequence: 3	Environmental Risk: 9	Likelihood: 3	Consequence: 5	Technical Execution Risk: 9	**30**

(continued)

Table 9.5-1. High-Level Risk Assessment Results (completed)

Candidate	Safety Hazard			Environmental Hazard			Technical Execution Hazard			Total
Other Candidates *(cont'd)*										
MC-28	The primary safety hazard is a loss of containment during closure leading to release of NAG tailings and/or water to the downstream environment, likely caused by flooding and overtopping of the NAG embankment. PAG tailings and waste rock are at a lesser risk of loss of containment as they are sequestered behind the NAG impoundment.			The primary environmental hazard is an inability to manage ML/ARD in the long-term due to a loss of the water cover. A loss of the pond may be caused by long-term variations in climatic conditions allowing a net evaporation state, and/or higher than anticipated seepages rates from the impoundment.			This option requires two individual embankments, and inherently has a greater construction complexity than MC-25. Interruptions in the production of cyclone sand (such as plant downtime, changes in production, unavailability of NAG tailings, etc.) may adversely impact the ability to maintain the construction schedule required for two separate impoundments. Delays in the construction schedule will likely result in an inability to manage the volume of tailings and waste rock produced.			
	Likelihood: 3	Consequence: 4	Safety Risk: 12	Likelihood: 2	Consequence: 3	Environmental Risk: 6	Likelihood: 4	Consequence: 4	Technical Execution Risk: 16	**34**
LC-28	The primary safety hazard is a loss of containment during closure leading to release of NAG tailings and/or water to the downstream environment, likely caused by flooding and overtopping of the NAG embankment. PAG tailings and waste rock are at a lesser risk of loss of containment as they are sequestered behind the NAG impoundment. The Lower Casino location has a large upstream catchment area, and as such the volume of water and tailings carried downstream in the event of a breach is expected to be greater than if a breach occurred at a Middle Casino location.			The primary environmental hazard is an inability to manage ML/ARD in the long-term due to a loss of the water cover. A loss of the pond may be caused by long-term variations in climatic conditions allowing a net evaporation state, and/or higher than anticipated seepages rates from the impoundment. This hazard is less of a concern compared to those options in the Middle Casino locations, as the larger catchment area will temper long-term climatic variability.			This option requires two individual embankments, and inherently has a greater construction complexity than MC-25. Interruptions in the production of cyclone sand (such as plant downtime, changes in production, unavailability of NAG tailings, etc.) may adversely impact the ability to maintain the construction schedule required for two separate impoundments. Delays in the construction schedule will likely result in an inability to manage the volume of tailings and waste rock produced.			
	Likelihood: 3	Consequence: 5	Safety Risk: 15	Likelihood: 1	Consequence: 3	Environmental Risk: 3	Likelihood: 4	Consequence: 4	Technical Execution Risk: 16	**34**
MC-34	The primary safety hazard is a loss of containment during closure leading to release of water and subsequent erosion of the downstream NAG tailings, likely caused by flooding and overtopping of the waste rock embankment. PAG tailings are at a lesser risk of loss of containment as they are sequestered behind the waste rock. In addition to water flooding the impoundment, run-off from Brynelson Creek will need to be managed to prevent saturation of the NAG tailings stack.			The primary environmental hazard is an inability to manage ML/ARD in the long-term due to a loss of the supernatant water cover. A loss of supernatant pond may be caused by long term variations in climatic conditions allowing a net evaporation state, and/or higher than anticipated seepages rates from the impoundment.			This option involves producing a significant volume of mechanically dewatered NAG tailings throughout the life of the mine, as well as constructing a cyclone sand embankment to sequester PAG tailings and waste rock together. This configuration inherently has a greater construction complexity than MC-25. Interruptions in the production of mechanically dewatered NAG tailings (filter press downtime, inability to achieve a consistent product, placement challenges, unavailability of NAG tailings, etc.) may have severe impacts on the ability to maintain the construction schedule required for the separate impoundments. Delays in the construction schedule will likely result in an excess of NAG tailings requiring storage in the PAG/waste rock impoundment, which may not be able to accommodate the influx of excess tailings, leading to containment issues and a potential cessation of production.			
	Likelihood: 3	Consequence: 4	Safety Risk: 12	Likelihood: 2	Consequence: 3	Environmental Risk: 6	Likelihood: 5	Consequence: 4	Technical Execution Risk: 20	**38**
LC-34	The primary safety hazard is a loss of containment during closure leading to release of water and subsequent erosion of the downstream NAG tailings, likely caused by flooding and overtopping of the waste rock embankment. PAG tailings are at a lesser risk of loss of containment as they are sequestered behind the waste rock. While the Lower Casino location has a large upstream catchment area, and as such the volume of water and tailings carried downstream in the event of a breach may be expected to be greater than if a breach occurred at the Middle Casino location, given that the comparable Middle Casino Creek candidate is already situated such that water from Brynelson Creek must be managed, the consequences are expected to be similar.			The primary environmental hazard is an inability to manage ML/ARD in the long-term due to a loss of the water cover. A loss of the pond may be caused by long-term variations in climatic conditions allowing a net evaporation state, and/or higher than anticipated seepages rates from the impoundment. This hazard is less of a concern compared to those options in the Middle Casino locations, as the larger catchment area will temper long-term climatic variability.			This option involves producing a significant volume of mechanically dewatered NAG tailings throughout the life of the mine, as well as constructing a cyclone sand embankment to sequester PAG tailings and waste rock together. This configuration inherently has a greater construction complexity than MC-25. Interruptions in the production of mechanically dewatered NAG tailings (filter press downtime, inability to achieve a consistent product, placement challenges, unavailability of NAG tailings, etc.) may have severe impacts on the ability to maintain the construction schedule required for the separate impoundments. Delays in the construction schedule will likely result in an excess of NAG tailings requiring storage in the PAG/waste rock impoundment, which may not be able to accommodate the influx of excess tailings, leading to containment issues and a potential cessation of production.			
	Likelihood: 3	Consequence: 4	Safety Risk: 12	Likelihood: 1	Consequence: 3	Environmental Risk: 3	Likelihood: 5	Consequence: 4	Technical Execution Risk: 20	**35**

Noting that MC-25 is the base case (i.e., CMC's optimized design), the relative risk assessment results are summarized in Table 9.5-2. Overall, MC-25 had the lowest risk rating (27), followed by LC-25 (30), MC-28/LC-28 (34), and LC-34 (35).

Table 9.5-2. Summary of HRLA Results

Analysis	Candidate(s) with lowest risk rating
Overall	MC-25*
Location: Middle Casino Creek	MC-25*
Location: Lower Casino Creek	LC-25*
Technology: thickened slurry NAG tailings	MC-25*
Technology: filtered NAG tailings	LC-34*
Lowest safety risk	MC-25*
Lowest environmental risk	LC-02, LC-14, LC-28*, and LC-34*
Lowest technical execution risk	MC-25* and LC-25*

** Selected to proceed to Step 4*

Based on these results, the working group selected five candidates (MC-25, MC-28, LC-25, LC-28, and LC-34) to proceed to Step 4. The TWG agreed that these candidates included the important factors to be considered in the next steps of the study, namely:

- Candidates are located at both Middle Casino and Lower Casino locations;
- Candidates include both ponded water and water table closure covers; and
- LC-34 was selected as the most viable candidate for filtered NAG tailings, although the working group agreed that the design of this candidate should be modified to make it technically and economically competitive with the other candidates.

TWG Highlights 9-4. Selection of Candidates

CMC consulted with the TWG to select the lower risk candidates that will be assessed further in the MAA. Considering the comparison of risks associated with each candidate in the HLRA, the TWG agreed that candidates MC-25, MC-28, LC-25, and LC-28 represented the two most viable location and closure concepts. In addition, the TWG wanted to carry through a candidate that involved filtered NAG tailings, and selected LC-34 as the lowest risk candidate for this technology. However, the working group agreed to modify this candidate to improve its feasibility by processing a smaller portion of the NAG tailings stream and placing in a filtered stack as a secondary facility, and the remainder as thickened slurry to be placed in a primary facility.

10. STEP 4: CHARACTERIZATION OF CANDIDATES

10.1 OVERVIEW

Step 4 involves the detailed description and characterization of the remaining five candidates, as described in Table 10.1-1, to prepare for the MAA in Step 5. In the MAA, the candidates are compared and contrasted at a detailed level; the characterization of candidates in Step 4 ensures that the necessary information is available to support this comparison.

Table 10.1-1. Candidates Included in Multiple Accounts Analysis

<table>
<tr><th>Candidate</th><th>Location</th><th>Description</th><th>Notes</th></tr>
<tr><td>MC-25</td><td>Middle Casino</td><td rowspan="4">Zoned storage of thickened slurry NAG and PAG tailings and waste rock behind a single embankment. NAG tailings located directly upstream of embankment; and waste rock located upstream of NAG tailings, PAG tailings located within a defined cell within the waste rock storage area. Secondary hydraulic containment feature (SHCF) provides a low-permeable zone downstream of the PAG tailings and majority of the waste rock.</td><td rowspan="2">• NAG: thickened slurry
• Water table closure concept</td></tr>
<tr><td>LC-25</td><td>Lower Casino</td></tr>
<tr><td>MC-28</td><td>Middle Casino</td><td rowspan="2">• NAG: thickened slurry
• Ponded water closure concept</td></tr>
<tr><td>LC-28</td><td>Lower Casino</td></tr>
<tr><td>LC-34</td><td>Lower Casino</td><td>As above, with the addition of: A portion of NAG tailings will be stored as a mechanically dewatered stack downstream of and abutting the embankment.</td><td>• NAG: thickened slurry (primary) and filtered stack (secondary)
• Ponded water closure concept</td></tr>
</table>

Based on ECCC Guidelines, characterization is typically conducted across four broad categories (referred to as "accounts"), including technical, project economics, environmental and socio-economics. CMC included an additional account relating to dam failure, in response to TWG comments. The remaining candidates were described and characterized for each of the five accounts as described in Section 10.2, based on the available baseline data and/or design information.

The accounts, sub-accounts and indicators define the criteria that differentiate the candidates. The ECCC Guidelines note that every project is unique and the characterization criteria must be developed with consideration to the impacts, concerns, and stakeholder and regulatory interests relevant to the project. CMC engaged the TWG in developing the criteria used to describe and differentiate the candidates.

10.2 DESCRIPTION OF CANDIDATES

10.2.1 Technical Design

10.2.1.1 Design Concept

To characterize the candidates, the design concepts of the remaining five candidates were further developed. The updated concept sheets are provided in **Appendix H**, and include plan and section illustrations over the mine life including Years 1, 10, 19, 22, and Closure. The updated design concepts are consistent with the descriptions provided in Section 9.5.3 (MC-25 and LC-25), Section 9.5.4 (MC-28 and LC-28) and 9.5.5 (LC-34), with minor modifications to optimize the candidates in response to the input from, and discussions with, the TWG.

TWG Highlights 10-1. Secondary Hydraulic Containment Facility

Feedback from the TWG on the initial characterization of the candidates highlighted a preference for candidates with an internal water-retaining structure to improve certainty that water levels would be maintained over the life of the mine, and to provide flexibility in the event of early closure. This design feature would be beneficial to candidates with both water table (MC-25, LC-25) and ponded water (MC-28, LC-28, LC-34) closure covers. Thus, the design for all candidates was updated to include a 50 m-wide zone of thickened NAG overflow tailings within the waste rock located between the PAG and NAG tailings. This secondary hydraulic containment feature (SHCF) would conceptually provide for a low-permeable zone downstream of the PAG tailings and the majority of waste rock, and is illustrated in the updated concept sheets in **Appendix H**.

10.2.1.1 MC-25 and LC-25

Location	Dam Height	Total Surface Area	Revegetated Surface Area	Ponded Water Surface Area	PMF
Middle Casino Creek (MC-25)	285 m	1,172 ha	1,172 ha	0 ha	13.4 Mm^3
Lower Casino Creek (LC-25)	200 m	1,540 ha	1,540 ha	0 ha	28.6 Mm^3

<u>Storage Concept</u>

MC-25 and LC-25 provide for zoned storage of thickened PAG tailings, a combination of thickened NAG whole tailings plus unthickened NAG overflow tailings, and waste rock, behind a main embankment. NAG tailings are located directly upstream of the embankment; waste rock is located upstream of NAG tailings, and PAG tailings are located within a defined cell within the waste rock storage area. No internal embankments separate tailings and waste rock. A process water pond will be located at the most upstream (north) end of the TMF; each of the PAG and NAG tailings areas will have small supernatant ponds.

For nine months of the year, NAG tailings will be cycloned to supply cyclone sand for the embankment. The overflow of NAG tailings (and full NAG tailings stream when cyclones are not operational) will be deposited adjacent to the embankment to develop and maintain above-water beaches.

In the final three years of operations, as PAG tailings are directed to the open pit, NAG tailings will continue to be deposited in the TMF so as to create a NAG cover over the waste rock and PAG tailings. The cover will range in thickness, from 2 m over the waste rock to as much as 10 m over the PAG tailings. This NAG cover will create a capping layer sufficient to minimize oxygen infiltration of the underlying materials over a wide range of precipitation conditions.

Embankment

The starter embankment will be water-retaining and will be constructed from local borrow material with supplement from non-reactive waste rock. Ongoing raises to the embankment will be constructed from cyclone sand sourced from the underflow of the NAG tailings and will utilize the centerline method of construction. Permafrost in the embankment foundations for the life-of-mine will be removed prior to construction. Ongoing raises will not include a low-permeable core zone, which will assist the tailings mass above the starter embankment to drain and consolidate during and after closure, while maintaining a sufficiently low level of oxygen infiltration to prevent the onset of ARD in the waste rock and PAG tailings.

Co-Disposal Deposition within TMF

Throughout the operating life of the TMF, all waste materials are placed such that they rise simultaneously, albeit at different rates. Waste rock platforms, both upstream and downstream of the PAG tailings, will always be higher than the tailings elevations to ensure that there is a platform for the haul trucks to drive and place the next lift. The embankment is raised such that the NAG tailings reach an elevation equal to or higher than the PAG tailings as quickly as possible during the operating mine life.

Within the waste rock located between the PAG and NAG tailings, an approximate 50 m-wide zone of thickened NAG overflow tailings will be placed along with the rising waste rock. The concept of the secondary hydraulic containment feature (SHCF) is to provide for a low-permeable zone downstream of the PAG tailings and majority of the waste rock to provide redundancy for maintaining saturation of the NAG cover in full closure, as well as provide alternatives under an early closure scenario, should the PAG tailings and waste rock be higher than the NAG tailings.

Technical Precedent and Reliability

There are numerous examples of mining projects utilizing thickened slurry tailings with ore processing throughputs at the scale of the proposed Casino Project. The proposed tailings technology is considered proven and not subject to any major implementation challenges. Additionally, thickened slurry tailings have a proven history of application in similar climate conditions as the project site. The tailings distribution and discharge strategy is unlikely to be affected in a significant way by any weather conditions. Extreme wet conditions can impact available storage capacity; however, this consideration was addressed in this concept. This tailings technology is the most flexible from an operational standpoint. Tailings discharge will not be the limiting factor for operational reliability.

Availability of Materials

There will be limitations in the availability of cyclone sand for embankment construction due to freezing temperatures preventing direct placement of sand during winter conditions. However, as there is one main embankment, there is operational flexibility to accommodate interruptions in the cyclone stream that are not available to other configurations. Furthermore, cycloning the full NAG tailings stream is under consideration, whereby materials produced during the winter periods would be stockpiled and then reclaimed during warmer temperatures, which would offset any material availability risks.

Closure Concept

These candidates include a drained closure concept of the NAG tailings mass, as well as a water table closure cover of NAG tailings over the PAG tailings and waste rock. At closure, a spillway channel will be excavated back to the low point of the NAG beach to drain off any water build-up. All tailings surfaces will be amended with a growth medium and revegetated, including the downstream face of the TMF embankment. The NAG tailings cover across the waste rock and PAG tailings within the TMF will act to minimize oxygen infiltration of the underlying materials under a wide range of precipitation conditions. Redundancy for the saturation of the NAG tailings cover over the PAG tailings and waste rock is provided through the SHCF.

Consolidation of the NAG and PAG tailings deposits will occur throughout operations and during the closure phase of the project, which may result in localized depressions within the TMF. Preferential deposition of NAG tailings in the final three years of operations, in addition to covering the PAG tailings and waste rock, will occur to prevent ponding on the tailings surface in closure and post-closure, and enhance shedding of runoff water. Water from the open pit, once it has reached the maximum elevation within the pit, will begin to drain towards the upper end of the TMF. It will drain through constructed wetlands located at the upstream end of the TMF prior to exiting the TMF through the closure spillway.

10.2.1.2 MC-28 and LC-28

Location	Dam Height	Total Surface Area	Revegetated Surface Area	Ponded Water Surface Area	PMF
Middle Casino Creek (MC-28)	285 m	1,172 ha	601 ha	571 ha	13.4 Mm^3
Lower Casino Creek (LC-28)	200 m	1,540 ha	727 ha	813 ha	28.6 Mm^3

Storage Concept

MC-28 and LC-28 provide for zoned storage of thickened PAG tailings, a combination of thickened NAG whole tailings plus unthickened NAG overflow tailings, and waste rock, behind a main embankment. NAG tailings are located directly upstream of the embankment; waste rock is located upstream of NAG tailings, and PAG tailings are located within a defined cell within the waste rock storage area. No internal embankments separate tailings and waste rock. A process water pond will be located at the most upstream (north) end of the TMF; each of the PAG and NAG tailings areas will have small supernatant ponds.

For nine months of the year, NAG tailings will be cycloned to supply cyclone sand for the embankment. The overflow of NAG tailings (and full NAG tailings stream when cyclones are not operational) will be deposited adjacent to the embankment to develop and maintain above-water beaches.

In the final three years of operations, as PAG tailings are directed to the open pit, NAG tailings will continue to be deposited in the TMF so as to create a NAG cover over the waste rock and PAG tailings. The cover will range in thickness, from 2 m over the waste rock to as much as 10 m over the PAG tailings. This NAG cover will create a capping layer sufficient to minimize oxygen infiltration of the underlying materials over a wide range of precipitation conditions. Additionally, a ponded water closure cover over the PAG tailings and waste rock will be developed as further redundancy to minimize oxygen infiltration.

Embankment

The starter embankment will be water-retaining and will be constructed from local borrow material with supplement from non-reactive waste rock. Ongoing raises to the embankment will be constructed from cyclone sand sourced from the underflow of the NAG tailings and will utilize the centerline method of construction. Permafrost in the embankment foundations for the life-of-mine will be removed prior to construction. Ongoing raises will not include a low-permeable core zone, which will assist the tailings mass above the starter embankment to drain and consolidate during and after closure, while maintaining a sufficiently low level of oxygen infiltration to prevent the onset of ARD in the waste rock and PAG tailings.

Co-Disposal Deposition within TMF

Throughout the operating life of the TMF, all waste materials are placed such that they rise simultaneously, albeit at different rates. Waste rock platforms, both upstream and downstream of the PAG tailings, will always be higher than the tailings elevations to ensure that there is a platform for the haul trucks to drive and place the next lift. The embankment is raised such that the NAG tailings reach an elevation equal to or higher than the PAG tailings as quickly as possible during the operating mine life.

Within the waste rock located between the PAG and NAG tailings, an approximate 50 m wide zone of thickened NAG overflow tailings will be placed along with the rising waste rock. The concept of the SHCF is to provide for a low-permeable zone downstream of the PAG tailings and majority of the waste rock to provide redundancy for maintaining saturation of the NAG cover in full closure, as well as provide alternatives under an early closure scenario, should the PAG tailings and waste rock be higher than the NAG tailings.

Technical Precedent and Reliability

There are numerous examples of mining projects utilizing thickened slurry tailings with ore processing throughputs at the scale of the Project. The proposed tailings technology is considered proven and not subject to any major implementation challenges. Additionally, thickened slurry tailings have a proven history of application in similar climate conditions as the project site. The tailings distribution and discharge strategy is unlikely to be affected in a significant way by any weather conditions. Extreme wet conditions can impact available storage capacity; however, this consideration was addressed in this concept. This tailings technology is the most flexible from an operational standpoint. Tailings discharge will not be the limiting factor for operational reliability.

Availability of Materials

There will be limitations in the availability of cyclone sand for embankment construction due to freezing temperatures preventing direct placement of sand during winter conditions. However, as there is one main embankment, there is operational flexibility to accommodate interruptions in the cyclone stream that are not available to other configurations. Furthermore, cycloning the full NAG tailings stream is under consideration, whereby materials produced during the winter periods would be stockpiled and then reclaimed during warmer temperatures, which would offset any material availability risks.

Closure Concept

These candidates include a drained closure concept of the NAG tailings mass, as well as a water table closure cover of NAG tailings over the PAG tailings and waste rock. Additionally, a ponded water closure cover will exist over the PAG tailings and waste rock areas. At closure, a spillway channel will be excavated back to the low point of the NAG beach to drain off any water build-up, but with the invert situated to allow for approximately 1.5 m of water to remain in the ponded water closure cover above the PAG tailings and waste rock areas.

All tailings surfaces will be amended with a growth medium and revegetated, including the downstream face of the TMF embankment. The ponded water closure cover across the waste rock and PAG tailings within the TMF will act to minimize oxygen infiltration of the underlying materials. Redundancy for maintaining the ponded water closure cover over the PAG tailings and waste rock is provided through the SHCF.

Consolidation of the NAG and PAG tailings deposits will occur throughout operations and during the closure phase of the project, which may result in localized depressions within the TMF. Preferential deposition of NAG tailings in the final three years of operations in the NAG tailings area will occur to prevent ponding on the tailings surface in closure and post-closure, and enhance shedding of runoff water. Water from the open pit, once it has reached the maximum elevation within the pit, will begin to drain towards the upper end of the TMF. It will drain through constructed wetlands located at the upstream end of the TMF prior to exiting the TMF through the closure spillway.

10.2.1.3 LC-34

Location	Dam Height	Total Surface Area	Revegetated Surface Area	Ponded Water Surface Area	PMF
Lower Casino Creek (LC-34)	205 m	1,428 ha	753 ha	675 ha	28.6 Mm^3

Storage Concept

LC-34 provides for zoned storage of thickened PAG tailings, a combination of thickened NAG whole tailings plus unthickened NAG overflow tailings, and waste rock, behind a main embankment. Additionally, a portion of the NAG tailings are mechanically dewatered and placed in a stack located downstream of the main embankment. Slurry NAG tailings are located directly upstream of the embankment; waste rock is located upstream of NAG tailings, and PAG tailings are located within a defined cell within the waste rock storage area. No internal embankments separate tailings and waste rock. A Process Water Pond will be located at the most upstream (north) end of the TMF; each of the PAG and NAG tailings areas will have small supernatant ponds.

For nine months of the year, NAG tailings will be cycloned to supply cyclone sand for the embankment. The overflow of NAG tailings (and full NAG tailings stream when cyclones are not operational) will be deposited adjacent to the embankment to develop and maintain above-water beaches. For the warmest six months of the year, NAG tailings will be directed through mechanical dewatering filters at a rate of 20,000 tonnes per day, with the resultant filtered tailings product placed in a stack downstream of the main embankment.

In the final three years of operations, as PAG tailings are directed to the open pit, NAG tailings will continue to be deposited in the TMF so as to create a NAG cover over the waste rock and PAG tailings. The cover will range in thickness, from 2 m over the waste rock to as much as 10 m over the PAG tailings. This NAG cover will create a capping layer sufficient to minimize oxygen infiltration of the underlying materials over a wide range of precipitation conditions. Additionally, a ponded water closure cover over the PAG tailings and waste rock will be developed as further redundancy to minimize oxygen infiltration.

TWG Highlights 10-2. Modification of LC-34

In the interest of minimizing the amount of water stored within the TMF, the TWG wanted to ensure the MAA included a candidate that incorporated mechanically dewatered ("dry stack") tailings technology. However, they also understood the limitations of this technology at the scale and climate of the Casino Project. Thus, in consultation with the TWG, the design of candidate LC-34 was adapted to provide a viable candidate that would mechanically dewater a portion of the NAG tailings stream (estimated based on current industry precedent) during the warmest six months of the year, and place this product downstream of the main embankment. The remainder of the NAG tailings stream would be thickened tailings, comparable to the other candidates.

Embankment

The starter embankment will be water-retaining and will be constructed from local borrow material with supplement from non-reactive waste rock. Ongoing raises to the embankment will be constructed from cyclone sand sourced from the underflow of the NAG tailings and will utilize the centerline method of construction. Permafrost in the embankment foundations for the life-of-mine will be removed prior to construction. Ongoing raises will not include a low-permeable core zone, which will assist the tailings mass above the starter embankment to drain and consolidate during and after closure, while maintaining a sufficiently low level of oxygen infiltration to prevent the onset of ARD in the waste rock and PAG tailings.

Co-Disposal Deposition within TMF

Throughout the operating life of the TMF, all waste materials are placed such that they rise simultaneously, albeit at different rates. Waste rock platforms, both upstream and downstream of the PAG tailings, will always be higher than the tailings elevations to ensure that there is a platform for the haul trucks to drive and place the next lift. The embankment is raised such that the NAG tailings reach an elevation equal to or higher than the PAG tailings as quickly as possible during the operating mine life.

Within the waste rock located between the PAG and NAG tailings, an approximate 50 m wide zone of thickened NAG overflow tailings will be placed along with the rising waste rock. The concept of the SHCF is to provide for a low-permeable zone downstream of the PAG tailings and majority of the waste rock to provide redundancy for maintaining saturation of the NAG cover in full closure, as well as provide alternatives under an early closure scenario, should the PAG tailings and waste rock be higher than the NAG tailings.

Technical Precedent and Reliability

There are numerous examples of mining projects utilizing thickened slurry tailings with ore processing throughputs at the scale of the proposed Casino Project. The proposed tailings technology is considered proven and not subject to any major implementation challenges. Additionally, thickened slurry tailings have a proven history of application in similar climate conditions as the project site. The tailings distribution and discharge strategy is unlikely to be affected in a significant way by any weather conditions. Extreme wet conditions can impact available storage capacity; however, this consideration was addressed in this concept. This tailings technology is the most flexible from an operational standpoint. Tailings discharge will not be the limiting factor for operational reliability.

In regard to the mechanical dewatering of NAG tailings, existing filtered tailings facilities at the scale envisioned have been in operation for some time to verify the long-term performance of such operations. Existing smaller scale operations in the region have exhibited issues with maintaining mechanically dewatered tailings production rates and tailings stack stability. There will be challenges inherent in maintaining a consistent solids product throughout the mine life, which may impact the production of the filtered product. However, by selecting a throughput that has precedent in the industry, and limiting to the warmer operating months, the impact from potential performance issues will be minimized.

Availability of Materials

There will be limitations in the availability of cyclone sand for embankment construction due to freezing temperatures preventing direct placement of sand during winter conditions. However, as there is one main embankment, there is operational flexibility to accommodate interruptions in the cyclone stream that are not available to other configurations. Furthermore, cycloning the full NAG tailings stream is under consideration, whereby materials produced during the winter periods would be stockpiled and then reclaimed during warmer temperatures, which would offset any material availability risks.

Closure Concept

This candidate includes a drained closure concept of the NAG tailings mass, as well as a water table closure cover of NAG tailings over the PAG tailings and waste rock. Additionally, a ponded water closure cover will exist over the PAG tailings and waste rock areas. At closure, a spillway channel will be excavated back to the low point of the NAG beach to drain off any water build-up, but with the invert situated to allow for approximately 1.5 m of water to remain in the ponded water closure cover above the PAG tailings and waste rock areas.

All tailings surfaces will be amended with a growth medium and revegetated, including the downstream face of the TMF embankment and the filtered stack. The ponded water closure cover across the waste rock and PAG tailings within the TMF will act to minimize oxygen infiltration of the underlying materials. Redundancy for maintaining the ponded water closure cover over the PAG tailings and waste rock is provided through the SHCF.

Consolidation of the NAG and PAG tailings deposits will occur throughout operations and during the closure phase of the project, which may result in localized depressions within the TMF. Preferential deposition of NAG tailings in the final three years of operations in the NAG tailings area will occur to prevent ponding on the tailings surface in closure and post-closure, and enhance shedding of runoff water. Water from the open pit, once it has reached the maximum elevation within the pit, will begin to drain towards the upper end of the TMF. It will drain through constructed wetlands located at the upstream end of the TMF prior to exiting the TMF through the closure spillway.

10.2.2 Biophysical Environmental Setting

The biophysical environment is described below for Middle Casino Creek (i.e., relevant to MC-25 and MC-28), and Lower Casino Creek (i.e., relevant to LC-25, LC-28, and LC-34).

10.2.2.1 Middle Casino Creek

The Middle Casino candidates are located in the Casino Creek catchment, with the dam located approximately 2 km upstream of the confluence with Brynelson Creek. Dip Creek is approximately 4.6 km downstream, and the TMF would effectively remove an estimated 13% of surface water from the Dip Creek catchment. In regard to groundwater, the alluvial deposit beneath the proposed foundation is estimated to have a cross-sectional area of 6,000 m^2. Slope and permeability conditions downstream are somewhat conducive for seepage to naturally discharge to the surface.

Water quality in Casino Creek is affected by naturally occurring ARD, including high levels of copper, aluminum, iron, acidity, hardness, conductivity, turbidity, and total dissolved solids from the Proctor Gulch tributary. There are also sources of cadmium, zinc, and lead from Meloy Creek.

The construction of the TMF at Middle Casino Creek would result in the loss of an estimated 2.9 ha of fish habitat. Fish habitat in this section of Casino Creek is poor quality with several medium-gradient flow-regulated barriers in the upper reaches that hinder fish migration into the area. Overall, fish habitat at Middle Casino Creek is rated as 'marginal'.

Field studies (2008-2013) identified only one species of fish—Arctic Grayling—found within the footprint of the TMF at Middle Casino Creek. The average catch-per-unit-effort was 0.20 fish per 100 seconds of electrofishing. Benthic sampling averaged 61 results per kicknet, representing a total of 9 taxa.

On land, the Middle Casino candidates would overlap with 156 ha of high quality terrestrial habitat (as measured for any species[25]). No wetland habitat would be affected. No rare plant habitat is identified within the footprint.

10.2.2.2 Lower Casino Creek

The Lower Casino candidates are located in the Casino Creek catchment, with the dam located approximately 3 km downstream of the confluence with Brynelson Creek. Dip Creek is approximately 700 m downstream, and the TMF would effectively remove an estimated 27% of surface water from the Dip Creek catchment. In regard to groundwater, the alluvial deposit beneath the proposed foundation is estimated to have a cross-sectional area of 30,000 m^2 (more for LC-34 with its greater footprint). Slope and permeability conditions downstream are not conducive for seepage to naturally discharge to the surface.

Water quality in Casino Creek is affected by naturally occurring ARD, including high levels of copper, aluminum, iron, acidity, hardness, conductivity, turbidity, and total dissolved solids from the Proctor Gulch tributary. There are also sources of cadmium, zinc, and lead from Meloy Creek. Dip Creek has higher water quality than Casino Creek.

The construction of the TMF at Lower Casino Creek would result in the loss of an estimated 7.8 ha of fish habitat. Fish habitat in this section of Casino Creek is poor quality in the upper section (i.e., overlapping with Middle Casino Creek, as described above), but there is higher quality habitat in the lower section (i.e., approaching Dip Creek). Brynelson Creek also contains higher quality habitat that would be lost with the construction of a TMF at Lower Casino Creek. Overall, fish habitat at Lower Casino Creek is rated as 'important'.

Field studies (2008-2013) identified three species of fish—Arctic Grayling, burbot, and slimy sculpin—found within the footprint of the TMF at Lower Casino Creek. The average catch-per-unit-effort was 0.34 fish per 100 seconds of electrofishing. Benthic sampling averaged 154 results per kicknet, representing a total of 21 taxa; this again highlights that the Lower Casino Creek location has a higher degree of aquatic life and diversity than Middle Casino Creek and other locations further up the Casino Creek valley.

On land, Lower Casino Creek would overlap with 182 ha of high quality terrestrial habitat (as measured for any species[26]). Minimal wetland area would be affected, ranging from 1 ha (LC-25 and LC-28) to 3 ha (LC-34). No rare plant habitat is identified within the footprint.

[25] This estimate represents the total (summed) loss of high quality/suitable habitat for all key indicator (KI) species/groups. This means there may be some overlap in habitat that is lost resulting in a conservatively high estimate due to potential double-counting. The following habitat categories were used for each KI (derived from existing habitat models): caribou and moose (high quality late winter habitat); Grizzly bear (suitable denning habitat); collard pika and horned grebe (suitable habitat); passerine birds, short-eared owl, olive-sided flycatcher, and rusty blackbird (high quality habitat); and cliff nesting raptors (number of known nest sites).
[26] *Ibid.*

10.2.3 Human Environment Setting

The remaining candidates show many similarities in terms of the human environment. As both locations are located in the Casino Creek catchment, there is no significant difference in proximity to communities in terms of downstream distance, or as-the-crow-flies.

Other factors determined to not be differentiating based on the available information include archaeological potential, employment and business opportunities, and potential overlap with commercial tenures (guide outfitting, trapping, mineral exploration, etc.).

10.2.3.1 Middle Casino Creek

No known archaeological sites would be affected by the Middle Casino candidates (MC-25 and MC-28). However, there are two historical sites within the footprint including the remnants of two log cabins (one dating between 1910 and the early 1940s, and the other dating to 1936).

As the Middle Casino candidates have a smaller surface footprint, and are further from Dip Creek (which may be navigated by boat), they are generally preferred in regard to minimizing potential impacts on First Nations interests. The embankment for the Middle Casino candidates would be approximately 4.6 km from the confluence with Dip Creek.

10.2.3.2 Lower Casino Creek

There are two known archaeological sites in the footprint of the Lower Casino candidates (LC-25, LC-28, and LC-34). Three historical sites are identified including a partially collapsed log cabin (dated earlier than 1936), partial remains of another cabin (late-19th or early-20th century), and remnants of a hide working frame. There is also a contemporary cabin on the northwest slope of the Casino Creek valley, belonging to the trapper who owns the trapping rights in the Project area. This cabin would be directly affected by the Lower Casino candidates.

As the Lower Casino candidates have a larger surface footprint, and are closer to Dip Creek (which may be navigated by boat), they are generally less preferred in regard to minimizing potential impacts on First Nations interests. The embankment for the Lower Casino candidates would be around 700 m from Dip Creek.

10.2.3.3 Closure Cover

Consultation with Selkirk First Nation indicated that since lakes are not a natural feature in the surrounding landscape, a closure pond is generally viewed as undesirable in terms of First Nations' perception of, and relationship to, the land in the vicinity of the Casino Project. MC-25 and LC-25 do not have a surface pond at closure, whereas MC-28, LC-28 and LC-34 have a pond.

10.2.4 Project Economics

Costs associated with the TMF were calculated relative (and incremental) to the estimated costs for MC-25 as the base case, and are presented in Table 10.2-1 and Table 10.2-2. The incremental capital cost for the competing alternatives was estimated using the same unit rates for comparable construction activities as used in the base case applied to the incremental quantities estimated by KP for the alternatives. The incremental capital cost is at a direct cost level.

Table 10-2.1. Estimated TMF Costs (MC-25 and MC-28)

Cost Parameter	MC-25	MC-28
Capital Costs		
CAPEX for internal dam	n/a	$72,825,000
Cover cost (reclamation)	$2,400,000	$1,056,000
Operating Costs		
Incremental OPEX/sustaining capital for internal embankment	Incremental cost increase = 0	$3,000,000 per year
Other		
Fish Habitat Offsetting Costs (offsetting ratios of 2:1 for known fish-bearing habitat, and 1:1 for inferred fish-bearing habitat, at a cost of $50-$100 per m²)	$2.1 million to $5.8 million	
Net Present Cost		
Net present cost, as attributable to the TMF (including CAPEX and OPEX, with 8% discount rate over 22 years operation)	$19.8 million	$19.6 million

Table 10.2-2. Estimated TMF Costs (LC-25, LC-28, and LC-34)

Cost Parameter	LC-25	LC-28	LC-34
Capital Costs			
Additional haul truck CAPEX	$30,000,000		
Extend slurry and reclaim water systems	$8,000,000		
Extend power & other utilities	$1,000,000		
Water treatment plant (500 m³/hr.)	$5,000,000		
Incremental power plant CAPEX	$1,700,000		
CAPEX for internal dam	$12,601,000	$12,601,000	$12,601,000
Dry Stack 20,000 tpd/183 days per year	n/a	n/a	$130,000,000
Stack foundation, etc.	n/a	n/a	$41,522,000
Total CAPEX increase	$58,301,000	$58,391,000	$229,823,000
Cover cost (reclamation)	$2,960,000	$1,340,000	$1,180,000
Operating Costs			
Incremental waste haul cost per year	$19,470,000 ($331,500,000 over LOM)		
Incremental pumping cost for reclaimed water	$900,000/yr. ($19,800,000 LOM)		
Water treatment cost per year	$1,300,000 ($29,000,000 LOM)		
Incremental OPEX/sustaining capital for internal embankment	$107,983	$107,983 per year	$101,622
Incremental OPEX/sustaining capital for dry stack (20,000 tpd of cyclone overflow material at $1.46/t)	n/a	n/a	$5,340,000/yr. ($117,560,000 LOM)
Net OPEX increase per year	$21,7777,983	$21,777,983	$27,111,622

(continued)

Table 10.2-2. Estimated TMF Costs (LC-25, LC-28, and LC-34) (completed)

Cost Parameter	LC-25	LC-28	LC-34
Operating Costs (cont'd)			
Fish Habitat Offsetting Costs (offsetting ratios of 2:1 for known fish-bearing habitat, and 1:1 for inferred fish-bearing habitat, at a cost of $50-$100 per m^2)	$7.2 million to $14.2 million		
Net Present Cost			
Net present cost, as attributable to the TMF (including CAPEX and OPEX, with 8% discount rate over 22 years operation)	$272,906,000	$280,699,000	$506,599,000

Long-Term Post-Closure Costs

CMC has considered post-closure infrastructure requirements including the need to maintain infrastructure, monitor performance, and support ongoing care-and-maintenance. The various activities and associated costs for the long-term monitoring and maintenance of the TMF, post-closure, do not materially differ based on the closure cover (flooded or saturated).

10.2.5 Consequences of Dam Failure

Table 10.2-3 summarizes the metrics used to characterize the potential consequence of dam failure for each candidate. The candidates are generally described as follows:

- Middle Casino candidates have a smaller upstream catchment area and therefore smaller PMF volume;
- Lower Casino candidates have lower dam heights;
- Candidates with a water table closure cover (MC-25 and LC-25) do not have a closure pond (i.e., no stored water post-closure);
- The filtered tailings candidate in Lower Casino Creek has the greatest volume of water in exposed waste rock under a dam breach scenario due to the smaller volume of contained NAG tailings slurry.
- Dam factor (a product of both dam height and stored volume, representative of the energy associated with a breach and resulting impact to the downstream environment) favours a smaller PMF, smaller volume of stored water, and lower dam height.

Table 10.2-3. Dam Failure Metrics

	MC-25	LC-25	MC-28	LC-28	LC-34
Operating pond volume	5.0 Mm^3	5.0 Mm^3	5.0 Mm^3	5.0 Mm^3	5.0 Mm^3
Closure pond volume	0	0	8.4 Mm^3	11.9 Mm^3	10.0 Mm^3
PMF volume	13.4 Mm^3	28.6 Mm^3	13.4 Mm^3	28.6 Mm^3	28.6 Mm^3

(continued)

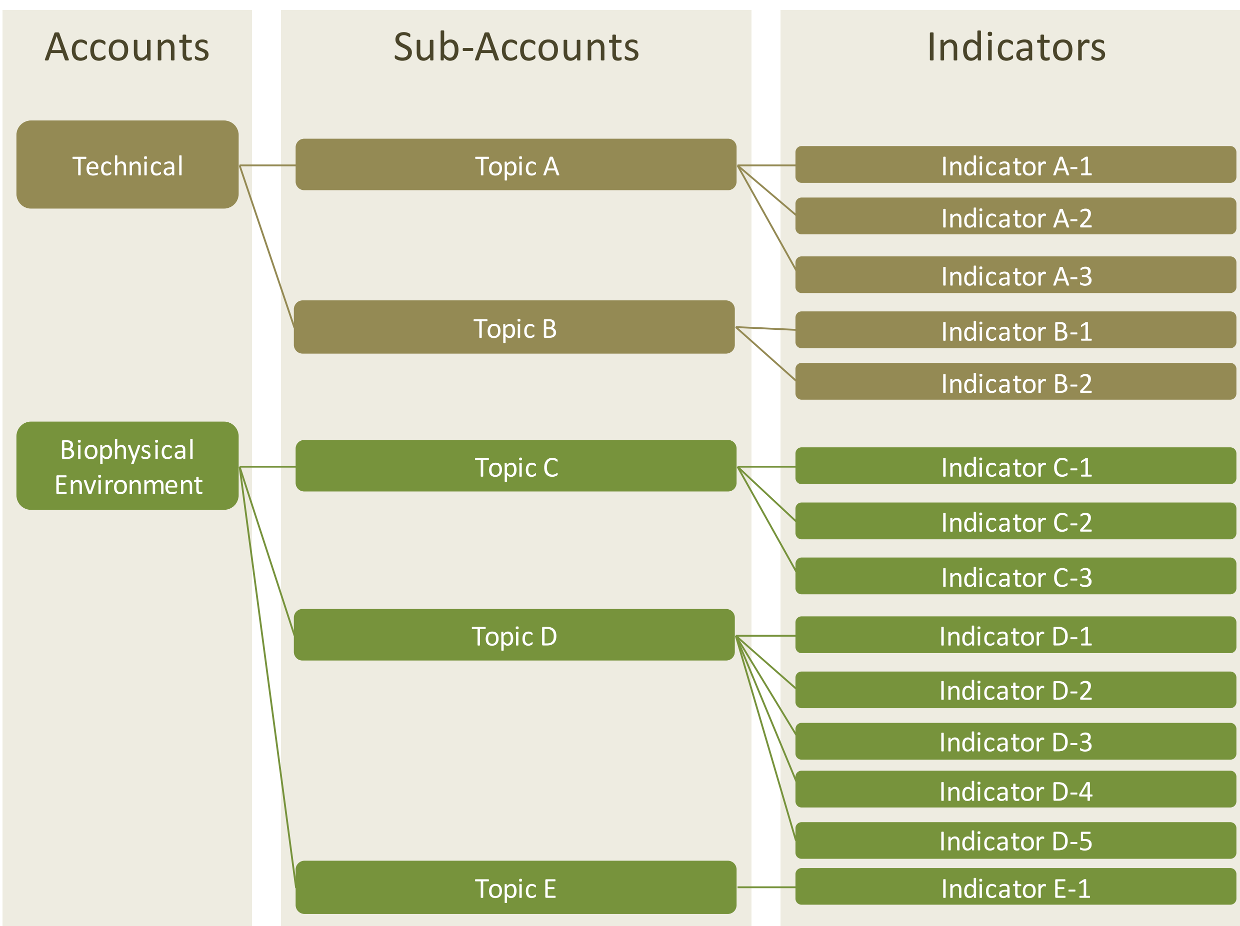
Table 10.2-3. Dam Failure Metrics (completed)

	MC-25	LC-25	MC-28	LC-28	LC-34
Dam height (max)	285 m	200 m	285 m	200 m	205 m
Potential volume of water in exposed waste rock	8.6 Mm^3 (10.0 Mm^3 in flood-induced scenario)	6.5 Mm^3 (7.0 Mm^3 in flood-induced scenario)	8.6 Mm^3 (10.0 Mm^3 in flood-induced scenario)	6.5 Mm^3 (7.0 Mm^3 in flood-induced scenario)	12.7 Mm^3 (14.6 Mm^3 in flood-induced scenario)
Potential downstream deposition of tailings	Within Casino Creek valley	Within Dip Creek valley	Within Casino Creek valley	Within Dip Creek valley	Within Dip Creek valley

10.3 CHARACTERIZATION CRITERIA

For each of the five accounts, sub-accounts and indicators were developed. The relationship of accounts, sub-accounts and indicators is illustrated in Figure 10.3-1.

Figure 10.3-1. Hierarchy of Accounts, Sub-accounts, and Indicators (Illustrative Example)



10.3.1 Accounts

Five accounts were identified for the Project (Table 10.3-1). The first four accounts align with ECCC Guidelines with respect to technical (engineered) elements, environmental conditions, socio-economic conditions, and project economics. The fifth account, "consequences of dam failure", was included in response to TWG comments and public interest.

Table 10.3-1. List of Accounts

Account	Rationale
Technical	The design, construction, operation and closure of the TMF is fundamental for safety and environmental protection, as well as project economics.
Biophysical Environment	The potential environmental effects of the TMF must be assessed and managed in accordance with Yukon and Canadian federal legislation and permitting, and are of interest to First Nations and communities.
Human Environment	The TMF may have adverse effects on land users, or may disrupt archaeology and heritage resources. It may also create benefits such as employment.
Project Economics	TMF costs influence overall project economics and project feasibility.
Consequences of Dam Failure	The consequences of a dam failure have safety, economic and potentially long-term environmental and social implications and are a concern for First Nations and the public.

10.3.2 Sub-accounts

Sub-accounts address the material issues within each account, and generally include the qualities outlined in ECCC Guidelines as summarized in Table 10.3-2.

Table 10.3-2. Qualities of Sub-accounts

Quality	Definition
Differentiating	Sub-accounts must define an aspect that distinctly differentiates at least one of the candidates, and this difference should be important to the decision-making process.
Impact-driven	Sub-accounts must be linked to an impact or risk, rather than being only factual. In other words, just because an element is measurable and differentiating does not mean it has relevance to the decision-making process. The sub-accounts should focus on what is relevant, rather than simply what is measurable.
Value relevant	Sub-accounts must be relevant in the context of the alternatives being considered.
Understandable	Sub-accounts must be unambiguous, such that the preferred outcome is clear to all parties, including external reviewers. Where potential ambiguity exists (e.g., whether a greater distance is preferred, or not) the preferred outcome should be clearly identified in the rationale.
Non-redundant	Sub-accounts must not overlap as this could lead to double-counting of some factors. Where similar topics are addressed, sub-accounts should either be combined or reconsidered to appropriately distinguish them.
Independent	Sub-accounts must be judgementally independent in that the determination of one sub-account should not be linked to, or dependent on, the results of another sub-account.

Sixteen relevant and differentiating sub-accounts were identified across the five accounts (Table 10.3-3). Sub-accounts are further defined by one or more specific indicators (Section 10.3.3).

Table 10.3-3. List of Sub-accounts

Account	Sub-account	Rationale
Technical	Operational risk	Lower risks are associated with candidates that have successfully operated at comparable scales and climates, and have less complex tailings and waste rock management systems. Candidates that minimize operational risks are preferred.
	Geochemical stability	Managing acid rock drainage (ARD) and metal leaching (ML) from tailings and waste rock is a critical function of the TMF. Candidates that have fewer technical challenges and increased certainty over geochemical stability are preferred.
	Water management	Water management is a critical component of any TMF design. Candidates that have less complex water management systems, and less contact water to manage are preferred.
	Physical stability	The physical stability of the TMF is dependent on the physical characteristics of the NAG tailings, and the spatial configuration of both tailings and waste rock. Candidates that are more physically stable are preferred.
Biophysical Environment	Air quality	Air quality may be affected through dust and GHG emissions. Candidates with less effects to air quality are preferred.
	Groundwater	Groundwater quality and quantity may be affected by TMF seepage and/or changes in groundwater recharge. Candidates with less potential to affect groundwater are preferred.
	Surface water quality	Downstream water quality of Casino Creek and Dip Creek may be affected by the TMF. Candidates with less potential to affect downstream surface water quality are preferred.
	Fish and aquatic habitat	Fish and aquatic habitat may be affected by the TMF. Candidates that minimize effects on fish and aquatic habitat are preferred.
	Terrestrial habitat	Terrestrial habitat, including endangered ecosystems and species, may be affected by the TMF. Candidates that minimize effects on terrestrial habitat are preferred.
Human Environment	Archaeology and cultural heritage	Archaeological and cultural heritage resources may be affected by the TMF. Candidates with less potential disturbance of archaeology and cultural heritage are preferred.
	First Nations' interests	Candidates with less potential to infringe on First Nations' interests—including the ability to pursue hunting, trapping, fishing, and other harvests and practices on lands—are preferred.
	Recreational and commercial land use	The TMF area may be used by recreational users and commercial land tenures. Candidates with less potential to adversely affect recreational and commercial land use are preferred.
	End land use	Candidates that provide for productive land use, following closure and reclamation of the TMF area, are preferred.
Project Economics	TMF costs	Candidates with lower overall project costs are more economically feasible and are preferred.
Consequences of Dam Failure	Fair weather failure	Based on a 'sunny day' (i.e., not flood-induced) scenario, candidates predicted to have lower downstream consequences as a result of a physical dam failure are preferred.
	Flood-induced failure	Based on a 'rainy day' (i.e., flood-induced) scenario, candidates predicted to have lower downstream consequences as a result of a physical dam failure are preferred.

10.3.3 Indicators

As sub-accounts are often not inherently measurable, indicators allow for quantitative or qualitative measurement of the risks or impacts within each sub-account. Indicators provide discretely measurable components that allow for qualitative and/or quantitative measurement of each sub-account. The measurable aspect of each indicator is clearly identified, along with its rationale (i.e., why the indicator is important to the sub-account, and to the decision-making process). Quantitative indicators were developed where possible, although qualitative indicators were also acceptable; for many indicators, quantitative measurement was not possible due to the nature of the indicator and/or the availability of information for the candidates at this stage.

Only differentiating indicators are included in the MAA (Step 5). Indicators found to be non-differentiating (i.e., the results are the same for all candidates) do not allow for a comparison of the candidates, and are therefore not included in the characterization summary tables.

In consultation with the TWG, CMC identified a total of 48 indicators. Table 10.3-4 defines the indicators for each sub-account, with one to eight indicators per sub-account. The rationale for each indicator is provided, along with specific quantitative or qualitative measurement parameters.

TWG Highlights 10-3. Selection of Indicators

The initial draft list of indicators presented to the TWG included more than 80 indicators. During the April 2018 workshop, and subsequent discussions with the TWG, the list was reduced to 48 indicators. The TWG recognized that there are many similarities in the design and location of the remaining candidates, so some of the indicators were removed because they did not differentiate between the candidates. Others were removed to avoid duplication between accounts; for example, water-related indicators appear in the Technical, Biophysical Environment, and Consequences of Dam Failure account, and the TWG ensured that each indicator was assigned to the correct sub-account and highlighted a unique impact or risk.

10.4 Data Sources

10.4.1 Technical Account

Data informing the technical characterization of the candidates was derived from the updated concept sheets provided in **Appendix H** and the summaries provided in Section 10.2. Based on these concepts, the technical experts involved in the MAA (including representatives from CMC, KP, Lorax, and technical consultants representing SFN and TH) also drew on their professional expertise and experience with comparable projects.

Table 10.3-4. List of Indicators

Sub-account	Indicator	Measurement	Rationale
Technical Account			
Operational Risk	Complexity of mine waste transport	Qualitative scale	Candidates with shorter distances to transport waste rock from the pit to the TMF, shorter distances to transport tailings and reclaim water between the mill to the TMF, and less elevation difference between the mill and TMF have lower operational risks, and are preferred.
	Complexity of operational water management	Qualitative scale	Candidates with less complex operational water management plans (including diversions and seepage management) are preferred.
	Complexity of closure cover	Qualitative scale	Candidates with less complex closure cover are preferred.
	Complexity of embankment structure	Embankment height x crest length (m^2)	Candidates with smaller and less complex embankment structure (height x crest length) are preferred.
Geochemical stability	ARD mitigation challenges (operations)	Maximum PAG surface area (ha)	Candidates with fewer technical challenges to mitigate ARD during operations are preferred.
	ARD mitigation challenges (post-closure)	Height of phreatic surface over PAG materials (m)	Candidates with fewer technical challenges to mitigate ARD post-closure are preferred.
	Metal leaching potential (operations)	Total surface area (ha)	Candidates with less potential to develop ML during operations, assuming successful design implementation, are preferred.
	Metal leaching potential (post-closure)	Unsaturated NAG tailings surface area (ha)	Candidates with less potential to develop ML post-closure, assuming successful design implementation, are preferred
	Adaptability of ML/ARD mitigation strategy for early closure	Surface area of PAG waste rock above NAG tailings (ha)	Candidates that are more adaptable for ML/ARD management in the event of early closure are preferred.
Water management	Control of operational water balance	Qualitative scale	Candidates with greater control of water balance are preferred.
	Complexity of underdrain system	Qualitative scale	Candidates with less complex foundation drainage requirements are preferred.

(continued)

Table 10.3-4. List of Indicators (continued)

Sub-account	Indicator	Measurement	Rationale
Technical Account *(cont'd)*			
Water management *(cont'd)*	Complexity of post-closure water management	Qualitative scale	Candidates with less complex post-closure water management plans are preferred.
	Ability to implement active water treatment (post-closure)	Volume of contact water (m^3)	If water treatment is required, candidates that minimize volumes of contact water are preferred.
Physical stability	Extent of foundation for dam(s)/stack	Area (ha)	Candidates with smaller areas of excavation and surface disturbance, as required for construction and expansion of foundations over the life of mine, are preferred.
	Enhanced stability (post-closure)	Qualitative scale	Candidates with a buttress/stack downstream of the dam have enhanced stability and are preferred.
Biophysical Environment Account			
Air quality	Fugitive dust emissions (TMF surface)	Area of exposed tailings (ha)	Candidates with less potential for fugitive dust emissions from the surface of the TMF, based on the area of exposed tailings/cyclone sand post-closure, will have lower impact to air quality and are preferred.
	TMF hauling distance	Tonnes of waste rock and distance travelled (Tonne-km)	Candidates with lower overall trucking distances to/from the TMF (and associated effects of road dust and GHG emissions), considering the total waste rock and distance traveled, are preferred.
Groundwater	Seepage Management (operations)	Qualitative scale	Candidates with TMF seepage that is easier to manage during operations are preferred.
	Seepage Management (post-closure)	Qualitative scale	Candidates with TMF seepage that is easier to manage during post-closure are preferred.
Surface water quality	Degradation of downstream water quality (operations)	Qualitative scale	Candidates with less potential to degrade downstream surface water quality during operations are preferred.
	Degradation of downstream water quality (post-closure)	Qualitative scale	Candidates with less potential for loading released to downstream surface water, post-closure, are preferred.
	TMF wetland requirements (post-closure)	Area (ha)	Candidates with more available area for passive water treatment are preferred.

(continued)

Table 10.3-4. List of Indicators (continued)

Sub-account	Indicator	Measurement	Rationale
Biophysical Environment Account *(cont'd)*			
Fish and aquatic habitat	Extent of fish habitat loss (direct)	Habitat area affected (ha)	Candidates that minimize the loss of fish habitat are preferred.
	Quality of lost fish habitat (direct)	Qualitative Scale (Count)	Candidates that avoid or minimize impacts to critical or important fish habitat (i.e., migration routes, spawning and/or overwintering areas) are preferred.
	Changes to surface water hydrology (operations)	Loss of flow in Dip Creek (%)	Candidates that minimize changes to surface water hydrology during operations, and therefore maintain downstream fish habitat (measured at Dip Creek) closer to baseline conditions, are preferred.
	Diversity of directly affected fish community	Number of fish species (Count)	Candidates that directly impact fewer fish species (i.e., lower diversity) have a smaller potential impact on biodiversity and are preferred.
	Diversity of directly affected benthic invertebrate community	Taxa richness (Number of taxa)	Candidates that directly affect less diverse benthic ecosystems are preferred.
Terrestrial habitat	Direct loss of wetlands	Wetland area affected (ha)	Candidates that avoid or minimize the loss of wetland habitat are preferred.
	Risk of metals uptake to wildlife (plant-based)	Area of revegetated surface (ha)	Candidates that minimize uptake of metals through vegetation, post-closure, are preferred. Risk of metal uptake is expected to be reduced with smaller TMF revegetated surface area.
	Risk of metals uptake to wildlife (water-based)	Area of open water (ha)	Candidates that minimize uptake of metals through water, post-closure, are preferred. Risk of metal uptake is expected to be reduced with smaller post-closure pond area.
Human Environment Account			
Archaeology and cultural heritage	Disturbance to known archaeological site(s)	Number of sites (Heritage Sites Summary Report)	Candidates with no impacts to known archaeological sites, or impacts to fewer sites, are preferred.
	Disturbance to historic sites	Number of sites (Heritage Sites Summary Report)	Candidates with no impacts to known historic sites, or impacts to fewer sites, are preferred.

(continued)

Table 10.3-4. List of Indicators (continued)

Sub-account	Indicator	Measurement	Rationale
Human Environment Account *(cont'd)*			
First Nations Interests	Cultural and/or spiritual relationship to the environment	Qualitative scale	Candidates that result in less disruption to the spiritual and emotional well-being of First Nations, based on real and perceived effects, are preferred.
	Effect on First Nations' ability to pursue land use and cultural activities	Qualitative scale	Candidates with less potential to impact First Nations' ability to pursue land use and cultural activities, based on real and perceived impacts, are preferred.
	Sensory disturbance (Noise, visual and dust) during operations	Qualitative scale	Candidates with lower potential for sensory disturbance are preferred.
Recreational and commercial land use	Built structures	Number of structures	Candidates with less potential to impact built structures (including camps, cabins, and water wells/withdrawal infrastructure) are preferred.
	Sensory disturbance (Noise, visual, dust) during operations	Qualitative scale	Candidates with less potential to impact aesthetics (e.g., noise, visual) for land users' enjoyment for land use and cultural activities are preferred.
End land use	Post-closure landscape	Qualitative scale	Candidates that can be reclaimed to blend in with the surrounding landscape, are preferred.
Project Economics Account			
TMF economics	Net present costs	Cost range ($)	Candidates with a lower estimated NPC, as attributable to the TMF (including CAPEX and OPEX, with 8% discount rate over 22 years operation), are preferred.
Consequences of Dam Failure Account			
Fair weather failure	Volume of water (post-closure)	Volume (Mm^3)	Candidates with smaller volumes of stored water will have less outflow volume and result in less impact to the downstream environment, and are preferred.
	Dam factor (post-closure)	Outflow volume x dam height above bottom of breach (Mm^3 x m)	Candidates with a lower overall dam factor will have less energy associated with a breach and result in less impact to the downstream environment, and are preferred.
	Tailings deposition at Dip Creek	Qualitative scale	Candidates with lower risk of creating a secondary dam outburst event through the deposited tailings are preferred.
	Secondary impact of dam failure (post-closure)	Volume of water in exposed waste rock (Mm^3)	Candidates with a lower risk for post-failure drainage of void water from the waste rock are preferred. (The assumption is that dam fails down to the top of the starter embankment.)

(continued)

Table 10.3-4. List of Indicators (completed)

Sub-account	Indicator	Measurement	Rationale
Consequences of Dam Failure Account *(cont'd)*			
Flood-induced failure	Volume of water (post-closure)	Volume (Mm^3)	Candidates with smaller volumes of stored water plus IDF will have less outflow volume and result in less impact to the downstream environment, and are preferred.
	Dam factor (operations)	Outflow volume x dam height above bottom of breach (Mm^3 x m)	Candidates with a lower overall dam factor will have less energy associated with a breach and result in less impact to the downstream environment, and are preferred.
	Dam factor (post-closure)	Outflow volume x dam height above bottom of breach (Mm^3 x m)	Candidates with a lower overall dam factor will have less energy associated with a breach and result in less impact to the downstream environment, and are preferred.
	Tailings deposition at Dip Creek	Qualitative scale	Candidates with lower risk of creating a secondary dam outburst event through the deposited tailings are preferred.
	Secondary impact of dam failure (post-closure)	Volume of water in exposed waste rock (Mm^3)	Candidates with a lower risk for post-failure drainage of void water from the waste rock are preferred. (The assumption is that dam fails down to the foundation.)

10.4.2 Biophysical Environment Account

Characterization of the biophysical environment was largely based on the baseline studies as described in the Casino Project Proposal[27], and summarized in Sections 4.1 and 4.2 of this report. Technical experts involved in the baseline studies also helped characterize the indicators and participated in the MAA. As the remaining five candidates are all located in the Casino Creek catchment, baseline information previously collected and reported in the Project Proposal provided an adequate level of detail to compare the candidates. Studies and reports that provided the information used in the characterization of candidates are summarized in Table 10.4-1.

Table 10.4-1. Sources of Information for Biophysical Characterization of Candidates

Title	Author	Year	Project Proposal Reference
Surficial Geology, Terrain and Soils Baseline Report	EDI Environmental Dynamics Inc.	2013	Appendix 6A
Terrain Hazards Assessment for Proposed Mine Site	Knight Piésold	2012	Appendix 6D
Water and Sediment Quality Baseline Report	Palmer Environmental Consulting Group Ltd.	2013	Appendix 7A
Baseline Hydrology Report	Knight Piésold Ltd.	2013	Appendix 7B
Baseline Hydrogeology Report	Knight Piésold Ltd.	2012	Appendix 7C
Water Quality Model Report	Source Environmental Associates Inc.	2013	Appendix 7G
Fish and Aquatic Resources Baseline Report	Palmer Environmental Consulting Group Ltd.	2013	Appendix 10A
Vegetation Baseline Report	EDI Environmental Dynamics Inc.	2013	Appendix 11A
Wildlife Baseline Report	EDI Environmental Dynamics Inc.	2013	Appendix 12A
Bird Baseline Report	EDI Environmental Dynamics Inc.	2013	Appendix 12B

In addition to the above studies, some biophysical environment indicators were also characterized based on the design concepts for the candidates. For example, the air quality indicators relate to the TMF surface area and length of roads.

10.4.3 Human Environment

Candidates' potential to impact archaeological sites or other historic sites was evaluated based on the information presented in the Heritage Sites Summary Report[28]. There are two known archaeological sites, as well as four historical sites dating from the late-19th/early-20th century in the area of the candidates.

First Nations' traditional (and ongoing) land use is a significant component of the Human Environment account, and CMC invited all First Nations involved in the TWG to provide input

[27] Casino Mining Corp (2014). Casino Project: Proposal for Executive Committee Review. January 2014.

[28] Appendix A.18A Casino Heritage Resources Summary Report. December 10, 2014. Supplementary Information Report B to the Casino Project Proposal for Executive Committee Review, Pursuant to the Yukon Environmental and Socio-Economic Assessment Act, January 3, 2014.

regarding their use and cultural value of the land in the vicinity of the TMF. TH deferred to SFN as the mine site and TMF is located within SFN's traditional territory. SFN provided input through in-person meetings in April and May 2018. To support consultation on these indicators, SFN also referred to information in traditional land use studies in the area of the candidates.

Recreational and commercial land use was evaluated through review of the Land Use Baseline Report[29] and associated maps describing land use tenures and sites of interest. CMC also discussed land use in the vicinity of the TMF with the TWG in April 2018. Preferences for end land use were considered in consultation with SFN in April and May 2018.

10.4.4 Project Economics

Information to support the characterization of the Project Economics account was provided by CMC. Estimates were based on financial estimates previously developed for the Project, and adjusted to reflect more recent optimizations included in the TMF design concepts at this stage.

10.4.5 Consequences of Dam Failure

Characterization of the consequences of dam failure was developed by Knight Piésold based on the TMF design concepts available at this stage, and with consideration of key metrics utilized in the field of dam breach analysis.

10.5 Criteria Considered and Not Included

In the development of the characterization criteria defined in Section 10.3, additional sub-accounts and indicators were considered but ultimately were not included as they were determined to be duplicative, or not sufficiently differentiating between the remaining candidates. **Appendix I** lists these criteria and the rationale for not including them in the MAA.

10.6 Characterization Summary

Tables 10.6-1 through 10.6-5 provide the characterization of each candidate against each of the indicators listed in Table 10.3-3.

> **TWG Highlights 10-4. Characterization Tables**
>
> CMC provided the characterization tables to the TWG in advance of the MAA workshop held in April 2018. During the workshop, participants provided comments on the characterizations. In some cases, additional detail was requested in terms of how estimates had been calculated, or the relationships between various indicators. As a result of these comments, the tables were amended and/or clarified, or additional detail was provided to support the characterization of the candidates.

[29] Appendix 19A Land Use and Tenure Baseline Report. October 2013. Casino Project Proposal for Executive Committee Review, Pursuant to the Yukon Environmental and Socio-Economic Assessment Act, January 3, 2014.

Table 10.6-1. Characterization of Candidates: Technical Account

Indicator and Rationale	MC-25	LC-25	MC-28	LC-28	LC-34
Operational Risk					
Complexity of mine waste transport Candidates with shorter distances to transport waste rock from the pit to the TMF, shorter distances to transport tailings and reclaim water between the mill to the TMF, and less elevation difference between the mill and TMF have lower operational risks, and are preferred.	Waste rock will be transported 4.5 km. Tailings will be thickened slurry. Tailings and reclaim water will be transported 6 km with an elevation change of 150 m. Considering this, MC-25 is expected to have a moderate-low complexity of mine waste transport.	Waste rock will be transported 9.5 km. Tailings will be thickened slurry. Tailings and reclaim water will be transported 11.5 km with an elevation change of 300 m. Considering this, LC-25 is expected to have a moderate complexity of mine waste transport.	Waste rock will be transported 4.5 km. Tailings will be thickened slurry. Tailings and reclaim water will be transported 6 km with an elevation change of 150 m. Considering this, MC-25 is expected to have a moderate-low complexity of mine waste transport.	Waste rock will be transported 9.5 km. Tailings will be thickened slurry. Tailings and reclaim water will be transported 11.5 km with an elevation change of 300 m. Considering this, LC-25 is expected to have a moderate complexity of mine waste transport.	Waste rock will be transported 9.0 km. Tailings will include a combination of thickened slurry and mechanically filtered. Tailings and reclaim water will be transported 10.5 km with an elevation change of 285 m. LC-34 has added complexity due to transport and placement for the filtered tailings. Considering this, LC-34 is expected to have moderate-high complexity of mine waste transport.
Complexity of operational water management Candidates with less complex operational water management plans (including diversions and seepage management) are preferred.	Low complexity: • No planned water diversions; • Seepage pumpback downstream of TMF; • Yukon River pumping system	Moderate complexity: • Some surface water diversions to minimize annual surplus; • Seepage pumpback downstream of TMF; • May still need Yukon River pumping system if size of process water pond is too large to manage annual inflows; • Likely need to release (and potentially treat) surplus water	Low complexity: • No planned water diversions; • Seepage pumpback downstream of TMF; • Yukon River pumping system	Moderate complexity: • Some surface water diversions to minimize annual surplus; • Seepage pumpback downstream of TMF; • May still need Yukon River pumping system if size of process water pond is too large to manage annual inflows; • Likely need to release (and potentially treat) surplus water	Moderate-high complexity: • Some surface water diversions to minimize annual surplus; • Seepage pumpback downstream of TMF; • Surface water management of filtered stack; • May still need Yukon River pumping system if size of process water pond is too large to manage annual inflows; • Likely need to release (and potentially treat) surplus water
Complexity of closure cover Candidates with less complex closure cover are preferred.	Moderate complexity: • Saturated closure cover results in more effort to shape and maintain NAG tailings cover to convey drainage to spillway • More erosion expected due to larger area of exposed NAG tailings (11.7 Mm^2)	Moderate-High complexity: • Saturated closure cover results in more effort to shape and maintain NAG tailings cover to convey drainage to spillway • More erosion expected due to larger area of exposed NAG tailings (15.4 Mm^2)	Low-Moderate complexity: • Flooded closure cover results in less effort to shape and maintain NAG tailings cover to convey drainage to spillway • Less erosion expected due to smaller area of exposed NAG tailings (6 Mm^2)	Low-Moderate complexity: • Flooded closure cover results in less effort to shape and maintain NAG tailings cover to convey drainage to spillway • Less erosion expected due to smaller area of exposed NAG tailings (7.3 Mm^2)	Moderate complexity: • Flooded closure cover results in less effort to shape and maintain NAG tailings cover to convey drainage to spillway • Less erosion expected due to smaller area of exposed NAG tailings (7.5 Mm^2) • Stack provides increased opportunity for erosion potential
Complexity of embankment structure Candidates with less complex embankment structure (height x crest length) are preferred.	712,500 (285 x 2500)	384,000 (200 x 1920)	712,500 (285 x 2500)	384,000 (200 x 1920)	538,125 (205 m x 2625 m)
Geochemical Stability					
ARD mitigation challenges (operations) ARD mitigation will be more challenging and present greater risk if larger areas of PAG materials are exposed. Candidates with smaller areas of exposed PAG materials, over the mine life, are preferred.	574 ha	813 ha	574 ha	813 ha	675 ha

(continued)

Table 10.6-1. Characterization of Candidates: Technical Account (continued)

Indicator and Rationale	MC-25	LC-25	MC-28	LC-28	LC-34
Geochemical Stability *(cont'd)*					
ARD mitigation challenges (post-closure) Candidates with greater thickness of water cover over PAG materials are more resilient to changes in water balance, and are preferred.	1.0 m	1.0 m	3.5 m	3.5 m	3.5 m
Metal leaching potential (operations) Candidates with lower degree of neutral-pH metal leaching during operations, assuming successful design implementation, are preferred. The degree of metal leaching is assumed to be proportional to overall surface area.	1,172 ha	1,540 ha	1,172 ha	1,540 ha	1,428
Metal leaching potential (post-closure) Candidates with lower degree of neutral-pH metal leaching during post-closure, assuming successful design implementation, are preferred. Neutral ML potential is assumed to be proportional to the area of unsaturated NAG tailings exposed at surface.	1,172 ha	1,540 ha	601 ha	727 ha	753 ha
Adaptability of ML/ARD mitigation strategy for early closure Candidates that are more adaptable for ML/ARD management in the event of early closure (based on ability to effectively saturate PAG materials) are preferred.	24 ha	28 ha	24 ha	28 ha	33 ha
Water Management					
Control of operational water balance Candidates with greater control of water balance are preferred.	Water surplus exists; requirement for Yukon River to provide make-up water; no operational surplus expected and therefore preferred.	Water surplus expected; requirement for Yukon River may still exist, if water storage volume too great; operational treat and release expected and therefore less preferred.	Water surplus exists; requirement for Yukon River to provide make-up water; no operational surplus expected and therefore preferred.	Water surplus expected; requirement for Yukon River may still exist, if water storage volume too great; operational treat and release expected and therefore less preferred.	Water surplus expected; requirement for Yukon River may still exist, if water storage volume too great; operational treat and release expected and therefore less preferred.
Complexity of underdrain system Candidates with less complex foundation drainage requirements are preferred.	Low complexity: Underdrain system understood and feasible; modest amount of alluvial materials in embankment foundation.	Moderate complexity: Underdrain system less understood but likely feasible; extensive alluvial materials in embankment foundations.	Low complexity: Underdrain system understood and feasible; modest amount of alluvial materials in embankment foundation.	Moderate complexity: Underdrain system less understood but likely feasible; extensive alluvial materials in embankment foundations.	Moderate-High complexity: Underdrain system less understood but likely feasible; will also be required under downstream filtered stack; extensive alluvial material in foundations.
Complexity of post-closure water management Candidates with less complex post-closure water management are preferred.	Moderate complexity: • Saturated cover results in additional surface drainage channels across TMF surface • Moderate volume of water to be managed and released.	Moderate-High complexity: • Saturated cover results in additional surface drainage channels across TMF surface • Large volume of water to be managed and released.	Low-Moderate complexity: • Flooded closure cover simplifies surface drainage across TMF • Moderate volume of water to be managed and released	Moderate complexity: • Flooded closure cover simplifies surface drainage across TMF • Large volume of water to be managed and released	Moderate-High complexity: • Flooded closure cover simplifies surface drainage across TMF • Large volume of water to be managed and released • Stack requires additional drainage channels across surface
Ability to implement active water treatment (post-closure) If water treatment is required, candidates that minimize volumes of contact water are preferred.	7 Mm^3	16 Mm^3	6 Mm^3	15 Mm^3	15 Mm^3

(continued)

Table 10.6-1. Characterization of Candidates: Technical Account (completed)

Indicator and Rationale	MC-25	LC-25	MC-28	LC-28	LC-34
Physical Stability					
Extent of foundation for dam(s)/stacks Candidates with smaller areas of excavation and surface disturbance, as required for construction and expansion of foundations over the life of mine, are preferred.	158 ha	96 ha	158 ha	96 ha	140 ha
Enhanced stability (post-closure) Candidates with a buttress/stack downstream of the dam have enhanced stability and are preferred.	No buttress/stack	No buttress/stack	No buttress/stack	No buttress/stack	Stack is present

Table 10.6-2. Characterization of Candidates: Biophysical Environment Account

Indicator	MC-25	LC-25	MC-28	LC-28	LC-34
Air Quality					
Fugitive dust emissions (TMF surface) Candidates with less potential for fugitive dust emissions from the surface of the TMF, based on the area of exposed tailings/cyclone sand post-closure, will have lower impact to air quality and are preferred.	1,172 ha	1,540 ha	601 ha	727 ha	753 ha
TMF hauling distance Candidates with lower overall trucking distances to/from the TMF (and associated effects of road dust and GHG emissions), considering the total waste rock and distance traveled, are preferred.	2,961 tonne-km	6,251 tonne-km	2,961 tonne-km	6,251 tonne-km	5,922 tonne-km
Groundwater					
Seepage Management (operations) Candidates with TMF seepage that is easier to manage during operations are preferred.	The alluvial deposit (seepage pathway) beneath the foundation is estimated to have a cross-sectional area of 6,000 m², resulting in potential to convey a moderate amount of seepage. Downstream conditions (slope, permeability) are somewhat conducive for promoting seepage to naturally discharge to surface. Implementing mitigation measures to collect seepage at this location seem feasible.	The alluvial deposit (seepage pathway) beneath the foundation is estimated to have a cross-sectional area of 30,000 m², resulting in potential to convey a moderately high amount of seepage. Downstream conditions (slope, permeability) are not conducive for promoting seepage to naturally discharge to surface. Implementing mitigation measures to collect seepage at this location seem feasible but require a greater level of effort.	The alluvial deposit (seepage pathway) beneath the foundation is estimated to have a cross-sectional area of 6,000 m², resulting in potential to convey a moderate amount of seepage. Downstream conditions (slope, permeability) are somewhat conducive for promoting seepage to naturally discharge to surface. Implementing mitigation measures to collect seepage at this location seem feasible.	The alluvial deposit (seepage pathway) beneath the foundation is estimated to have a cross-sectional area of 30,000 m², resulting in potential to convey a moderately high amount of seepage. Downstream conditions (slope, permeability) are not conducive for promoting seepage to naturally discharge to surface. Implementing mitigation measures to collect seepage at this location seem feasible but require a greater level of effort.	The alluvial deposit (seepage pathway) beneath the foundation is estimated to have a cross-sectional area >30,000 m². Water in contact with the stack footprint may infiltrate the subsurface, creating additional seepage. Potential to generate/convey a high amount of seepage. Downstream conditions (slope, permeability) are not conducive for promoting seepage to naturally discharge to surface. Implementing mitigation measures to collect seepage at this location may be challenging.

(continued)

Table 10.6-2. Characterization of Candidates: Biophysical Environment Account (continued)

Indicator	MC-25	LC-25	MC-28	LC-28	LC-34
Groundwater *(cont'd)*					
Seepage Management (post-closure) Candidates TMF seepage that is easier to manage during post-closure are preferred.	Dry facility in post-closure potentially decreases flow through and beneath the dam. The alluvial deposit (seepage pathway) beneath the foundation is estimated to have a cross-sectional area of 6,000 m^2 and has potential to convey a moderately low amount of seepage. Downstream conditions (slope, permeability) are somewhat conducive for promoting seepage to naturally discharge to surface. If required, implementing mitigation measures to collect seepage at this location seem feasible.	Dry facility in post-closure potentially decreases flow through and beneath the dam. The alluvial deposit (seepage pathway) beneath the foundation is estimated to have a cross-sectional area of 30,000 m^2 and has potential to convey a moderate amount of seepage. Downstream conditions (slope, permeability) are not conducive for promoting seepage to naturally discharge to surface. Implementing mitigation measures to collect seepage at this location seem feasible.	Presence of a pond in post-closure potentially increases flow through and beneath the dam. The alluvial deposit (seepage pathway) beneath the foundation is estimated to have a cross-sectional area of 6,000 m^2 and has potential to convey a moderate amount of seepage. Downstream conditions (slope, permeability) are somewhat conducive for promoting seepage to naturally discharge to surface. Implementing mitigation measures to collect seepage at this location seem feasible.	Presence of a pond in post-closure potentially increases flow through and beneath the dam. The alluvial deposit (seepage pathway) beneath the foundation is estimated to have a cross-sectional area of 30,000 m^2 and has potential to convey a moderately high amount of seepage. Downstream conditions (slope, permeability) are not conducive for promoting seepage to naturally discharge to surface. Implementing mitigation measures to collect seepage at this location seem feasible but require a greater level of effort.	Presence of a pond in post-closure potentially increases flow through and beneath the dam. The alluvial deposit (seepage pathway) beneath the foundation is estimated to have a cross-sectional area >30,000 m^2. Water in contact with the stack footprint may infiltrate the subsurface, creating additional seepage. Potential to generate a moderately high amount of seepage. Downstream conditions (slope, permeability) are not conducive for promoting seepage to naturally discharge to surface. Implementing mitigation measures to collect seepage at this location may be challenging.
Surface Water Quality					
Degradation of downstream water quality (operations) Candidates with less potential to degrade downstream surface water quality during operations are preferred.	No discharge during operations.	Potential discharge of treated water.	No discharge during operations.	Potential discharge of treated water.	Potential discharge of treated water.
Degradation of downstream water quality (post-closure) Candidates with less potential for loading released to downstream surface water, post-closure, are preferred.	The seepage pathway (alluvial deposit) is estimated to be smaller (200 m x 30 m = 6,000 m^2) and so can carry a moderately-low amount of flow and hence lower loading. Downstream conditions (slope, permeability, and distance from Dip Creek) are more conducive to recovering seepage so it can be treated.	The seepage pathway (alluvial deposit) is estimated to be larger (30,000 m^2) and hence capable of conveying moderate amount of flow, and hence higher loading. Downstream conditions (slope, permeability, distance from Dip Creek) are less conducive for recovering seepage so it can be treated, such that more loading is likely to reach Dip Creek (either with or without wetland treatment).	The seepage pathway (alluvial deposit) is estimated to be smaller (200 m x 30 m = 6,000 m^2) and so can carry a moderately-low amount of flow and hence lower loading. Downstream conditions (slope, permeability, and distance from Dip Creek)) are more conducive to recovering seepage so it can be treated.	The seepage pathway (alluvial deposit) is estimated to be larger (30,000 m^2) and hence capable of conveying moderate amount of flow, and hence higher loading. Downstream conditions (slope, permeability, distance from Dip Creek) are less conducive for recovering seepage so it can be treated, such that more loading is likely to reach Dip Creek (either with or without wetland treatment).	The seepage pathway (alluvial deposit) is estimated to be larger (>30,000 m^2) and hence capable of conveying a moderately high amount of flow, and hence loading. Downstream conditions (slope, permeability, distance from Dip Creek) are less conducive for recovering seepage so it can be treated, such that more loading is likely to reach Dip Creek (either with or without wetland treatment).
TMF wetland requirements (post-closure) Candidates with more available area for passive water treatment are preferred.	82 ha	22 ha	82 ha	22 ha	<10 ha
Fish and Aquatic Habitat					
Extent of fish habitat loss (direct) Candidates that minimize the loss of fish habitat are preferred.	2.9 ha	7.8 ha	2.9 ha	7.8 ha	7.8 ha
Quality of lost fish habitat (direct) Candidates that avoid or minimize impacts to critical or important fish habitat (i.e., migration routes, spawning and/or overwintering areas) are preferred.	Casino Creek within the footprint of MC-25 has poor quality habitat with several medium gradient flow-regulated barriers in the upper section that hinder fish migration into the area. Overall, habitat is rated as marginal.	Casino Creek within the footprint of LC-25 has poor quality habitat in the upper section (overlaps with MC footprint), but higher quality habitat is available in the lower section. Brynelson Creek (tributary) also contains higher quality habitat. Overall, habitat is rated as important.	Casino Creek within the footprint of MC-28 has poor quality habitat with several medium gradient flow-regulated barriers in the upper section that hinder fish migration into the area. Overall, habitat is rated as marginal.	Casino Creek within the footprint of LC-28 has poor quality habitat in the upper section (overlaps with MC footprint), but higher quality habitat is available in the lower section. Brynelson Creek (tributary) also contains higher quality habitat. Overall, habitat is rated as important.	Casino Creek within the footprint of LC-34 has poor quality habitat in the upper section (overlaps with MC footprint), but higher quality habitat is available in the lower section. Brynelson Creek (tributary) also contains higher quality habitat. Overall, habitat is rated as important.

(continued)

Table 10.6-2. Characterization of Candidates: Biophysical Environment Account (completed)

Indicator	MC-25	LC-25	MC-28	LC-28	LC-34
Fish and Aquatic Habitat *(cont'd)*					
Changes to surface water hydrology (operations) Candidates that minimize changes to surface water hydrology during operations, and therefore maintain downstream fish habitat (measured at Dip Creek) closer to baseline conditions, are preferred.	13%	27%	13%	27%	27%
Diversity of directly affected fish community Candidates that directly impact fewer fish species (i.e., lower diversity) have a smaller potential impact on biodiversity and are preferred.	Field studies conducted between 2008 and 2013 identified one species of fish (Arctic Grayling) within the footprint of MC-25.	Field studies conducted between 2008 and 2013 identified three species of fish (Arctic Grayling, Burbot, and Slimy Sculpin) within the footprint of LC-25.	Field studies conducted between 2008 and 2013 identified one species of fish (Arctic Grayling) within the footprint of MC-28.	Field studies conducted between 2008 and 2013 identified three species of fish (Arctic Grayling, Burbot, and Slimy Sculpin) within the footprint of LC-28.	Field studies conducted between 2008 and 2013 identified three species of fish (Arctic Grayling, Burbot, and Slimy Sculpin) within the footprint of LC-34.
Diversity of directly affected benthic invertebrate community Candidates that directly affect less diverse benthic ecosystems are preferred.	9 (n=3 sites)	14 (n=5 sites)	9 (n=3 sites)	14 (n=5 sites)	14 (n=5 sites)
Terrestrial Habitat					
Direct loss of wetlands Candidates that avoid or minimize the loss of wetland habitat are preferred.	0 ha	1 ha	0 ha	1 ha	3 ha
Risk of metals uptake to wildlife (plant-based) Candidates that minimize uptake of metals through vegetation, post-closure, are preferred. Risk of metal uptake is expected to be reduced with smaller TMF revegetated surface area.	1,172 ha	1,540 ha	601 ha	727 ha	753 ha
Risk of metals uptake to wildlife (water-based) Candidates that minimize uptake of metals through water, post-closure, are preferred. Risk of metal uptake is expected to be reduced with smaller post-closure pond area.	Pond: 0 ha Stream: 0.03 ha (300 m x 1 m)	Pond: 0 ha Stream: 0.15 ha (1,500 m x 1 m)	Pond: 571 ha Stream: 0.03 ha (300 m x 1 m)	Pond: 813 ha Stream: 0.15 ha (1,500 m x 1 m)	Pond: 675 ha Stream: 0.15 ha (1,500 m x 1 m)

Table 10.6-3. Characterization of Candidates: Human Environment Account

Indicator	MC-25	LC-25	MC-28	LC-28	LC-34
Archaeology and Cultural Heritage					
Disturbance to known archaeological site(s) Candidates with no impacts to known archaeological sites, or impacts to fewer sites, are preferred.	There are zero known archaeological sites within the MC-25 footprint.	There are two known archaeological sites within the LC-25 footprint.	There are zero known archaeological sites within the footprint of MC-28.	There are two known archaeological sites within the LC-28 footprint.	There are two known archaeological sites within the LC-34 footprint.
Disturbance to historic sites Candidates with no impacts to known historic sites, or impacts to fewer sites, are preferred.	The two historical sites identified within the MC-25 footprint include a partly obliterated log cabin associated with Euro-Canadian or historic Native hunting and trapping dating between 1910 and the early 1940s, and a second partially collapsed cabin dating to 1936.	The three historical sites identified within the LC-25 footprint include a partially collapsed log cabin dating to before 1936, a corner of a log cabin dating to late 19th or early 20th century, and an ethno-historic hide working frame piece.	The two historical sites identified within the MC-28 footprint include a partly obliterated log cabin associated with Euro-Canadian or historic Native hunting and trapping dating between 1910 and the early 1940s, and a second partially collapsed cabin dating to 1936.	The three historical sites identified within the LC-28 footprint include a partially collapsed log cabin dating to before 1936, a corner of a log cabin dating to late 19th or early 20th century, and an ethno-historic hide working frame piece.	The three historical sites identified within the LC-34 footprint include a partially collapsed log cabin dating to before 1936, a corner of a log cabin dating to late 19th or early 20th century, and an ethno-historic hide working frame piece.
First Nations' Interests					
Cultural and/or spiritual relationship to the environment Candidates that result in less disruption to the spiritual and emotional well-being of First Nations, based on real and perceived effects, are preferred.	Small-to-moderate, irreparable impact: • MC-25 has the smallest footprint at closure (1,172 ha). A smaller footprint is more desirable. • Affected First Nations have indicated that a surface water pond at closure would cause greater disruption to spiritual and emotional wellbeing and relationship to the land; MC-25 does not include a pond at closure. • Dip Creek is 4.6 km from the TMF. Due to this distance, MC-25 is expected to have a relatively low impact on traditional travelling routes in the Dip Creek valley.	Moderate-to-major, irreparable impact: • LC-25 has a larger footprint at closure (1,540 ha). The larger footprint is less desirable. • Affected First Nations have indicated that a surface water pond at closure would cause greater disruption to spiritual and emotional wellbeing and relationship to the land; LC-25 does not include a pond at closure. • Dip Creek is 0.7 km from the TMF. Due to this distance, LC-25 has a moderate potential impact on traditional travelling routes in Dip Creek Valley.	Moderate, irreparable impact: • MC-28 has the smallest footprint at closure (1,172 ha). A smaller footprint is more desirable. • Affected First Nations have indicated that a surface water pond at closure would cause greater disruption to spiritual and emotional wellbeing and relationship to the land; MC-28 does include a pond at closure. • Dip Creek is 4.6 km from the TMF. Due to this distance, MC-28 is expected to have a relatively low impact on traditional travelling routes in the Dip Creek valley.	Moderate-to-major, irreparable impact: • LC-28 has a larger footprint at closure (1,540 ha). The larger footprint is less desirable. • Affected First Nations have indicated that a surface water pond at closure would cause greater disruption to spiritual and emotional wellbeing and relationship to the land; LC-25 does include a pond at closure. • Dip Creek is 0.7 km from the TMF. Due to this distance, LC-28 has a moderate potential impact on traditional travelling routes in Dip Creek Valley.	Moderate-to-major, irreparable impact: • LC-34 has a larger footprint at closure (1,428 ha). The larger footprint is less desirable. • Affected First Nations have indicated that a surface water pond at closure would cause greater disruption to spiritual and emotional wellbeing and relationship to the land; LC-25 does include a pond at closure. • Dip Creek is 0.7 km from the TMF. Due to this distance, LC-28 has a major potential impact on traditional travelling routes in Dip Creek Valley.
Effect on First Nations' ability to pursue land use and cultural activities Candidates with less potential to impact First Nations' ability to pursue land use and cultural activities, based on real and perceived impacts, are preferred.	Based on the footprint area, lack of pond at closure, and distance to Dip Creek travelling routes, MC-25 is expected to have a small-to-moderate potential impact on First Nations land use and cultural activities.	Based on the footprint area, lack of pond at closure, and proximity to Dip Creek travelling routes, LC-25 is expected to have a moderate-to-major potential impact on First Nations land use and cultural activities.	Based on the footprint area, presence of pond at closure, and distance to Dip Creek travelling routes, MC-28 is expected to have a moderate potential impact on First Nations land use and cultural activities.	Based on the footprint area, presence of pond at closure, and proximity to Dip Creek travelling routes, LC-28 is expected to have a moderate-to-major potential impact on First Nations land use and cultural activities.	Based on the footprint area, presence of pond at closure, and close proximity to Dip Creek travelling routes, LC-34 is expected to have a moderate-to-major potential impact on First Nations land use and cultural activities.
Sensory disturbance (noise, visual, dust) during operations Candidates with lower potential for sensory disturbance are preferred.	First Nations expect that, based on the potential dust impacts, overall sensory disturbance for land users will be moderately high.	First Nations expect that, based on the potential dust impacts, overall sensory disturbance for land users will be very high.	First Nations expect that, based on the potential dust impacts, overall sensory disturbance for land users will be high.	First Nations expect that, based on the potential dust impacts, overall sensory disturbance for land users will be very high.	First Nations expect that, based on the potential dust impacts, overall sensory disturbance for land users will be very high.
Recreational and Commercial Land Use					
Built structures Candidates with less potential to impact built structures (including camps, cabins, and water wells/withdrawal infrastructure) are preferred.	No impacted structures. MC-25 is not expected to impact the cabin on northwest hill slope of Casino Creek.	One (1) impacted structure. LC-25 is expected to impact the cabin on northwest hill slope of Casino Creek.	No impacted structures. MC-28 is not expected to impact the cabin on northwest hill slope of Casino Creek.	One (1) impacted structure. LC-28 is expected to impact the cabin on northwest hill slope of Casino Creek.	One (1) impacted structure. LC-34 is expected to impact the cabin on northwest hill slope of Casino Creek.

(continued)

Table 10.6-3. Characterization of Candidates: Human Environment Account (completed)

Indicator	MC-25	LC-25	MC-28	LC-28	LC-34
Recreational and Commercial Land Use *(cont'd)*					
Sensory disturbance (noise, visual, dust) during operations Candidates with less potential to impact aesthetics (e.g., noise, visual) for land users' enjoyment for land use and cultural activities are preferred.	Visual quality: footprint of 11.7 Mm^2 and dam height of 285 m. TMF overlaps with Casino Ck. Noise and dust (vehicles): TMF is 4.5 km from the open pit. Overall sensory disturbance is expected to be moderate.	Visual quality: footprint of 15.4 Mm^2 and maximum dam height of 200 m. TMF overlaps with Casino Ck and Brynelson Ck. Noise and dust (vehicles): TMF is 9.5 km from the open pit. Overall sensory disturbance is expected to be moderately high.	Visual quality: footprint of 11.7 Mm^2 and dam height of 285 m. TMF overlaps with Casino Ck. Noise and dust (vehicles): TMF is 4.5 km from the open pit. Overall sensory disturbance is expected to be moderate.	Visual quality: footprint of 15.4 Mm^2 and maximum dam height of 200 m. TMF overlaps with Casino Ck and Brynelson Ck. Noise and dust (vehicles): TMF is 9.5 km from the open pit. Overall sensory disturbance is expected to be moderately high.	Visual quality: footprint of 14.3 Mm^2 and maximum dam height of 205 m. TMF overlaps with Casino Ck and Brynelson Ck. Noise and dust (vehicles): TMF is 9 km from the open pit. Overall sensory disturbance is expected to be moderately high.
End Land Use					
Post-closure landscape Candidates that can be reclaimed to blend in with the surrounding landscape, are preferred.	Closure is considered to be more natural if the embankment height is lower and the closure pond is smaller, allowing it to blend in better with the surrounding landscape. In MC-25, the tailings surface is revegetated as well as the downstream face of the embankment. There are design features in place to prevent ponding and to encourage the shedding of runoff water. A wetland area will be created at the upstream end of the TMF, which will be unnatural to the area. The final embankment height is 285 m.	Closure is considered to be more natural if the embankment height is lower and the closure pond is smaller, allowing it to blend better with the surrounding landscape. In LC-25, the tailings surface is revegetated as well as the downstream face of the embankment. There are design features in place to prevent ponding and to encourage the shedding of runoff water. A wetland area will be created at the upstream end of the TMF, which will be unnatural to the area. The final embankment height is 200 m.	Closure is considered to be more natural if the embankment height is lower and the closure pond is smaller, allowing it to blend better with the surrounding landscape. In MC-28, the PAG tailings and waste rock will be flooded creating a closure pond that will have a surface are of 5.7 Mm^2 and a volume of 8.4 Mm^3. This size and type of water feature is unnatural to the area. The NAG tailings and the downstream face of the embankment will be revegetated. The final embankment height is 285 m.	Closure is considered to be more natural if the embankment height is lower and the closure pond is smaller, allowing it to blend better with the surrounding landscape. In LC-28, the PAG tailings and waste rock will be flooded and the overall surface area of the pond will be 8.1 Mm^2 and the volume will be 11.9 Mm^3. This size and type of water feature is unnatural to the area. The NAG tailings and the downstream face of the embankment will be revegetated. The final embankment height is 200 m.	Closure is considered to be more natural if the embankment height is lower and the closure pond is smaller, allowing it to blend better with the surrounding landscape. In LC-34, the PAG tailings and waste rock will be flooded creating a closure pond that will have a surface are of 6.8 Mm^2 and a volume of 10 Mm^3. This size and type of water feature is unnatural to the area. The NAG tailings, filtered stack and exposed cyclone sand embankments will be revegetated. The final embankment height is 205 m.

Table 10.6-4. Characterization of Candidates: Project Economics Account

Indicator	MC-25	LC-25	MC-28	LC-28	LC-34
TMF Economics					
Net present cost Candidates with a lower estimated NPC, as attributable to the TMF (including CAPEX and OPEX, with 8% discount rate over 22 years operation), are preferred.	$19 million	$272 million	$19 million	$280 million	$506 million

Table 10.6-5. Characterization of Candidates: Consequences of Dam Failure Account

Indicator	MC-25	LC-25	MC-28	LC-28	LC-34
Fair Weather Failure					
Volume of water (post-closure) Candidates with smaller volumes of stored water plus IDF will have less outflow volume and result in less impact to the downstream environment, and are preferred.	No stored water post-closure ($0 Mm^3$)	No stored water post-closure ($0 Mm^3$)	$8.4 Mm^3$	$11.9 Mm^3$	$10.0 Mm^3$
Dam factor (post-closure) Candidates with a lower overall dam factor will have less energy associated with a breach and result in less impact to the downstream environment, and are preferred.	No surface pond post-closure (Dam factor = 0)	No surface pond post-closure (Dam factor = 0)	$8.4 Mm^3$ x 285 m = 2,394 (though likely no discharge of water due to placement of pond and internal water retaining feature)	$11.9 Mm^3$ x 200 m = 2,380 (though likely no discharge of water due to placement of pond and internal water retaining feature)	$10.0 Mm^3$ x 205 m = 2,050 (though likely no discharge of water due to placement of pond)
Tailings deposition at Dip Creek Candidates with lower risk of creating a secondary dam outburst event through the deposited tailings are preferred.	Majority of tailings deposition is expected to occur within the Casino Creek valley; risk of creating a dam type formation is medium	Majority of tailings deposition is expected to occur within the Dip Creek valley; risk of creating a dam type formation is high	Majority of tailings deposition is expected to occur within the Casino Creek valley; risk of creating a dam type formation is medium	Majority of tailings deposition is expected to occur within the Dip Creek valley; risk of creating a dam type formation is high	Majority of tailings deposition is expected to occur within the Dip Creek valley; risk of creating a dam type formation is high
Secondary impact of dam failure (post-closure) Candidates with a lower risk for post failure drainage of void water from the waste rock are preferred. (The assumption is that dam fails down to the foundation.)	$8.6 Mm^3$	$6.5 Mm^3$	$8.6 Mm^3$	$6.5 Mm^3$	$12.7 Mm^3$
Flood-Induced Failure					
Volume of water (post-closure) Candidates with smaller volumes of stored water plus IDF will have less outflow volume and result in less impact to the downstream environment, and are preferred.	$13.4 Mm^3$	$28.6 Mm^3$	$21.8 Mm^3$	$40.5 Mm^3$	$38.6 Mm^3$
Dam factor (operations) Candidates with a lower overall dam factor will have less energy associated with a breach and result in less impact to the downstream environment, and are preferred.	(5+13.4) Mm^3 x 285 m = 5,244 (Closure pond volume of $5 Mm^3$ added to PMF volume of $13.4 Mm^3$.)	(5+28.6) Mm^3 x 200 m = 6,720 (Operating pond volume of $5 Mm^3$ added to PMF volume of $28.6 Mm^3$.)	(5+13.4) Mm^3 x 285 m = 5,244 (Closure pond volume of $5 Mm^3$ added to PMF volume of $13.4 Mm^3$.)	(5+28.6)Mm^3 x 200 m = 6,720 (Operating pond volume of $5 Mm^3$ added to PMF volume of $28.6 Mm^3$.)	(5+28.6) Mm^3 x 205 m = 6,888 (Operating pond volume of $5 Mm^3$ added to PMF volume of $28.6 Mm^3$.)
Dam factor (post-closure) Candidates with a lower overall dam factor will have less energy associated with a breach and result in less impact to the downstream environment, and are preferred.	(0+13.4) Mm^3 x 285 m = 3,819 (Closure pond volume of $0 Mm^3$ added to PMF volume of $13.4 Mm^3$.)	(0+28.6) Mm^3 x 200 m = 5,720 (Closure pond volume of $0 Mm^3$ added to PMF volume of $28.6 Mm^3$.)	(8.4+13.4) Mm^3 x 285 m = 6,213 (Closure pond volume of $8.4 Mm^3$ added to PMF volume of $13.4 Mm^3$.)	(11.9+28.6) Mm^3 x 200 m = 8,100 (Closure pond volume of $11.9 Mm^3$ added to PMF volume of $28.6 Mm^3$.)	(10+28.6) Mm^3 x 205 m = 7,913 (Closure pond volume of $10 Mm^3$ added to PMF volume of $28.6 Mm^3$.)
Tailings deposition at Dip Creek Candidates with lower risk of creating a secondary dam outburst event through the deposited tailings are preferred.	Majority of tailings deposition is expected to occur within the Casino Creek valley; risk of creating a dam type formation is medium.	Majority of tailings deposition is expected to occur within the Dip Creek valley; risk of creating a dam type formation is high.	Majority of tailings deposition is expected to occur within the Casino Creek valley; risk of creating a dam type formation is medium.	Majority of tailings deposition is expected to occur within the Dip Creek valley; risk of creating a dam type formation is high.	Majority of tailings deposition is expected to occur within the Dip Creek valley; risk of creating a dam type formation is high.
Secondary impact of dam failure (post-closure) Candidates with a lower risk for post failure drainage of void water from the waste rock are preferred. (The assumption is that dam fails down to the foundation.)	$10.0 Mm^3$	$7.0 Mm^3$	$10.0 Mm^3$	$7.0 Mm^3$	$14.6 Mm^3$

11. STEP 5: MULTIPLE ACCOUNTS ANALYSIS

The MAA is a multi-step process that draws on the characterization of the candidates (as summarized in Section 10.6) to compare and evaluate the candidates. Based on the characterization described in Table 10.6-1 through Table 10.6-5, candidates were assigned a numerical score in relation to each indicator. Separately, each account, sub-account, and indicator was weighted in terms of its importance to the decision-making process. In the analysis, the scores and weightings were combined following the calculation provided in ECCC Guidelines, resulting in weighted merit ratings for each candidate. This process, results, and sensitivity analysis is described below.

11.1 MULTIPLE ACCOUNTS LEDGER

The multiple accounts ledger provides the basis for the MAA. For each indicator, the ledger describes how the indicator is measured, summarizes the relevant information for each candidate, and identifies the means by which candidates will be scored. Table 11.1-1 provides a condensed example of the multiple accounts ledger. The completed ledger documents scores for each candidate against each indicator.

Table 11.1-1. Multiple Accounts Ledger (Example)

Sub-account	Indicator	Rationale	Parameter (unit)	Candidate			Scale	Score		
				X	Y	Z		X	Y	Z
Technical Account										
Topic A	Indicator A-1	Text describing why the indicator is important and what state is preferred	For example: Area (ha) Volume (m^3)	Describe the indicator for each candidate			1 – worst case 2 – 3 – 4 – 5 – 6 – best case	2	4	6
	Indicator A-2	… as above…								
	Indicator A-3	… as above…								
Topic B	Indicator B-1	… as above…								
	Indicator B-2	… as above…								
	Etc.									

11.2 SCORING

The "scoring" component of the MAA is designed to provide an objective, fact-based comparison of each candidate by developing scales for each indicator, and scoring each candidate against these scales. As for the characterization of candidates, the resulting scores should be objectively agreeable to all parties.

11.2.1 Indicator Scales and Scoring

CMC engaged the technical consultants previously involved in the Project Proposal to provide input into the development of meaningful and useful indicators, as described in Section 10. After the candidates were characterized—and indicators were confirmed to be differentiating—the technical experts developed appropriate scales for each indicator, and to subsequently score each candidate using this scale.

Six-Point Scales

Scales were developed for each indicator, with values ranging from one (1) to six (6). Higher scores are preferred (i.e., less adverse impact). Scales are defined to cover the range of values embodied by the remaining candidates as well as other realistically conceivable alternatives. In most cases, the end points are defined to be realistic best- and worst-case scenarios, even if these end points are beyond the bounds of the remaining candidates (i.e., the best case for habitat loss would be 'no habitat loss', regardless of whether any of the remaining candidates would result in 'no habitat loss').

Consistent with ECCC Guidelines, the six-point scales were designed to be:

- **Operational**, such that the scale should be relevant and able to accommodate any other realistically conceivable alternative that may be added at a later time;
- **Reliable**, in that different parties should arise at the same score given the same scale and background information;
- **Relevant,** to the indicator being scored; and
- **Justifiable**, so that any external party should agree that the scale is reasonable.

As there are both quantitative and qualitative indicators (Section 10.3.3), the development of scales provides a consistent approach to scoring all indicators. Examples of the six-point scales are provided in Table 11.2-1.

Table 11.2-1. Examples of Six-Point Scales for Quantitative and Qualitative Indicators

Scales for Quantitative Indicators	Scales for Qualitative Indicators
Example: Maximum surface area	Example: Operational complexity
1. 1,600 ha or more	1. High complexity
2. 1,200 to 1,599 ha	2. Moderate-high complexity
3. 800 to 1,199 ha	3. Moderate complexity
4. 400 to 799 ha	4. Low-Moderate complexity
5. 1 to 399 ha	5. Low complexity
6. 6. 0 ha (no exposed PAG surface area)	6. Simple

(continued)

Table 11.2-1. Examples of Six-Point Scales for Quantitative and Qualitative Indicators (completed)

Scales for Quantitative Indicators	Scales for Qualitative Indicators
Example: Volume of contact water	Example: Quality of affected fish habitat
1. More than 20.0 Mm^3	1. Critical habitat
2. 15.0 to 19.9 Mm^3	2. -
3. 10.0 to 14.9 Mm^3	3. Important habitat
4. 5.0 to 9.9 Mm^3	4. -
5. 0.1 to 4.9 Mm^3	5. -
6. 0 Mm3	*6.* Marginal habitat

The scales developed for this BAT study are included in the comprehensive MAA ledger (**Appendix J**), and in the summary tables in Section 11.2.2.

<u>Scoring</u>

Based on the scale for each indicator, each candidate was assigned the appropriate score, ranging from one (1) to six (6). For a given indicator, candidates with higher scores are preferred over those with lower scores. In accordance with the ECCC Guidelines, the robust and transparent characterization of each candidate supports scores that are clear and easily reproducible so that any external party would arrive at the same conclusions.

TWG Highlights 11-1. Scales and Scoring

During the MAA workshop in April 2018, and in subsequent discussions in June 2018, the working group provided a detailed review of the scales and resulting scores for each indicator. The workshop provided a forum for the TWG to engage with the technical experts involved in the MAA, and to question whether the scales appropriately captured the differences (or similarities) between the candidates. A number of scales were reconsidered and modified as a result of participants' comments, either to decrease or increase the differential between candidates.

11.2.2 Summary Tables

Table 11.2-2 provides the scales for each indicator, and resulting scores for each candidate. For brevity, Table 11.2-2 does not reproduce the characterization of each candidate (provided in Tables 10.6-1 through 10.6-5) although these characterizations are inextricably linked to the scores. The comprehensive MAA ledger, including characterization, scales, and scores, is provided in **Appendix J**.

Table 11.2-2. Indicator Scales and Scoring

Indicator	Measurement	Scale	Candidate Scores				
			MC-25	LC-25	MC-28	LC-28	LC-34
TECHNICAL ACCOUNT							
Operational Risk							
Complexity of mine waste transport	Qualitative scale	1 High complexity 2 Moderate-high complexity 3 Moderate complexity 4 Low-Moderate complexity 5 Low complexity 6 Simple	4	3	4	3	2
Complexity of operational water management	Qualitative scale	1 High complexity 2 Moderate-high complexity 3 Moderate complexity 4 Low-Moderate complexity 5 Low complexity 6 Simple	5	3	5	3	2
Complexity of closure cover	Qualitative scale	1 High complexity 2 Moderate-high complexity 3 Moderate complexity 4 Low-Moderate complexity 5 Low complexity 6 Simple	3	2	4	4	3
Complexity of embankment structure	Embankment height x crest length (m^2)	1 Higher than 1,000,000 m^2 2 800,000 to 999,000 m^2 3 600,000 to 799,000 m^2 4 400,000 to 599,000 m^2 5 200,000 to 399,000 m^2 6 Less than 200,000 m^2	3	5	3	5	4
Geochemical Stability							
ARD mitigation challenges (operations)	Maximum PAG surface area (ha)	1 1,600 ha or more 2 1,200 to 1,599 ha 3 800 to 1,199 ha 4 400 to 799 ha 5 1 to 399 ha 6 0 ha (no exposed PAG surface area)	4	3	4	3	4

(continued)

Table 11.2-2. Indicator Scales and Scoring (continued)

Indicator	Measurement	Scale		Candidate Scores MC-25	LC-25	MC-28	LC-28	LC-34
TECHNICAL ACCOUNT *(cont'd)*								
Geochemical Stability *(cont'd)*								
ARD mitigation challenges (post-closure)	Height of phreatic surface over PAG materials (m)	1 2 3 4 5 6	0.6 m or less 0.7 m to 1.2 m 1.3 m to 1.8 m 1.9 m to 2.4 m 2.5 m to 3.0 m 3.1 m or greater	2	2	6	6	6
Metal leaching potential (operations)	Total surface area (ha)	1 2 3 4 5 6	1,600 ha or more 1,200 to 1,599 ha 800 to 1,199 ha 400 to 799 ha 1 to 399 ha 0 ha (no exposed PAG surface area)	3	2	3	2	2
Metal leaching potential (post-closure)	Unsaturated NAG tailings surface area (ha)	1 2 3 4 5 6	1,600 ha or more 1,200 to 1,599 ha 800 to 1,199 ha 400 to 799 ha 1 to 399 ha 0 ha (no exposed PAG surface area)	3	2	4	4	4
Adaptability of ML/ARD mitigation strategy for early closure	Surface area of PAG waste rock above NAG tailings (ha)	1 2 3 4 5 6	1,600 ha or more 1,200 to 1,599 ha 800 to 1,199 ha 400 to 799 ha 1 to 399 ha 0 ha (no exposed PAG surface area)	5	5	5	5	5
Water Management								
Control of operational water balance	Qualitative scale	1 2 3 4 5 6	- Operational surplus expected. Treat and release may be required. - - - No operational surplus expected.	6	2	6	2	2

(continued)

Table 11.2-2. Indicator Scales and Scoring (continued)

Indicator	Measurement	Scale	Candidate Scores				
			MC-25	LC-25	MC-28	LC-28	LC-34
TECHNICAL ACCOUNT *(cont'd)*							
Water Management *(cont'd)*							
Complexity of underdrain system	Qualitative scale	1 High complexity 2 Moderate-high complexity 3 Moderate complexity 4 Low-Moderate complexity 5 Low complexity 6 Simple	5	3	5	3	2
Complexity of post-closure water management	Qualitative scale	1 High complexity 2 Moderate-high complexity 3 Moderate complexity 4 Low-Moderate complexity 5 Low complexity 6 Simple	3	2	4	3	2
Ability to implement active water treatment (post-closure)	Volume of contact water (m^3)	1 More than 20.0 Mm^3 2 15.0 to 19.9 Mm^3 3 10.0 to 14.9 Mm^3 4 5.0 to 9.9 Mm^3 5 0.1 to 4.9 Mm^3 6 0 Mm^3	4	2	4	2	2
Physical Stability							
Extent of foundation for dam(s)/ stacks	Foundation area (ha)	1 250 ha or more 2 200 to 249 ha 3 150 to 199 ha 4 100 to 149 ha 5 50 to 99 ha 6 Less than 50 ha	3	5	3	5	4
Enhanced stability (post-closure)	Qualitative Scale	1 No buttress or stack is present 2 - 3 - 4 - 5 - 6 Buttress or stack is present	1	1	1	1	6

(continued)

Table 11.2-2. Indicator Scales and Scoring (continued)

Indicator	Measurement	Scale		Candidate Scores				
				MC-25	LC-25	MC-28	LC-28	LC-34
BIOPHYSICAL ENVIRONMENT ACCOUNT								
Air Quality								
Fugitive dust emissions (TMF surface)	Area of exposed tailings (ha)	1 2 3 4 5 6	1,600 ha or more 1,200 to 1,599 ha 800 to 1,199 400 to 799 ha 1 to 399 ha 0 ha	3	2	4	4	4
TMF hauling distance	Tonnes of waste rock and distance travelled (Tonne-km)	1 2 3 4 5 6	10,000 or more 8,000 to 9,999 6,000 to 7,999 4,000 to 5,999 2,000 to 3,999 Less than 2,000	5	3	5	3	4
Groundwater								
Seepage Management (operations)	Qualitative scale	1 2 3 4 5 6	Potential for high overall seepage from the facility; implementing mitigation measures is likely challenging Potential for high overall seepage from the facility; implementing mitigation measures feasible but require greater level of effort 'Potential for moderately high overall seepage from the facility; implementing mitigation measures feasible but require greater level of effort Potential for moderate overall seepage from the facility, implementing mitigation measures feasible Potential for moderately low overall seepage from the facility; implementing mitigation measures feasible (if required) Potential for negligible overall seepage from the facility, implementing mitigation measures feasible (if required)	4	3	4	3	1

(continued)

Table 11.2-2. Indicator Scales and Scoring (continued)

Indicator	Measurement	Scale		Candidate Scores MC-25	LC-25	MC-28	LC-28	LC-34
BIOPHYSICAL ENVIRONMENT ACCOUNT *(cont'd)*								
Groundwater *(cont'd)*								
Seepage Management (post-closure)	Qualitative scale	1 2 3 4 5 6	Potential for high overall seepage from the facility; implementing mitigation measures is likely challenging Potential for moderately high overall seepage from the facility; implementing mitigation measures is likely challenging Potential for moderately high overall seepage from the facility; implementing mitigation measures feasible but require greater level of effort Potential for moderate overall seepage from the facility, implementing mitigation measures feasible Potential for moderately low overall seepage from the facility; implementing mitigation measures feasible (if required) Potential for negligible overall seepage from the facility, implementing mitigation measures feasible (if required)	5	4	4	3	2
Surface Water Quality								
Degradation of downstream water quality (operations)	Qualitative scale	1 2 3 4 5 6	- - - - Potential discharge of treated water No discharge during operations	6	5	5	5	5
Degradation of downstream water quality (post-closure)	Qualitative scale	1 2 3 4 5 6	Extreme loading to Dip Creek (i.e., observed toxic effects) High loading to Dip Creek (i.e., WQ >10x CCME) Moderate loading to Dip Creek (i.e., WQ <10x CCME) Low loading to Dip Creek (i.e., WQ <2x CCME) Minor loading to Dip Creek (i.e., WQ <80% CCME) Negligible loading to Dip Creek (i.e., WQ within 20% of median baseline)	4	3	4	3	2

(continued)

Table 11.2-2. Indicator Scales and Scoring (continued)

Indicator	Measurement	Scale		Candidate Scores				
				MC-25	LC-25	MC-28	LC-28	LC-34
BIOPHYSICAL ENVIRONMENT ACCOUNT *(cont'd)*								
Fish and Aquatic Habitat								
Extent of fish habitat loss (direct)	Habitat area affected (ha)	1	12.0 ha or more	4	3	4	3	3
		2	9.0 ha to 11.9 ha					
		3	6.0 ha to 8.9 ha					
		4	3.0 ha to 5.9 ha					
		5	0.1 ha to 2.9 ha					
		6	No overlap with fish habitat (0 ha)					
Quality of lost fish habitat (direct)	Qualitative scale	1	Critical habitat	6	3	6	3	3
		2	-					
		3	Important habitat					
		4	-					
		5	-					
		6	Marginal habitat					
Changes to surface water hydrology (operations)	Loss of flow in Dip Creek (%)	1	More than 70%	5	4	5	4	4
		2	56 to 70%					
		3	41 to 55%					
		4	26 to 40%					
		5	10 to 25%					
		6	Less than 10%					
Diversity of directly affected fish community	Number of fish species	1	5 species present	5	3	5	3	3
		2	4 species present					
		3	3 species present					
		4	2 species present					
		5	1 species present					
		6	No species present					
Diversity of directly affected benthic invertebrate community	Taxa richness (number of taxa)	1	25 or more taxa	5	4	5	4	4
		2	20 to 24 taxa					
		3	15 to 19 taxa					
		4	10 to 14 taxa					
		5	5 to 9 taxa					
		6	Less than 5 taxa					
Terrestrial Habitat								
Direct loss of wetlands	Wetland area affected (ha)	1	10 ha or more	6	6	6	6	5
		2	8 to 9 ha					
		3	6 to 7 ha					
		4	4 to 5 ha					
		5	2 to 3 ha					
		6	0 to 1 ha					

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Table 11.2-2. Indicator Scales and Scoring (continued)

Indicator	Measurement	Scale		Candidate Scores				
				MC-25	LC-25	MC-28	LC-28	LC-34
BIOPHYSICAL ENVIRONMENT ACCOUNT *(cont'd)*								
Terrestrial Habitat *(cont'd)*								
Risk of metals uptake to wildlife (plant-based)	Area of revegetated surface (ha)	1 2 3 4 5 6	2,501 ha or more 2,001 ha to 2,500 ha 1,501 to 2,000 ha 1,001 to 1,500 ha 501 to 1,000 ha Less than 500 ha	4	3	5	5	5
Risk of metals uptake to wildlife (water-based)	Area of open water (ha)	1 2 3 4 5 6	2,501 ha or more 2,001 ha to 2,500 ha 1,501 to 2,000 ha 1,001 to 1,500 ha 501 to 1,000 ha Less than 500 ha	6	6	5	5	5
HUMAN ACCOUNT								
Archaeology and Cultural Heritage								
Disturbance to known archaeolog-ical site(s)	Number of sites	1 2 3 4 5 6	5+ known archaeological sites within the footprint 4 known archaeological sites within the footprint 3 known archaeological sites are within the footprint 2 known archaeological sites within the footprint 1 known archaeological site within the footprint No known archaeological sites in the footprint	6	4	6	4	4
Disturbance to historic sites	Number of sites	1 2 3 4 5 6	5+ known historic sites within the footprint 4 known historic sites within the footprint 3 known historic sites within the footprint 2 known historic sites within the footprint 1 known historic site within the footprint No known historic sites within the footprint	4	3	4	3	3

(continued)

Table 11.2-2. Indicator Scales and Scoring (continued)

Indicator	Measurement	Scale		Candidate Scores: MC-25	LC-25	MC-28	LC-28	LC-34
HUMAN ACCOUNT *(cont'd)*								
First Nations' Interests								
Cultural and/or spiritual relationship to the environment	Qualitative scale	1 2 3 4 5 6	May result in a major and irreparable impact on spiritual or emotional wellbeing, or relationship to the environment. May result in a moderate-to-major and irreparable impact on spiritual or emotional wellbeing, or relationship to the environment. May result in a moderate and irreparable impact on spiritual or emotional wellbeing, or relationship to the environment. May result in a small-to-moderate and irreparable impact on spiritual or emotional wellbeing, or relationship to the environment. May result in a small but noticeable impact on spiritual or emotional wellbeing, or relationship to the environment. No significant disruption to spiritual or emotional wellbeing, or relationship to the environment, is expected.	4	2	3	2	2
Effect on First Nations' ability to pursue land use and cultural activities	Qualitative scale	1 2 3 4 5 6	May result in a major and irreparable impact to First Nations' land use and cultural activities. May result in a moderate-to-major and irreparable impact to First Nations' land use and cultural activities. May result in a moderate and irreparable impact to First Nations' land use and cultural activities. May result in a minor-to-moderate and irreparable impact to First Nations' land use and cultural activities. May result in a small but noticeable impact to First Nations' land use and cultural activities. No significant disruption to First Nations' land use and cultural activities is expected.	4	2	3	2	2
Sensory disturbance (noise, visual and dust) during operations	Qualitative scale	1 2 3 4 5 6	Very high sensory disturbance High sensory disturbance Moderately high sensory disturbance Moderate sensory disturbance Moderately low sensory disturbance Low sensory disturbance	3	1	2	1	1

(continued)

Table 11.2-2. Indicator Scales and Scoring (continued)

Indicator	Measurement	Scale		Candidate Scores: MC-25	LC-25	MC-28	LC-28	LC-34
HUMAN ACCOUNT *(cont'd)*								
Recreational and Commercial Land Use								
Built structures	Number of structures	1	Five or more impacted structures	6	5	6	5	5
		2	Four impacted structures					
		3	Three impacted structures					
		4	Two impacted structures					
		5	One impacted structure					
		6	No impacted structures					
Sensory disturbance (Noise, visual, dust) during operations	Qualitative scale	1	Very high sensory disturbance	4	3	4	3	3
		2	High sensory disturbance					
		3	Moderately high sensory disturbance					
		4	Moderate sensory disturbance					
		5	Moderately low sensory disturbance					
		6	Low sensory disturbance					
End Land Use								
Post-closure landscape	Qualitative scales	1	Closure features that are in stark contrast with natural landscape	5	5	3	3	3
		2	Closure features that are distinct from the natural landscape					
		3	Closure features have natural features but do not align with the surrounding natural landscape					
		4	Closure features moderately blend in with natural landscape					
		5	Closure features highly blend in with natural landscape					
		6	Closure features fully blend in with natural landscape					
PROJECT ECONOMICS ACCOUNT								
TMF Costs								
Net present cost	Cost range ($)	1	$300 million or more	6	2	6	2	1
		2	$200 to 300 million					
		3	$150 to 200 million					
		4	$100 to 150 million					
		5	$50 to $100 million					
		6	Less than $50 million					

(continued)

Table 11.2-2. Indicator Scales and Scoring (continued)

Indicator	Measurement	Scale		Candidate Scores				
				MC-25	LC-25	MC-28	LC-28	LC-34
CONSEQUENCES OF DAM FAILURE ACCOUNT								
Fair Weather Failure								
Volume of water (post-closure)	Volume (Mm^3)	1 2 3 4 5 6	40.1 Mm^3 or more 30.1 to 40.0 Mm^3 20.1 to 30.0 Mm^3 10.1 to 20.0 Mm^3 0.1 to 10.0 Mm^3 No stored water (0 Mm^3)	6	6	5	4	5
Dam factor (post-closure)	Outflow volume x dam height above bottom of breach (Mm^3 x m)	1 2 3 4 5 6	7,000 or more 5,500 to 6,999 4,000 to 5,499 100 to 3,999 - 0 to 99 (no to minimal discharge of pond water)	6	6	4	4	4
Tailings deposition at Dip Creek	Qualitative scale	1 2 3 4 5 6	High - Medium - Low -	3	1	3	1	1
Secondary impact of dam failure (post-closure)	Volume of water in exposed waste rock (Mm^3)	1 2 3 4 5 6	10.1 Mm^3 or more 7.6 to 10.0 Mm^3 5.1 to 7.5 Mm^3 2.6 to 5.0 Mm^3 0.1 to 2.5 Mm^3 0 Mm^3	2	3	2	3	1
Flood-Induced Failure								
Volume of water (post-closure)	Volume (Mm^3)	1 2 3 4 5 6	40.1 Mm^3 or more 30.1 to 40.0 Mm^3 20.1 to 30.0 Mm^3 10.1 to 20.0 Mm^3 0.1 to 10.0 Mm^3 No stored water (0 Mm^3)	4	3	3	1	2

(continued)

Table 11.2-2. Indicator Scales and Scoring (completed)

Indicator	Measurement	Scale		Candidate Scores				
				MC-25	LC-25	MC-28	LC-28	LC-34
CONSEQUENCES OF DAM FAILURE ACCOUNT *(cont'd)*								
Flood-Induced Failure *(cont'd)*								
Dam factor (operations)	Outflow volume x dam height above bottom of breach (Mm^3xm)	1 2 3 4 5 6	7,000 or more 5,500 to 6,999 4,000 to 5,499 100 to 3,999 - 0 to 99 (no to minimal discharge of pond water)	3	2	3	2	2
Dam factor (post-closure)	Outflow volume x dam height above bottom of breach (Mm^3xm)	1 2 3 4 5 6	7,000 or more 5,500 to 6,999 4,000 to 5,499 100 to 3,999 - 0 to 99 (no to minimal discharge of pond water)	4	2	2	1	1
Tailings deposition at Dip Creek	Qualitative scale	1 2 3 4 5 6	High - Medium - Low -	3	1	3	1	1
Secondary impact of dam failure (post-closure)	Volume of water in exposed waste rock (Mm^3)	1 2 3 4 5 6	10.1 Mm^3 or more 7.6 to 10.0 Mm^3 5.1 to 7.5 Mm^3 2.6 to 5.0 Mm^3 0.1 to 2.5 Mm^3 0 Mm^3	2	3	2	3	1

11.3 WEIGHTING

Weightings highlight the relevant importance of indicators, sub-accounts, and/or accounts over others. This value-based exercise recognizes that not all factors carry the same weight in the decision-making process. Different parties may apply different weightings reflective of their value systems.

CMC developed weightings in consultation with its technical consultants. Weightings are provided on a scale of one (1) to six (6), where a weight of six indicates that a criteria is six-times as important as a comparable criteria with a weight of one. Weightings are only determined relative to a criteria's peers; in other words, all indicators within a given sub-account are weighted against each other, and the indicators in a separate sub-account are considered separately. Weightings are also consistent across all candidates; in other words, a given criteria cannot be considered more or less important for one candidate compared to the others.

Weightings are value-based and inherently subjective. CMC's weightings are informed by the company's values, the TWG and CMC's technical experts. Justification for CMC's weightings is provided, with the objective that external parties will understand the logic behind CMC's weightings, even if they would weight things differently. To this end, members of the TWG were provided with the opportunity to develop their own weightings to see how the results may be different, or aligned, under different scenarios.

The following sections provide CMC's weightings.

TWG Highlights 11-2. Value-based Weightings from the TWG

CMC presented the draft results of the MAA to the TWG in June 2018, and provided an opportunity for working group members to prepare their own set of weightings to inform the analysis. CMC's weightings (described below) were also shared with the group. At the time of writing, no weightings have been received from the TWG; however, if weightings are received before the BAT study is concluded, the results will be calculated, shared, and discussed.

11.3.1 Account Weighting

Table 11.3-1 provides CMC's weightings for the five accounts. The weightings for the Technical, Biophysical Environment, and Human Environment accounts follow ECCC Guidelines. CMC elected to weight the Project Economics account lower than the Guidelines' recommended weight of 1.5, and assigned a weight of 4 to the Consequences of Dam Failure account. The Consequences of Dam Failure account is not a standard account under ECCC Guidelines, but based on TWG comments and public interest, CMC determined that it warranted a relatively high weight; however, as the design, construction, and operation of the TMF will ensure the likelihood of dam failure is very low, this account is weighted a 4, rather than a 6, as it is very unlikely to occur.

Table 11.3-1. Account Weightings (CMC)

Account	Weight
Technical	3
Biophysical environment	6
Human environment	3
Project economics	1
Consequences of dam failure	4

11.3.2 Sub-account Weightings

Table 11.3-2 provides CMC's weightings for the sub-accounts within each account. These weightings were developed by CMC in consultation with technical experts in the appropriate fields, and rationale is described below. The weightings for the Human Environment account also involved consultation with representatives of Selkirk First Nation.

Table 11.3-2. Sub-account Weightings (CMC)

Sub-account	Weight
Technical Account	
Operational risk	3
Water management	6
Geochemical stability	4
Physical stability	6

Sub-account	Weight
Human Environment Account	
Archaeology and cultural heritage	5
First Nations' interests	6
Recreational and commercial land use	1
End land use	4

Sub-account	Weight
Biophysical Environment Account	
Air quality	2
Groundwater	3
Surface water quality	5
Fish and aquatic habitat	6
Terrestrial habitat	4

Sub-account	Weight
Project Economics Account	
TMF Costs	1

Sub-account	Weight
Consequences of Dam Failure Account	
Fair weather failure	3
Flood-induced failure	4

Technical Account

The physical stability and water management sub-accounts were weighted the highest of the four categories. The long-term physical stability of the TMF is the basis for establishing long-term geochemical stability, hence the higher rating. Additionally, water management is the key driver in many of the design criteria, including determination of the IDF, collection/diversion ditches, pump/pipeline sizing and spillway sizing; hence, this indicator can have a substantive effect on many design aspects and risk profile for a given candidate.

Biophysical Environment Account

Fish and aquatic habitat is the highest-rated sub-account, as it is ultimately the downstream receptor of any changes in the quality of surface water or groundwater. Groundwater is weighted lower than surface water as downstream effects of changes in groundwater quality would arise through the surface water pathway. Terrestrial habitat is also linked to surface water quality, and weighted slightly less. Air quality is the lowest-rated sub-account as there are few air quality receptors in the vicinity of the Project due to relatively low levels of biodiversity and human presence compared to other areas in the region.

Human Environment Account

First Nations’ interests is the highest rated sub-account to reflect the value of the area to First Nations, and use of the Casino Creek catchment, Dip Creek, and surrounding valleys by First Nations. Archaeology and cultural heritage—also related to First Nations history in the area—closely follow, as does the interest of First Nations and other stakeholders in the end land use (i.e., the state and availability of the land post-closure).

Project Economics Account

As the Project Economics account has only one sub-account, the weighting of this sub-account has no effect. It is nominally appointed a weight of 1.

Consequences of Dam Failure Account

The flood-induced failure is weighted slightly higher than the fair weather failure because the former would result in more severe and wider spread consequences due to the additional volume of water present in the TMF. However, the likelihood of both scenarios is very low.

11.3.3 Indicator Weightings

Tables 11.3-3 to 11.3-7 provide CMC's weightings for the indicators within each sub-account, and the associated rationale for weightings is provided below. As for the sub-accounts, these weightings were developed by CMC in consultation with technical experts in the appropriate fields, and the Human Environment weightings also benefited from consultation with representatives of Selkirk First Nation.

Table 11.3-3. Technical Account: Indicator Weightings (CMC)

Indicator	Weight
Operational Risk	
Complexity of mine waste transport	2
Complexity of operational water management	4
Complexity of closure cover	5
Complexity of embankment structure	3

Indicator	Weight
Water Management	
Control of operational water balance	6
Complexity of post-closure water management	3
Complexity of underdrain system	2
Ability to implement active water treatment (post-closure)	6

Indicator	Weight
Geochemical Stability	
ARD mitigation challenges (operations)	1
ARD mitigation challenges (post-closure)	6
Metal leaching potential (operations)	1
Metal leaching potential (post-closure)	6
Adaptability of ML/ARD mitigation strategy for early closure	5

Indicator	Weight
Physical Stability	
Extent of foundation for dam(s)/stacks	2
Enhanced stability (post-closure)	3

Table 11.3-4. Biophysical Environment Account: Indicator Weightings (CMC)

Indicator	Weight
Air Quality	
Fugitive dust emissions (TMF surface)	2
TMF hauling distance	4

Indicator	Weight
Groundwater	
Seepage Management (operations)	2
Seepage Management (post-closure)	4

Indicator	Weight
Surface Water Quality	
Degradation of downstream water quality (operations)	4
Degradation of downstream water quality (post-closure)	5
TMF wetland requirements (post-closure)	6

Indicator	Weight
Fish and Aquatic Habitat	
Extent of fish habitat loss (direct)	5
Quality of lost fish habitat (direct)	6
Changes to surface water hydrology (operations)	5
Diversity of directly affected fish community	3
Diversity of directly affected benthic community	3

Indicator	Weight
Terrestrial Habitat	
Direct loss of wetlands	3
Risk of metals uptake to wildlife (plant-based)	5
Risk of metals uptake to wildlife (water-based)	5

Table 11.3-5. Human Environment Account: Indicator Weightings (CMC)

Indicator	Weight
Archaeology and Cultural Heritage	
Disturbance to known archaeological site(s)	6
Disturbance to historic sites	5

Indicator	Weight
Recreational and Commercial Land Use	
Built structures	2
Sensory disturbance (noise, visual, dust) - operations	1

Indicator	Weight
End Land Use	
Post-closure landscape	1

Indicator	Weight
First Nations' Interests	
Cultural and/or spiritual relationship to the environment	6
Effect on First Nations' ability to pursue land use/cultural activities	6
Sensory disturbance (Noise, visual and dust) during operations	1

Table 11.3-6. Project Economics Account: Indicator Weightings (CMC)

Indicator	Weight
TMF Costs	
Net present cost	1

Table 11.3-7. Consequences of Dam Failure Account: Indicator Weightings (CMC)

Indicator	Weight
Fair Weather Failure	
Volume of water (post-closure)	6
Dam factor (post-closure)	4
Tailings deposition at Dip Creek	3
Secondary impact of dam failure (post-closure)	3

Indicator	Weight
Flood-induced Failure	
Volume of water (post-closure)	6
Dam factor (operations)	5
Dam factor (post-closure)	5
Tailings deposition at Dip Creek	3
Secondary impact of dam failure (post-closure)	3

11.3.3.1 Technical Account

Operational Risk

The complexity of the closure cover is considered to have the greatest weighting in the Operational Risk sub-account, as the deposition of tailings in the final years of the mine operations will be key to implementing a successful closure cover for each of the candidates. Given the difference in surface areas between the ponded water versus water table closure covers, the complexity to create and maintain each type of cover varies substantively and therefore justifies the strongest weighting for this sub-account.

The complexity of operational water management indicator was also weighted relatively high in this overall sub-account, as the large differences in reporting catchment size will have an effect on the effort required to manage water operationally. The complexity of mine waste transport is ranked on the lower end in this sub-account, as the key criteria driving the differences are primarily distance and elevation for hauling waste rock and transporting tailings. Complexity of embankment structure was ranked in the middle of the sub-account, given that the structures for each of the candidates are similarly large, although there are differences in the overall height and crest length between the candidates.

Water Management

The control of operational water balance and the ability to implement active water treatment (post-closure) were weighted the highest for the water management sub-account as the differences in the volume of water between the middle and lower Casino Creek candidates is substantive, and will therefore have a big impact on each of these indicators. The other two indicators (complexity of underdrain system and complexity of post-closure water management) were weighted lower, as the differences between the various candidates were not considered substantive.

Geochemical Stability

The three indicators that were weighted the highest for the geochemical stability sub-account were ARD mitigation challenges (post-closure), metal leaching potential (post-closure) and adaptability of ML/ARD mitigation strategy for early closure. Both ARD and ML stability in the long-term (post-closure) is the key aspect for this sub-account, and thus should be weighted as the most important. The early closure adaptability indicator was also ranked high, as the challenges associated with early closure are primarily related to full implementation of the closure strategy to create long-term geochemical stability (i.e., via a water table or ponded water closure cover over the PAG tailings and waste rock).

The ARD mitigation challenges (operations) and metal leaching potential (operations) are weighted the least important, given that the onset of ARD and/or ML conditions operationally is considered a low likelihood based on the current geochemical characterization of the tailings and waste rock. Additionally, the proposed placement of materials in the facility, where they are submerged either with water or fresh tailings within a relatively short timeframe, minimize the opportunity for operational issues to arise.

Physical Stability

The indicator for enhanced stability (post-closure) was weighted only slightly higher than the indicator for extent of foundation for dam(s) / stacks, as the opportunity to have enhanced stability in the long-term only has an upside to any given candidate, and should be explored further, regardless of the candidate that is selected.

11.3.3.2 Biophysical Environment Account

Air quality

The indicator of TMF hauling distance was weighted greater than that of fugitive dust emissions as the potential impacts from a longer hauling distance are derived from both dust emissions from the road surface, as well as vehicle emissions from the waste rock haul trucks and support equipment that maintain the haul road in good working order throughout the operational life of the mine.

Groundwater

The post-closure seepage management indicator was weighted greater than that during operations, as the duration of the operating period is substantively shorter than the post-closure period. Furthermore, during operations, there is equipment and personnel on-site that can readily adjust seepage management plans based on observations, whereas during the post-closure phase, no full-time active presence is expected to remain onsite and will therefore be more challenging to implement adjustments to the seepage management plans, if required.

Surface water quality

The indicator for the TMF wetland requirements during post-closure were weighted the greatest of the surface water quality indicators, as the wetlands are key to continuous and long-term good water quality downstream of the TMF, and therefore the success of the reclamation and closure plan for the Casino Project.

Degradation of downstream water quality during post-closure was weighted slightly stronger than during operations, given the much longer duration that the post-closure phase covers compared to the relatively brief operations phase.

Fish and aquatic habitat

The quality of affected fish habitat receives the highest weight as fish habitat quality is a primary determinant of fish population and health. Related effects on hydrology (i.e., water availability and flow) and the amount of habitat affected are also highly weighted. Of less importance when comparing effects on fish and fish habitat, the ecological diversity of fish and benthic organisms are given approximately half the weight of habitat quality.

Terrestrial habitat

The risk of metal uptake to wildlife, via water or vegetation, is weighted the highest in this sub-account due to the potential implications for human health through consumption of wild game. The loss of wetlands is not unimportant, and is weighted slightly more than half the weight of metal uptake.

11.3.3.3 Human Environment Account

Archaeology and cultural heritage

Both archaeological and other historic sites and resources are highly valued in Yukon and protected under the *Historic Resources Act* and Archaeological Sites Regulation. Recognizing the scientific value of archaeological sites (in addition to historic and cultural importance), this indicator is weighted slightly higher than non-archaeological historic sites.

First Nations' Interests

In consultation with Selkirk First Nation, the indicators related to cultural/spiritual relationship to the land, and the ability to pursue activities on the land, are very highly weighted in terms of importance to First Nations. Sensory disturbance is recognized to be temporary in nature, and the degree of disturbance would vary with the individual; thus, this indicator carries the lowest weight.

Recreational and commercial land use

The presence of, and potential impact on, built structures including contemporary cabins, is weighted twice as high as potential sensory disturbance. As above, sensory disturbance is temporary in nature, and affected land users have an opportunity to move away from the disturbance to less affected areas. Structures such as cabins are fixtures on the landscape. The higher rating for structures also recognizes the effort that a land user has invested in building the structure at that site.

End land use

As the End Land Use sub-account only has one indicator, the weighting of this indicator has no effect. It is nominally appointed a weight of 1.

11.3.3.4 Project Economics Account

TMF costs

As the TMF Costs sub-account only has one indicator, the weighting of this indicator has no effect. It is nominally appointed a weight of 1.

11.3.3.5 Consequences of Dam Failure Account

Fair weather and/or flood-induced failure

The volume of water (post-closure) is weighed the highest in both cases because it is considered to be the most significant driver in a dam breach development. Together with dam height, the volume of water constitutes the dam factor, which has an important role for dam failure development and level of consequences. Because the dam factor includes the volume of water, it is given a lower weight than the volume of water alone.

The indicators for tailings deposition at Dip Creek, and the secondary impact of dam failure (in terms of discharge of interstitial water from waste rock), are considered more localized and secondary to the actual dam breach event, and are therefore weighed lower than both volume of water and dam factor.

11.4 QUANTITATIVE ANALYSIS

11.4.1 Calculations

The ECCC Guidelines provide equations by which to calculate the weighted merit ratings of each candidate based on the relevant scores and weightings. The weighted merit rating for each candidate is calculated per the calculations in Table 11.4-1.

Table 11.4-1. Merit Rating Calculations

Parameters			
Indicator score (S)	Indicator weight (W_I)	Sub-account weight (W_S)	Account weight (W_A)
Calculations			
Indicator merit score	$(S \times W_I)$		
Sub-account merit rating	$R_S = \sum(S \times W_I)/\sum W_I$	(for all indicators within the sub-account)	
Account merit rating	$R_A = \sum(R_S \times W_S)/\sum W_S$	(for all sub-accounts within the account)	
Candidate merit rating	$R_C = \sum(R_A \times W_A)/\sum W_A$	(for all accounts)	

The resulting "candidate merit rating" is a number between 1.0 and 6.0, where higher numbers indicate a greater degree of preference. The sub-account and account merit ratings can also be compared across candidates.

11.4.2 Results

Table 11.4-2 provides the overall merit ratings for each of the five remaining candidates. Ratings are shaded from yellow to green; lower ratings are shaded yellow, and higher ratings are shaded green, and darker green indicates an even higher rating. The results indicate that MC-25 has the highest merit rating (4.46) followed by MC-28 (4.15). The candidates located at Lower Casino Creek have significantly lower merit ratings.

Table 11.4-2. Candidate Merit Ratings

Candidate	Description	Merit Rating
MC-25	Middle Casino, thickened slurry NAG tailings, water table closure cover	4.46
LC-25	Lower Casino, thickened slurry NAG tailings, water table closure cover	3.09
MC-28	Middle Casino, thickened slurry NAG tailings, ponded water closure cover	4.15
LC-28	Lower Casino, thickened slurry NAG tailings, ponded water closure cover	2.98
LC-34	Lower Casino, thickened slurry and filtered NAG tailings, ponded water closure cover	2.90

Investigating the results further, Table 11.4-3 and Figure 11.4-1 show how each candidate performs in regard to each of the five accounts. Candidate MC-25 has the highest rating for all accounts except the Technical Account. MC-28 also maintains the highest or second-highest ratings for all accounts, with the exception of the Consequences of Dam Failure Account. The weighted results can be further disaggregated by sub-account, as shown in Table 11.4-4.

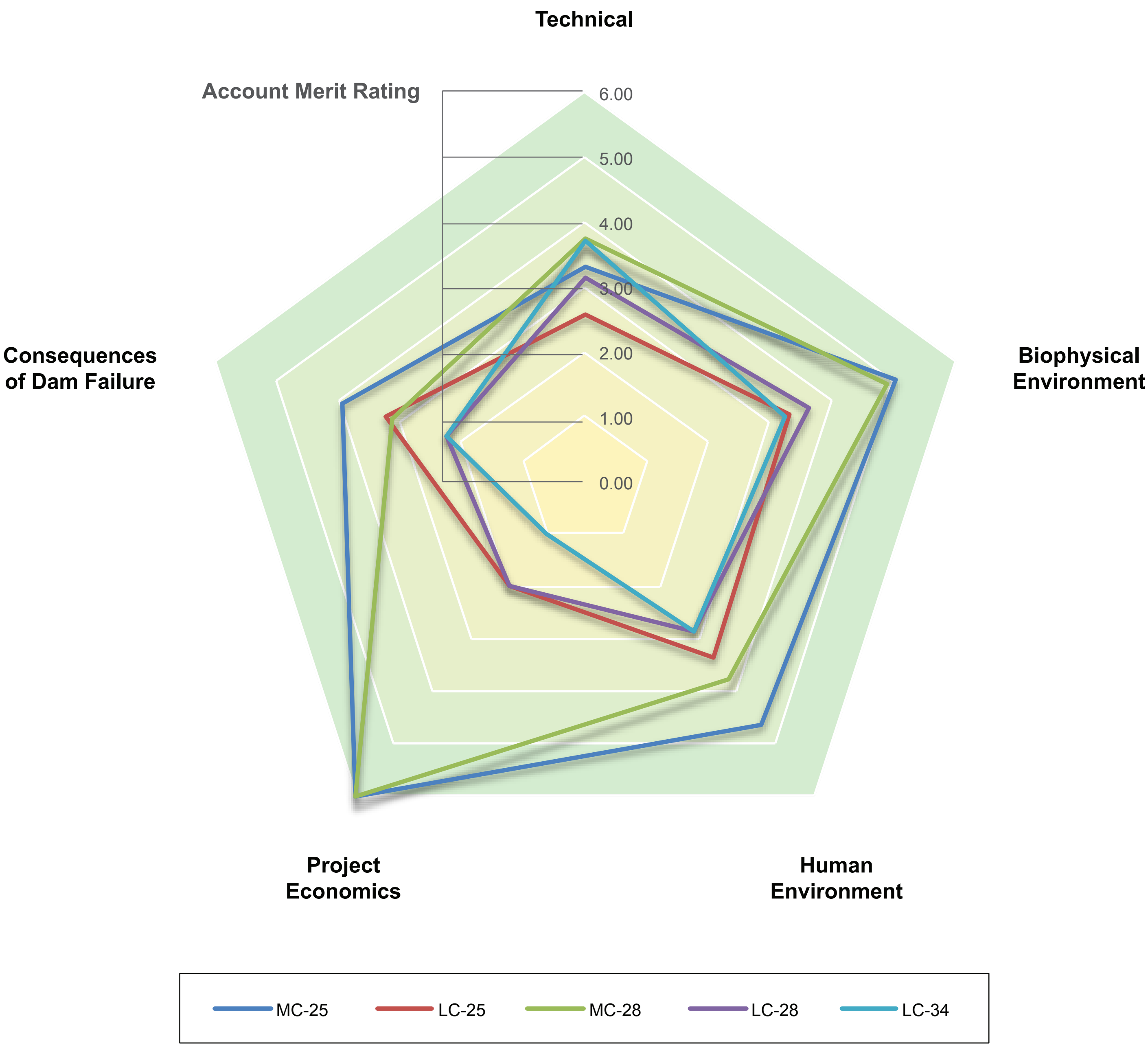
Table 11.4-3. Account Merit Ratings for Each Candidate

	Account Merit Weightings				
Candidate	Technical	Biophysical	Human	Economics	Consequences
MC-25	3.31	5.03	4.65	6.00	3.93
LC-25	2.57	3.30	3.35	2.00	3.23
MC-28	3.75	4.89	3.77	6.00	3.14
LC-28	3.14	3.62	2.85	2.00	2.25
LC-34	3.72	3.26	2.85	1.00	2.25

Considering the results, the following factors are highlighted:

- The physical stability sub-account is influenced by the presence of a filtered stack downstream of the embankment post-closure for LC-34. The filtered stack benefits stability by providing an effectively larger stabilizing buttress; this is a feature that will be investigate further for the remaining options in the FMEA (Section 12.1).
- The geochemical stability sub-account is influenced by the presence of a ponded water closure cover, to the benefit of candidates MC-28, LC-28, and LC-34.
- The biophysical environment and human environment sub-accounts are influenced by both the footprint of the facility, as well as proximity of the dam to Dip Creek. The Lower Casino candidates have a larger footprint and are closer to Dip Creek.
- The ‘end land use’ sub-account shows a strong preference for MC-25 and LC-25. This reflects feedback from representatives of Selkirk First Nation that they prefer an un-flooded closure cover as ponds and lakes are not natural water features in the area.
- Both fair weather and flood-induced dam failure scenarios benefit from the smaller upstream catchment area of the Middle Casino candidates.

Figure 11.4-1
Account Merit Ratings (Radar Chart)



Note: Higher account merit rating indicates higher preference.

Table 11.4-4. Sub-account Merit Ratings for Each Candidate

	Sub-account Merit Weightings				
Technical Account	**MC-25**	**LC-25**	**MC-28**	**LC-28**	**LC-34**
Operational risk	3.71	3.07	4.07	3.79	2.79
Geochemical stability	3.26	2.84	4.84	4.74	4.79
Water management	4.65	2.12	4.82	2.29	2.00
Physical stability	1.80	2.60	1.80	2.60	5.20
Biophysical Environment Account					
Air quality	4.33	2.67	4.67	3.33	4.00
Groundwater	4.67	3.67	4.00	3.00	1.67
Surface water quality	5.33	3.13	5.07	3.13	2.40
Fish and aquatic habitat	5.05	3.36	5.05	3.36	3.36
Terrestrial habitat	5.23	3.46	5.23	5.23	5.00
Human Environment Account					
Archaeology and cultural heritage	5.09	3.55	5.09	3.55	3.55
First Nations' interests	3.92	1.92	2.92	1.92	1.92
Recreational and commercial land use	5.33	4.33	5.33	4.33	4.33
End land use	5.00	5.00	3.00	3.00	3.00
Project Economics Account					
TMF costs	6.00	2.00	6.00	2.00	1.00
Consequences of Dam Failure Account					
Fair weather failure	4.69	4.50	3.81	3.25	3.25
Flood-induced failure	3.36	2.27	2.64	1.50	1.50

11.5 SENSITIVITY ANALYSIS

Sensitivity analyses were conducted to probe the strength of the results and identify areas where a change in weightings may significantly alter the results. Considering the results of the quantitative analysis, the objective of the sensitivity analysis is to understand possible sources of bias and subjectivity in the preceding calculations. This is achieved by changing the value-based weightings and examining the results. Although the "scores" should be fact-based and therefore not subject to variation, the weightings of accounts, sub-accounts, and indicators may vary between stakeholders and could have a significant impact on the results.

Specific sensitivity scenarios were identified in consultation with the TWG. The results are compared to the preliminary results generated by CMC, with efforts to identify areas where the value-based weightings influence the outcomes of the MAA. A total of 12 sensitivity scenarios were evaluated. Table 11.5-1 and Figure 11.5-1 summarize the results of the sensitivity analysis, and indicate that candidates MC-25 and MC-28 maintain the highest merit ratings across all scenarios.

Table 11.5-1. Sensitivity Analysis

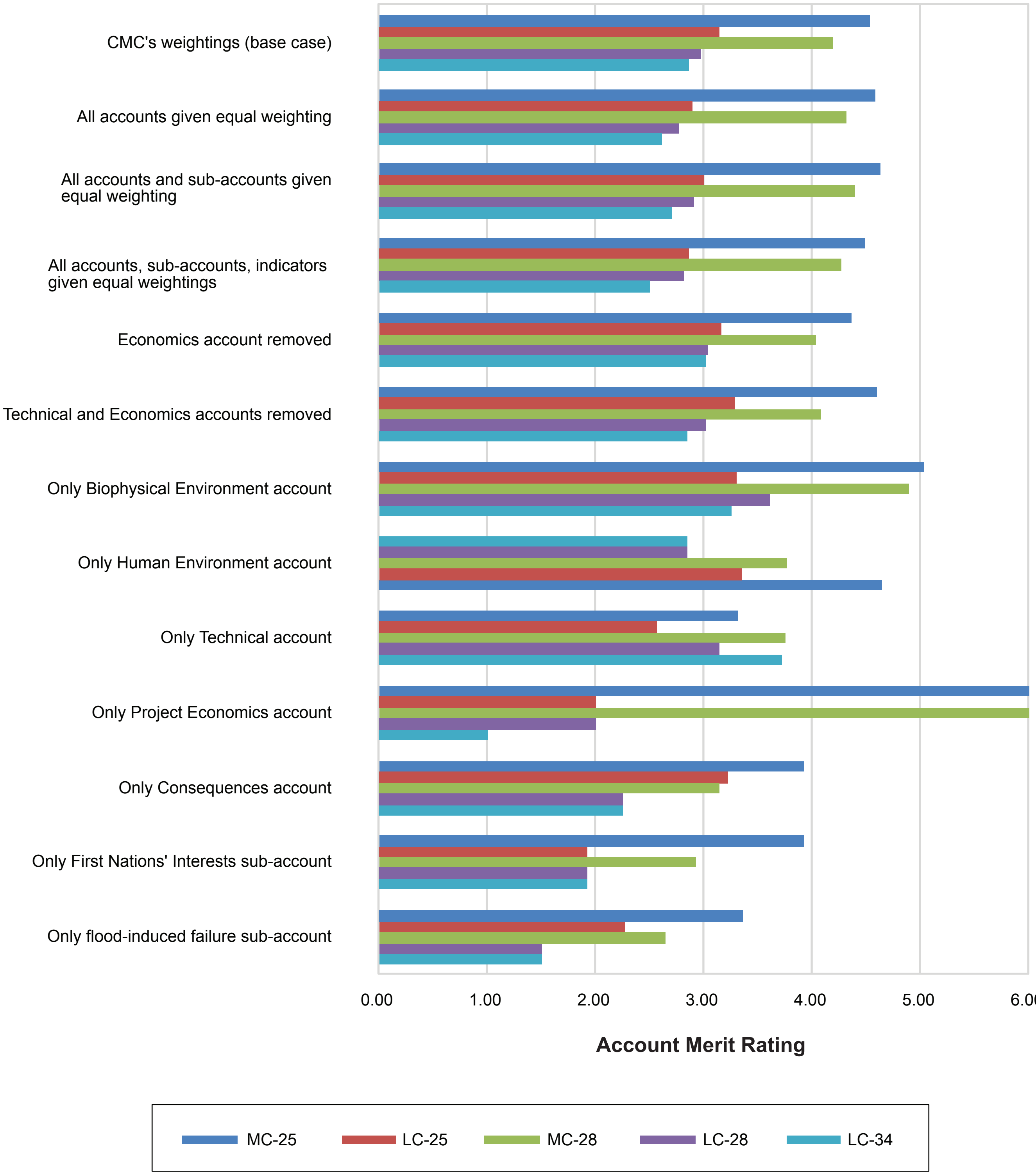
Scenario	Candidate Merit Ratings				
	MC-25	LC-25	MC-28	LC-28	LC-34
1. CMC's weightings (base case)	4.46	3.09	4.15	2.98	2.90
2. All accounts given equal weighting	4.58	2.89	4.31	2.77	2.62
3. All accounts and sub-accounts given equal weighting	4.63	3.00	4.40	2.91	2.71
4. All accounts, sub-accounts, indicators given equal weighting	4.49	2.87	4.27	2.82	2.50
5. Economics account removed	4.36	3.16	4.03	3.04	3.02
6. Technical and Economics accounts removed	4.60	3.29	4.09	3.02	2.85
7. Only Biophysical Environment account	5.03	3.30	4.89	3.62	3.26
8. Only Human Environment account	4.65	3.35	3.77	2.85	2.85
9. Only Technical account	3.31	2.57	3.75	3.14	3.72
10. Only Project Economics account	6.00	2.00	6.00	2.00	1.00
11. Only Consequences account	3.93	3.23	3.14	2.25	2.25
12. Only First Nations' Interests sub-account	3.92	1.92	2.92	1.92	1.92
13. Only flood-induced failure sub-account	3.36	2.27	2.64	1.50	1.50

11.6 Selection of Preferred Candidate(s)

Based on the results described above, including the sensitivity analysis, it is clear that the Middle Casino candidates are preferred as they have the highest ratings across all accounts and all sensitivity scenarios. However, the two Middle Casino candidates—MC-25 and MC-28—are both rated highly and, for many parameters, the difference between them is minimal. Ultimately, these two candidates have the same design and construction, and the difference lies in the closure concept: a water table closure cover (with no surface pond) is proposed for MC-25, whereas a more traditional ponded water closure cover is proposed for MC-28.

Therefore, at the end of the multiple accounts analysis, two candidates are identified as the "preferred" candidates. These candidates (MC-25 and MC-28) represent the same location, configuration, and basic design, and present two options for TMF closure. At this time, both options will be evaluated further in the FMEA (Section 12.1) and through ongoing optimization.

Figure 11.5-1
Sensitivity Analysis Results



Note: Higher account merit rating indicates higher preference.

12. STEPS 6-8: OPTIMIZATION, DESIGN, AND DOCUMENTATION

12.1 FAILURE MODES AND EFFECTS ANALYSIS

Following on the results of the MAA, as described in Section 11, the TWG was involved in the Failure Modes and Effects Analysis (FMEA) exercise designed to identify and understand the specific risks associated with the two preferred BAT candidates. As described in Section 11.5, the preferred BAT candidates represent a single alternative in terms of location, design, and configuration, but with two viable options for the TMF cover at closure (Table 12.1-1).

Table 12.1-1. Summary of Preferred BAT Candidates

Attribute	MC-25	MC-28
Location	• Middle Casino Creek	
Configuration	• Zoned storage of thickened slurry NAG and PAG tailings and waste rock behind a single embankment. • NAG tailings will be located directly upstream of embankment; waste rock located upstream of NAG tailings; and PAG tailings located within a defined cell in the waste rock storage area. • NAG tailings will be depyritized and cycloned to produce cyclone sand for embankment construction. The depyritization/cyclone circuit will run 9 months of the year (will not operate in winter) • TMF will be covered by a layer of NAG tailings in the final years of operations, during which time PAG tailings and waste rock will be backfilled to the open pit.	
Embankment	• Cyclone sand embankment (285 m high) • Centreline construction • No internal embankments separate tailings and waste rock.	
Closure Concept	Water Table: • NAG cover will be revegetated. • Water table will establish below the surface to maintain saturation of PAG materials.	Ponded Water: • NAG cover will be flooded to create a surface pond at closure.

12.1.1 Identification of Failure Modes

A risk identification workshop in June 2018 involved the participation of CMC, Knight Piésold, Lorax Environmental, ERM, and members of the TWG. During this workshop, participants identified potential modes of failure that could occur for each of the preferred candidates. Failure modes could include events related to:

- Design and engineering;
- Systems and processes;
- Implementation (including construction and operational activities);
- Monitoring and maintenance;
- Extreme weather, natural disasters and other external events;

- Human error; or
- Negligence.

Table 12.1.-2 summarizes the potential failure modes identified for the preferred BAT candidates. A total of 88 risks were identified. Many of these failure modes apply to both MC-25 and MC-28 alike; any issues unique to either option (i.e., related to closure cover) are described separately at the end of the table.

Table 12.1-2. Identification of Potential Failure Modes

No.	Phase(s)[1]				Risk Description
	C	O	CL	PC	
Embankment Stability Hazards					
1-1	x				Extreme precipitation or runoff event causing breach of construction cofferdam
1-2	x				Erosion of cofferdam due to extreme weather events resulting in sediment loading downstream and damage to construction area
1-3		x	x	x	Extreme precipitation or runoff event causing overtopping of dam resulting in loss of containment
1-4		x			Early Mine Life: Extreme precipitation or runoff event causing overtopping of dam resulting in loss of containment.
1-5		x	x	x	Foundation failure: foundation movement resulting in embankment deformation with loss of containment
1-6	x	x			Foundation conditions are not as expected
1-7		x	x	x	Extreme seismic activity: large earthquake resulting in embankment deformation and/or tailings liquefaction with loss of containment
1-8	x				Extreme seismic activity during construction causes deformation of starter dam with loss of containment
1-9		x	x	x	NAG mischaracterization: phreatic surface is higher than expected, resulting in pore pressure increase ultimately resulting in embankment deformation and loss of containment
1-10		x	x	x	Underdrain system fails to perform: phreatic surface is higher than expected, resulting in pore pressure increase ultimately resulting in embankment deformation and loss of containment
1-11		x	x	x	Embankment failure caused by piping
1-12		x			Instability of waste rock
1-13	x	x			Poor construction practices resulting in embankment deformation
Tailings Characterization Hazards					
2-1		x	x		Pyrite circuit not effective (sub-optimal sulphide removal), leading to greater than anticipated volumes of PAG tailings generated over life of mine
2-2		x			Pyrite circuit not effective (sub-optimal sulphide removal), leading to off-spec NAG cyclone sand that is placed in TMF shell
2-3	x	x	x	x	NAG tailings permeability: higher than anticipated seepage rate allows for drainage of NAG layer/closure pond

(continued)

Table 12.1-2. Identification of Potential Failure Modes (continued)

No.	Phase(s)[1]				Risk Description
	C	O	CL	PC	
Closure-Related Hazards					
3-1			x		Premature permanent closure of the mine requires modified closure plan
3-2			x		Temporary closure (care and maintenance [C&M]): accumulation of water during C&M, requiring management
3-3				x	Failure to perform post-closure monitoring and maintenance as prescribed
3-4			x		Unplanned mill shutdown causes temporary closure
3-5	x	x			Erosion of embankment surface
3-6			x	x	Erosion of embankment surface
3-7			x	x	Spillway: blockage of spillway by ice, debris, and/or sediment
3-8			x	x	Spillway: erosion of spillway
Water Management Hazards					
4-1	x				Water balance modelling underestimates water volumes, resulting in unexpected surplus of water
4-2		x			Water balance modelling underestimates water volumes, resulting in unexpected surplus of water
4-3	x				Water balance modelling overestimates water volumes, resulting in unexpected deficit of water
4-4		x			Water balance modelling overestimates water volumes, resulting in unexpected deficit of water
4-5		x	x	x	Higher than anticipated embankment seepage (volume and/or quality) reports to downstream environment and causes a material impact on water quality
4-6				x	Closure seepage management/treatment system does not function as designed
Mine Site Infrastructure Hazards					
5-1		x			NAG Tailings pipeline failure between mill site and TMF discharge points resulting in an uncontrolled tailings discharge
5-2		x			PAG Tailings pipeline failure between mill site and TMF discharge points resulting in an uncontrolled tailings discharge
5-3		x			Failure of tailings distribution line on tailings dam resulting in release of tailings and embankment erosion
5-4		x			Physical LGO stockpile failure into the TSF, resulting in a seiche
5-5		x			LGO stockpile contact water and seepage flows into the TSF
5-6		x			Physical heap leach failure into the TSF
5-7		x			Failure of heap leach liner system allows contact water and cyanide solution into the TSF
5-8		x	x		Exceedance of downstream water management pond and pumpback systems leads to discharge
Mine Operation Hazards					
6-1	x				Inadequate construction materials available to meet starter dam fill requirements
6-2		x			Inadequate construction materials available to meet staging requirements
6-3		x			Operations not responding to changes at the site resulting in inadequate tailings pond capacity and unplanned discharge to receiving streams

(continued)

Table 12.1-2. Identification of Potential Failure Modes (continued)

No.	Phase(s)[1]				Risk Description
	C	O	CL	PC	
6-4	x				Ponding on tailings dam crest or downstream shell: erosion of dam fill leading to localized scour of slopes
6-5	x	x	x		Labour disruptions
6-6	x				Extreme weather events resulting in construction schedule delays
6-7		x			Extreme weather events causes delays
6-8	x	x	x		Change in design standards and codes requires updated design criteria and responsive action
6-9	x	x			Unplanned change of Engineer of Record or owner
6-10		x			ML/ARD generation rate higher than anticipated, requires remedial action prior to closure
6-11		x			PAG and Hypogene waste rock go acidic before submergence
6-12			x		Temporary closure (C&M): waste rock submergence
6-13		x	x	x	Waste rock goes acidic despite submergence
6-14	x	x			Specification of embankment construction material does not meet design criteria
6-15					Inability to form beaches as designed, leading to larger than expected water volumes close to embankment
6-16		x			Inability to manage gradients as designed
6-17		x			Ice entrainment in tailings slurry leads to faster rate-of-rise than anticipated
6-18		x			Displacement of PAG tailings when placing NAG cover
6-19			x		Early permanent closure as a result of bankruptcy
Hazards Specific to MC-25 (i.e., water table closure cover)					
7-1			x		Failure to perform closure monitoring and maintenance as prescribed
7-2				x	Closure cap permeability greater than anticipated, allowing oxidation of PAG tailings and waste rock
7-3			x		Erosion of NAG cover leads to sediment/NAG transport, hindering ability to achieve closure objectives
7-4				x	Erosion of NAG cover leads to sediment/NAG transport to downstream environments
7-5				x	Erosion of NAG cover leads to exposure and oxidation of PAG and waste rock
7-6				x	Erosion of NAG cover leads to topography changes of facility
7-7				x	Consolidation of PAG and/or NAG tailings exceeds predictions and leads to ponding on closure cover
7-8				x	TMF basin seepage rates higher than anticipated, prevents closure cover from remaining saturated and allowing oxidation of PAG tailings and waste rock
7-9				x	Frostjacking damages closure cap, allowing oxygen infiltration
7-10				x	Landslide into pit causes displacement wave to TMF
7-11				x	Pit water quality more adverse than expected
7-12			x		Inability to meet revegetation targets during closure phase
7-13			x		Water balance modelling underestimates water volumes, resulting in unexpected surplus of water

(continued)

Table 12.1-2. Identification of Potential Failure Modes (completed)

No.	Phase(s)[1]				Risk Description
	C	O	CL	PC	
7-14				x	Water balance modelling underestimates water volumes, resulting in unexpected surplus of water
7-15			x		Water balance modelling overestimates water volumes, resulting in unexpected deficit of water
7-16				x	Water balance modelling overestimates water volumes, resulting in unexpected deficit of water
Hazards Specific to MC-28 (i.e., ponded water closure cover)					
8-1			x		Failure to perform closure monitoring and maintenance as prescribed
8-2				x	Climate change affects ability to maintain pond size
8-3				x	Water quality in tailings pond not adequate to discharge to receiving streams during closure/post closure
8-4				x	Higher than anticipated seepage rates increase embankment pore pressure, leading to instability, deformation, and loss of containment
8-5				x	TMF basin seepage rates higher than anticipated, facilitating drainage of the closure pond and allowing oxidation of PAG tailings and waste rock
8-6			x		Erosion of NAG beach leads to sediment/NAG transport hindering ability to achieve closure objectives
8-7				x	Erosion of NAG beach leads to sediment/NAG transport to downstream environments
8-8				x	Erosion of NAG beach leads to expansion of flooded cover towards embankment
8-9				x	Landslide into pit causes displacement wave to TMF
8-10				x	Pit water quality more adverse than expected
8-11			x		Inability to meet revegetation targets at closure
8-12			x		Water balance modelling underestimates water volumes, resulting in unexpected surplus of water
8-13				x	Water balance modelling underestimates water volumes, resulting in unexpected surplus of water
8-14			x		Water balance modelling overestimates water volumes, resulting in unexpected deficit of water
8-15				x	Water balance modelling overestimates water volumes, resulting in unexpected deficit of water

Note: (1) Phases include construction (C), operations (O), closure (CL) and post-closure (PC)

12.1.2 Risk Assessment

For each of the failure modes identified in Table 12.1-2, the TWG then assessed the likelihood that the event will occur, and the consequence if it does occur, to provide an overall risk rating for the failure mode. Tables 12.1-3 and 12.1-4 define the criteria used to determine likelihood and consequence, respectively. For likelihood, an option to determine the "confidence in data" was included to account for scenarios where there were insufficient data by which to gauge likelihood.

Table 12.1-3. Definition of Likelihood

Score	Likelihood		Confidence in Data
	Certainty	Expected Frequency	
1	Very rare: Highly unlikely, but it may occur in exceptional circumstances. It could happen, but probably never will.	Less than 1 event per 10,000 years	Highly confident: have good data to support predictions
2	Unlikely: Not expected, but there is a slight possibility it may occur at some time.	Less than 1 event per 1,000 years	Confident
3	Possible: The event might occur at some time as there has been a similar event in the last couple decades at similar facilities.	Less than 1 event per 100 years	Moderately confident
4	Likely: There is a strong possibility the event will occur, as occurrences in similar facilities are not uncommon.	Less than 1 event per 20 years (i.e. within mine life)	Low confidence
5	Almost certain: There is a history of regular occurrence in similar facilities.	1 event per year	Very low confidence: do not have necessary data to support predictions

Note: If likelihood cannot be determined based on the available data, the confidence criteria are used to determine the score.

For each of the identified failure modes, the likelihood and consequence were rated in the FMEA risk register (**Appendix K**). The score for likelihood was multiplied by the highest applicable score for consequence to determine the risk rating for the failure mode. Risk ratings can range from 1 to 25, and are classified on a scale from "very low" to "very high" in accordance with Table 12.1-5. Once all ratings have been developed, they are placed on a heat map to demonstrate how many failure modes are in each category. Table 12.1-5 is an example of the heat map.

The priority failure modes—i.e., those identified as medium, high, or very high—are summarized in Table 12.1-6. There were no risks identified as very high. These risks will be the focus of mitigation and management measures to optimize the design and reduce the overall level of risk.

Differentiating MC-25 and MC-28

The FMEA highlighted the difference in closure cover of the remaining candidates during closure and post-closure. The water table closure concept presented for MC-25 does not involve a surface water pond. Risks primarily relate to the ability to maintain saturation and avoid oxidation of PAG tailings and waste rock in the post-closure phase. This includes uncertainty about the permeability of the closure cover and seepage rates, which could result in an overestimation of water volume and an unexpected deficit of water. Potential erosion of the NAG cover at the surface, including erosion as a result of low revegetation success, could also lead to exposure and oxidation of PAG materials.

The closure concept for MC-28 involves a pond on the surface of the TMF. Compared to MC-25, the closure pond provides a more conventional means of maintaining saturation of PAG materials in the post-closure phase. However, use of a flooded cover is associated with risks of embankment instability and potential loss of containment. Higher than expected seepage rates could also lead to pond drainage and subsequent oxidation of PAG materials.

Table 12.1-4. Definition of Consequence

Rating / Descriptor	Description[1]									
	Environmental Impact			Health & Safety		Economic Impact				
	Magnitude	Geographic Extent	Duration	Human Safety	Population at Risk	Production Delay	Financial Costs (C-O-CL)	Financial Costs (PC)	Human Use of Lands and Resources	Reputational, Legal, or Regulatory Risk
1. Negligible	Effect is contained within previously disturbed areas with no significant loss or deterioration of fish or wildlife habitat.	Effects are contained within the TMF	Days: Baseline conditions will be re-established in a few days with standard reclamation / restoration measures.	Minor Injuries or near miss	None	<1 day	<$0.5M	<$0.5M	Land and natural resources (including water, fish, wildlife, plants, trails, campsites, etc.) continue to be accessible, available, and safe for use and consumption.	• No media or regulatory attention. • Any concern limited to site personnel.
2. Minor	Loss of marginal habitat but no significant loss or deterioration of fish or wildlife habitat. In-kind habitat restoration or compensation is very possible.	Effects are contained within Casino mine site footprint	Weeks: Habitat function can be re-established within a few weeks to months.	First aid case	Irregular land users, no residents	1 day to 1 week	$0.5M - $5M	$0.5M - $2M	Affected lands and natural resources can be remediated in the short-term, and made accessible, available, and safe for use and consumption; long-term monitoring is not required.	• Local media attention. • Potential letter of variance. • Minor breach of regulation.
3. Serious	Significant loss or deterioration of fish or wildlife habitat. In-kind habitat restoration or compensation is very possible.	Effects are contained within Casino Creek watershed	Months: Habitat function can be re-established within a year	Significant injury resulting in lost time	Regular land users, no residents	1 week to 1 month	$5M - $25M	$2M - $10M	Affected lands and natural resources can be remediated but require monitoring to ensure they are safe for use; return to safe use and consumption will be delayed (up to 1 year) until monitoring results are satisfactory; perceived effects may alter land and resource use/consumption, even if safety is proven.	• Report to board, shareholder concerns. • Adverse media coverage. • Prosecution and/or moderate fine possible. • Serious breach of regulation with investigation or report to authority.
4. Critical	Significant loss or deterioration of critical fish or wildlife habitat. In-kind habitat restoration or compensation is difficult and success may vary.	Effects reach Dip Creek	Years: Habitat function is expected to be re-established within a few years	Serious injuries resulting in extended loss time	Frequent land users, no residents	1 month to 6 months	$25M - $100M	$10M - $25M	Affected lands and natural resources can be remediated in the long-term but will require ongoing monitoring to verify they are safe for use and consumption; access, use and consumption will be restricted for more than a year. Perceived effects may also exacerbate changes in land use.	• Board involved. • Significant loss of shareholder support. • Adverse media coverage. • Major litigation. • Major breach of regulation.
5. Catastrophic	Major, significant loss of critical fish or wildlife habitat. In-kind habitat restoration or compensation is impossible.	Effects reach Klotassin River	Permanent: Habitat function can not be re-established.	Single or multiple fatalities or injury resulting	Populated area with permanent residents	>6 months	>$100 M	>$25M	Affected lands and natural resources cannot be made accessible or safe for use; use and consumption will be restricted indefinitely. Perceived effects may also exacerbate changes in land use.	• Significant loss of shareholder support. • Adverse media coverage and major public concerns. • Very serious litigation, including class actions. • Government inquiry, significant fines and prosecution.

Note: (1) Consequence rating is determined by the description with the highest rating.

Table 12.1-5. FMEA Risk Classification

	1	2	3	4	5
5					Very high
4				High	
3			Medium		
2		Low			
1	Very low				

Table 12.1-6. Priority Failure Modes (Medium and High)

No.	Phase(s)[1]				Risk Description	Comments
	C	O	CL	PC		
Risk Classification: High						
1-9		x	x	x	NAG mischaracterization: phreatic surface is higher than expected, resulting in pore pressure increase ultimately resulting in embankment deformation and loss of containment	Assumes instrumentation is installed during construction and monitored in accordance with OMS plans
1-10		x	x	x	Underdrain system fails to perform: phreatic surface is higher than expected, resulting in pore pressure increase ultimately resulting in embankment deformation and loss of containment	
1-11		x	x	x	Embankment failure caused by piping	
2-2		x			Pyrite circuit not effective (sub-optimal sulphide removal), leading to off-spec NAG cyclone sand that is placed in TMF shell	Sensitivity will be highly dependent on ore type. May need to increase sampling frequency, or not cyclone, for some ore types
2-3		x			NAG tailings permeability: higher than anticipated seepage rate allows for drainage of NAG layer/closure pond	Consequence: degraded water quality downstream
3-1			x		Premature permanent closure of the mine requires modified closure plan	Current staging plan has waste rock and PAG tailings situated at higher elevations than embankment during early mine life, so remobilization of waste rock and PAG tailings may be required
3-2			x		Temporary closure (C&M): accumulation of water during C&M, requiring management	Design does not include spillway during operations (i.e., water management implications) Risk assumes that temporary closure does occur (5 years C&M, no pit available for storage, WT required)

(continued)

Table 12.1-6. Priority Failure Modes (Medium and High; continued)

No.	Phase(s)[1] C	O	CL	PC	Risk Description	Comments
6-19			x		Early permanent closure as a result of bankruptcy	Rely on government to take over closure
7-2				x	MC25 - Water table closure cover permeability greater than anticipated, allowing oxidation of PAG tailings and waste rock	Potential causes include mis-characterization of NAG cover, or degradation of NAG cover due to cryo processes, vegetation etc.
7-4				x	MC25 - Erosion of NAG cover leads to sediment/NAG transport to downstream environment	
7-6				x	MC25 - Erosion of NAG cover leads to topography changes of facility	Channel development, ponding on surface, drainage affected
7-9				x	MC25 - Frostjacking damages water table closure cover, allowing oxygen infiltration	Effects of frost penetration have not been studied to date Frostjacking has potential to bring waste rock chunks to surface (similar to stone rings and frost boils observed in nature)
8-4				x	MC28 - Higher than anticipated seepage rates increase embankment pore pressure, leading to instability, deformation, and loss of containment	
Risk Classification: Medium						
1-1	x				Extreme precipitation or runoff event causing breach of construction cofferdam	Cofferdam in place for ~2 years. Plan for at least 1/100 or 1/200-year event.
1-2	x				Erosion of cofferdam due to extreme weather events resulting in sediment loading downstream and damage to construction area	Similar to (1-1), but lesser consequence
1-6	x	x			Foundation conditions are not as expected	Geotechnical investigations conducted, with additional investigations recommended by IERP for ongoing design
1-13	x	x			Poor construction practices resulting in embankment deformation	Includes both human error and willful disregard for design
2-1			x	x	Pyrite circuit not effective (sub-optimal sulphide removal), leading to greater than anticipated volumes of PAG tailings generated over life of mine	20% PAG estimate is designed to be conservative, but by how much is unconfirmed
3-3				x	Failure to perform post-closure monitoring and maintenance as prescribed	
3-4			x		Unplanned mill shutdown causes temporary closure	
3-6			x	x	Erosion of embankment surface	

(continued)

Table 12.1-6. Priority Failure Modes (Medium and High; continued)

No.	Phase(s)[1]				Risk Description	Comments
	C	O	CL	PC		
3-7			x	x	Spillway: blockage of spillway by ice, debris, and/or sediment	
4-5		x	x	x	Higher than anticipated embankment seepage (volume and/or quality) reports to downstream environment and causes a material impact on water quality	Water table of tailings in impoundment is maintained Assumes seepage exceeds design capacity of downstream seepage collection system
4-6				x	Closure seepage management/treatment system does not function as designed	Downstream seepage collection and treatment.
5-8		x	x		Exceedance of downstream water management pond and pumpback systems leads to discharge	
6-2		x			Inadequate construction materials available to meet staging requirements.	• Cyclone sand operations account for challenges to place sand during cold weather • Generating and stockpiling sand during winter considered feasible, and will be evaluated during next phase of design • Tailings characteristics change or are not as expected
6-3		x			Operations not responding to changes at the site resulting in inadequate tailings pond capacity and unplanned discharge to receiving streams	• Site changes could include: Design tailings dry density cannot be achieved, unexpected variations in climate, etc. • Grind size/thickening not achieved as intended • Assumes treat and release measures not in place
6-5	x	x	x		Labour disruptions	
6-8		x			Change in design standards and codes requires updated design criteria and responsive action	BC Mine Code update as example, drives forward-thinking design
6-10		x			ML/ARD generation rate higher than anticipated, requires remedial action prior to closure	Issue: incorrect prediction of ML/ARD generation Magnitude of error considered inversely proportional to Likelihood
6-15		x			Inability to form beaches as designed, leading to larger than expected water volumes close to embankment	Relates to ability to move water towards back of impoundment
6-16		x			Inability to manage gradients as designed	Solids and water gradients are based on material characteristics and volume balances
7-1			x		MC25: Failure to perform closure monitoring and maintenance as prescribed	

(continued)

Table 12.1-6. Priority Failure Modes (Medium and High; continued)

No.	Phase(s)[1] C	O	CL	PC	Risk Description	Comments
7-3			x		MC25: Erosion of NAG cover leads to sediment/NAG transport, hindering ability to achieve closure objectives	
7-5				x	MC25: Erosion of NAG cover leads to exposure and oxidation of PAG and waste rock	Spillway invert above PAG and waste rock by >2 m
7-8				x	MC25: TMF basin seepage rates higher than anticipated, prevents closure cover from remaining saturated and allowing oxidation of PAG tailings and waste rock	Confidence related to foundation conditions and predicted permeabilities through tailings and waste rock mass
7-10				x	MC25: Landslide into pit causes displacement wave to TMF	Assumes significant enough volume of water displaced to cause material damage to closure cover
7-11				x	MC25: Pit water quality more adverse than expected	Issue: incorrect prediction of ML/ARD generation • Magnitude of error considered inversely proportional to Likelihood • Mitigation options more favorable than general ML/ARD incorrect prediction as water source is isolated
7-12			x		MC25: Inability to meet revegetation targets during closure phase	Forces extension of closure phase until objectives met; assumes no surface discharge downstream due to active seepage and sediment management during closure • Erosion effects caused by lack of vegetation covered under 7-4 to 7-6
7-15			x		MC25: Water balance modelling overestimates water volumes, resulting in unexpected deficit of water	• Considers climate change • Assumes that if left unchecked leads to desaturation of NAG cover • Requires significant change in closure concept to address
7-16				x	MC25: Water balance modelling overestimates water volumes, resulting in unexpected deficit of water	• Considers climate change • Assumes issue manifests during PC phase • Considers additional data collection during O/CL phases • Assumes issue is not addressed until adverse downstream effects are observable
8-1			x		MC28: Failure to perform closure monitoring and maintenance as prescribed	

(continued)

Table 12.1-6. Priority Failure Modes (Medium and High; completed)

No.	Phase(s)[1] C	O	CL	PC	Risk Description	Comments
8-2				x	MC28:Climate change affects ability to maintain pond size	• Assumes O/CL phase climate data collection • Assumes PAG/waste rock becomes unsaturated leading to ML/ARD • Likelihood of occurrence lesser than for MC-25 option
8-3				x	MC28: Water quality in tailings pond not adequate to discharge to receiving streams during closure/post closure	Assumes perpetual treatment of supernatant water required
8-5				x	MC28: TMF basin seepage rates higher than anticipated, facilitating drainage of the closure pond and allowing oxidation of PAG tailings and waste rock	Confidence related to foundation conditions and predicted permeabilities through tailings and waste rock mass
8-8				x	MC28: Erosion of NAG beach leads to expansion of ponded water cover towards embankment	Assumes that erosion is mitigated prior to risk of embankment failure developing
8-9				x	MC28: Landslide into pit causes displacement wave to TMF	
8-10				x	MC28: Pit water quality more adverse than expected	Issue: incorrect prediction of ML/ARD generation • Magnitude of error considered inversely proportional to Likelihood • Mitigation options more favorable than general ML/ARD incorrect prediction as water source is isolated
8-11			x		MC28: Inability to meet revegetation targets at closure	
8-14			x		MC28: Water balance modelling overestimates water volumes, resulting in unexpected deficit of water	Considers climate change leads to net evaporation state Requires significant change in closure concept to address
8-15				x	MC28: Water balance modelling overestimates water volumes, resulting in unexpected deficit of water	• Considers climate change • Assumes issue manifests during PC phase, and that issue is not addressed until adverse downstream effects are observable • Considers additional data collection during O/CL phases • Assumes that if left unchecked leads to net evaporation state in TMF with eventual desaturation of NAG cover

Note: (1) Phases include construction (C), operations (O), closure (CL) and post-closure (PC)

12.2 NEXT STEPS

The outcomes of the FMEA risk identification and assessment process, and input from the TWG to date, will be the focus of the next steps of the TMF engineering and design. TMF design updates will reflect current state of practice, including industry standards from organizations such as the International Commission on Large Dams (ICOLD), and MAC, and, the TMF design, construction, operation and closure will receive senior level oversight from the IERP.

Complementary to the design modifications developed to address the priority risks from the FMEA, CMC will identify BAP and other measures that apply to the TMF and that will further reduce risk and ensure that the Project will be constructed, operated, closed, and reclaimed in accordance with the intended design. Management measures will be aligned with good international industry practice, applicable laws and regulations, and the principles and outcomes of this BAT study. The development of BAP and risk management measures comprises Step 7 of this BAT study, and will be undertaken following the design refinements detailed above.

The updated design will be included in CMC's ESE Statement, including BAP and other elements identified through this BAT study and in consultation with the TWG. Some of the concepts developed over the course of this BAT study, which will be further examined in the next stage of design, include:

- Producing cyclone sand year-round to effectively reduce the volume of NAG tailings that will be stored within the impoundment;
- Inclusion of a cyclone overflow thickener circuit to reduce the circulating water volumes in the TMF and to provide a thickened cyclone overflow product to be impounded instead of a low density slurry. The cyclone overflow thickener circuit provides more positive water management capability;
- Achieving a NAG tailings elevation at the embankment that is higher than the PAG tailings as quickly as possible; and
- Backfill of waste rock in the pit in the final years of mine operations to reduce the storage requirements in the TMF.

13. CONCLUSIONS

The results of the BAT study confirm that the Middle Casino site is the preferred site for the TMF, and that the preferred configuration involves zoned storage of thickened slurry NAG and PAG tailings and waste rock behind a single embankment, with:

- NAG tailings located directly upstream of embankment;
- Waste rock located upstream of NAG tailings; and
- PAG tailings located within a defined cell within the waste rock storage area.

NAG tailings will be depyritized and cycloned to produce cyclone sand for the TMF embankment. The cyclone (depyritization) circuit is currently planned to run nine months of the year (i.e., cycloning will be suspended in winter), but CMC will investigate the feasibility of running the cyclone circuit year-round and to stockpile sand over the winter to be reclaimed and placed on the dam shell during the summer months.

In the final years of mine operations, the TMF will be covered by layer of NAG tailings, during which time PAG tailings and waste rock will be backfilled to the open pit. Two viable closure options are identified in this BAT study: a water table closure cover, wherein the surface of the TMF would be revegetated, or a ponded water closure cover. CMC will continue to evaluate these options over the next stages of design.

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