Klohn Crippen Berger

65 years of service

Seabridge Gold Inc.

KSM Project

Best Available Technology (BAT) Study for Tailing Management at the KSM Project

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ISO 9001
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June 2016

Klohn Crippen Berger
65 years of service

June 22, 2016

Seabridge Gold Inc.
106 Front Street East, Suite 400
Toronto, Ontario
M5A 1E1

Peter Williams
Senior VP, Technical Services

Dear Mr. Williams:

KSM Project
Best Available Technology (BAT) Study for Tailing Management at the KSM Project

Klohn Crippen Berger Ltd. is pleased to submit our Best Available Technology (BAT) Study for tailing management at the KSM Project. The study includes an assessment of available technologies and also reviews locations of the potential tailing management facilities for various technology alternatives. The report includes a recommendation of the most appropriate tailing management strategy for the KSM Project.

This study is an update on the Assessment of Alternatives for KSM Project Tailing Management Facility specifically looking at alternative tailing technologies and incorporates inputs from Seabridge Gold Inc., the KSM Project Independent Geotechnical Review Board and other consultants.

Please contact the undersigned if you have any questions or require any further assistance.

Yours truly,

KLOHN CRIPPEN BERGER LTD.

Kate Patterson, M.Eng., P.Eng.
Project Manager

KP:jcp/dl

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Seabridge Gold Inc.

KSM Project

Best Available Technology (BAT) Study for Tailing Management at the KSM Project

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EXECUTIVE SUMMARY

Seabridge Gold Inc. (Seabridge) is proposing the gold-copper KSM Project located in north-western British Columbia (BC). The project plan estimates 130,000 tonnes per day of ore will be processed over the life of the project of approximately 51.5 years. The total quantity of tailing produced by the mine is estimated to be up to 2.3 billion tonnes. Two tailing streams will be produced by the plant: the bulk Non-Potentially Acid Generating (NPAG) flotation tailing representing approximately 90% of the total tailing (by dry weight) and a fine, Potentially Acid Generating (PAG) sulphide-rich CIL residue comprising 10% of the total tailing.

The project received Environmental Assessment (EA) approvals from a joint harmonized provincial and federal environmental assessment review. Approvals were received from independent agencies consisting of the BC Government on July 30, 2014, followed by the federal government approval which was granted on December 19, 2014. On August 4, 2014, five days after the BC EA approval was received, the unfortunate Mount Polley incident occurred. This incident subsequently delayed the federal government's approval of the KSM Project by at least three months until late December 2014. The EA approved Tailing Management Facility (TMF) consists of compacted cycloned sand dams located at the divide between Teigen Creek and Treaty Creek.

Seabridge commissioned Klohn Crippen Berger (KCB) to conduct a Best Available Technology (BAT) study post the Mount Polley failure to review the proposed tailing management strategy that was submitted for the EA, to confirm that the current EA approved plan was recommending the most appropriate strategy to minimize the physical and geochemical risks over the life of the facility, to identify any optimizations that could decrease risk of tailing management, and to comply with the Independent Expert Panel that investigated the Mount Polley incident, recommendations on BAT and Best Available Practices (BAP) for tailing management.

This study is an assessment of tailing technologies, tailing facility location and management practices. It is an update to the tailing alternative assessment for the project that was previously completed as part of the EA in which the currently EA approved TMF design was selected.

Tailing facilities may pose both physical and geochemical risks that must be managed throughout the life cycle of the facilities, from design and construction, right through to long-term post-closure. The Mount Polley dam breach has heightened the awareness of tailing dam safety; in particular, since the resulting Independent Expert Engineering Investigation and Review Panel (the Panel) recommendations regarding BAT and BAP, and their suggestion that filtered tailing as "a prime candidate" for BAT for tailing management, there has been a focus on the feasibility and appropriateness of dewatering process technologies for tailing in the mining industry.

The framework for the study is separated into three main parts:

- **Part 1 – Best Available Technology (BAT) and Best Available Practice (BAP) Review and Assessment of Filtered Tailing for the KSM Project**

  This part of the study includes a review of the recommendations for BAT and BAP with respect to the proposed KSM Project. An assessment of the applicability of filtered tailing for the project was also completed taking into consideration scale, tailing properties (physical and geochemical) and climate.

- **Part 2 - Tailing Management Alternatives Assessment**

  This part of the study includes a re-evaluation of the previous alternatives assessment completed for the EA that considered potential use of alternative tailing management methods, including filtered tailing disposal, and ultimately focused on locations of cyclone sand facilities. This update includes assessing alternative tailing technologies at different candidate sites. The assessment used the framework of the Environment Canada's *Guidelines for the Assessment of Alternatives for Mine Waste Disposal* (Environment Canada 2013).

- **Part 3 - BAT Study Conclusions**

  This part summarizes the key conclusions and recommendations of the study.

Part 1 – Best Available Technology (BAT) and Best Available Practice (BAP) Review and Assessment of Filtered Tailing for the KSM Project

Filter technology is not practical for the KSM Project because:

- Scale of filter plant is unprecedented.
- Filter plant complexity will result in significant unscheduled downtime which would result in frequent shut-down of mining and milling.
- Target moisture content for the tailing will not always be achieved due to ore variability and operational difficulty, causing significant placement challenges and potential pile stability concerns.
- Conveyor placement of the KSM tailing production rate in a wet, cold climate is unprecedented and will present significant challenges. Topography of the region is mountainous which provides difficulty for conveyor arrangements.
- Placement and compaction of tailing in a wet, cold climate will be challenging. Strict quality control and potential re-handling of tailing will be required. Ponding of water during extreme precipitation events will be required and increase the risk of failure.
- Drainage of the facility is critical to stability and will require significant underdrains and potential internal slope drains. Adequate drainage will be more challenging in areas of upwelling groundwater (which is the case at several of the potential TMF sites).
- De-saturated CIL residue will generate acid. Surface runoff and seepage will have poor water quality and will require long term water treatment.
- Small percentage of sulphides in de-saturated flotation tailing will cause elevated sulphate loadings and require management.
- A 135 m high external collection dam with the capacity of 10.8 Mm^3 will be required for collection of runoff and seepage water from the facility to store for mill reclaim and seasonal release. Water quality in this facility is expected to be poor due to the oxidation of tailing. This

facility would need to be located further downstream than a conventional TMF seepage dam in Teigen Creek, where there is less hydrogeological containment, creating a larger overall disturbance area of the TMF and resulting in poor quality seepage.

- Perpetual post-closure water treatment of seepage water will likely be required because of the oxidation of tailing.

Part 2 - Tailing Management Alternatives Assessment

Thirteen TMF candidate sites were assessed for storing high density thickened, paste or filtered tailing. Preliminary location screening of the sites for dewatered tailing technology facilities found the following sites to be potentially suitable: Teigen-Treaty Valley, Scott Creek Valley, Upper Treaty Valley, Unuk Valley Terrace, and McTagg Valley. The other sites were discarded at this stage for various reasons including deposition in a fish-bearing lake, insufficient capacity, accessibility, sterilizing mineral deposits, and no perceivable advantage of re-evaluating the site with a new technology.

A critical flaws assessment of 31 TMF alternatives (layouts with various tailing technologies) at the five candidate sites was completed. A critical flaw in this assessment is defined as a flaw so unfavourable that it alone is sufficient to eliminate the alternative from further consideration for tailing disposal in the context of the KSM Project. The critical flaws used for the assessment were:

- required pile or embankment height exceeding 400 m;
- insufficient capacity for storage of all tailing;
- required Structural fill volume exceeds 50% of flotation tailing volume;
- no suitable runoff/seepage collection pond location; and
- reliance on tailing paste slopes as structural fill.

A Multiple Accounts Analysis (MAA) was completed on the six identified potential TMF alternatives that were carried forward after the critical flaws assessment:

- Teigen-Treaty Cyclone Sand TMF;
- Teigen-Treaty Filtered TMF - Option 1 - Filtered CIL residue;
- Teigen-Treaty Filtered TMF - Option 2 - Thickened CIL residue;
- Upper Treaty Filtered TMF;
- Unuk Valley Terrace Filtered TMF; and
- Scott Creek Filtered TMF.

The MAA included developing a systematic evaluation of the TMF alternatives by developing a Multiple Account Ledger, conducting a values-based assessment and completing sensitivity analyses to consider differing value systems.

The Multiple Accounts Ledger consists of three elements: Accounts (i.e., main categories), Sub-Accounts (i.e., evaluation criteria) and Indicators (i.e., measurement criteria). A Multiple Accounts Ledger was developed for the 2013 Alternatives Study's MAA. To be consistent, the ledger was used as the basis for this updated assessment. An additional Account was added to the MAA to review the risks and potential impacts for the TMF alternatives. Additional Sub-Accounts and Indicators were also added in consultation with the judgement of relevant experts and Seabridge to address the differences between alternative tailing technologies.

The value-based assessment to identify the preferred TMF alternative was based on weighing the Accounts, Sub-Accounts and Indicators. The Indicators are rated on a scoring system determined by the relevant expert and the quantitative range of the alternatives. The standard Account weighting is based on the recommendation from the Environment Canada Guidelines. Sensitivity analyses were performed to consider different value systems when weighting the Accounts, Sub-accounts, and Indicators. Sensitivity analysis addresses the potential that there may be opposing value systems when deriving Indicator, Sub-Account, and Account weightings.

The conclusions of the MAA are:

1. **Site Selection** - based on the 2013 Alternatives Study's MAA and the updated MAA from this study, the Teigen-Treaty site is the most appropriate TMF location because it has:
    - more favorable foundation conditions and hydrogeological containment;
    - a small upstream catchment;
    - less high value and sensitive fisheries and terrestrial habitat;
    - fewer geohazards; and
    - more favorable storage to structural fill ratios.
2. **Preferred Management Strategy** - The Teigen-Treaty Cyclone Sand TMF
    - Based on the results of the MAA, the Teigen-Treaty Cyclone Sand TMF is the most appropriate TMF alternative.
    - The Teigen-Treaty Cyclone Sand TMF scored the highest for each Account.
    - It has the lowest impact on environmental considerations, is the most technically feasible to construct, operate and close in a safe manner, has the fewest associated socio-economic concerns and has the least amount of risks and potential impacts.

Part 3 – BAT Study Conclusions

As stated previously, the conclusion from Part 1 of the study is that filtered tailing is not practical for the KSM Project.

The conclusions from Part 2 of study are that the Teigen-Treaty site is the most appropriate TMF location and the Teigen-Treaty Cyclone Sand TMF is the preferred management strategy for the KSM Project.

The EA approved TMF design included a number of BAT and BAP features. The key BAT features of the proposed EA approved Teigen-Treaty Cyclone Sand TMF are:

- **Site Selection**
  - Located at a catchment divide, therefore able to minimize upstream catchment area for flood management.
  - Favourable geology and foundation conditions for stability and hydrogeological containment.
  - Good storage capacity to dam volume ratio therefore able to minimize footprint.
  - Area is exposed to fewer geohazards compared to the surrounding region.
  - No high value fish habitat (i.e. food fishery) within the footprint of the facility.
- **Design Features Providing Physical Stability**
  - Compacted NPAG centerline raised cyclone sand dams with low permeability cores provide a dense, gradient controlled, free draining and de-saturated containment structure.
  - Over 50 years of precedence constructing centerline raise sand dams in the mining industry. Raising of these structures is simpler than other types of dams, minimizing the risk of human error.
  - Dams are designed with 3H:1V downstream slopes which results in Factors of Safety (FOS) that exceed CDA guidelines.
  - Cyclone sand dams are not as prone to piping failures as other dam types, such as zoned rockfill dams, as cyclone sand is filter compatible with the glacial till core and tailing.
  - Long tailing beaches between the ponds in the flotation tailing cells and the tailing dams decrease the likelihood of piping failures and catastrophic release of the pond if a hypothetical dam failure were to occur.
- **Design Features Providing Geochemical Stability**
  - De-sulphuring of the tailing by flotation so the majority of the tailing is NPAG.
  - PAG CIL residue is kept saturated in a lined cell to limit seepage and oxidation preventing metal leaching/acid rock drainage (ML/ARD).

- Flotation tailing contains <0.3% sulphides by weight. The majority of the flotation tailing will be stored behind a low permeability core and will remain at or close to saturation, which will limit sulphate generation.

- **Closure**
  - The TMF configuration allows two (redundant) spillways to be cut into rock, and allows drawing the closure pond down to a minimal volume. The redundancy adds to the resiliency of the TMF during a hypothetical failure of one of the spillways.
  - Lowering the spillway invert on final closure minimizes the pond volume stored on the tailing surface and increases the distance from the dam crests to the pond, decreasing the likelihood of a hypothetical overtopping failure and the likelihood the pond will be released during a hypothetical slumping failure of the dam.
  - At closure, the surface will be contoured to return the flow patterns similar to pre-mine conditions to achieve environmental objectives identified during the EA review process.
  - Rock cover on dam slopes will minimize erosion.
  - PAG CIL residue will be covered with flotation tailing and the phreatic surface will be maintained above the CIL residue, maintaining saturation of the CIL residue to limit oxidation and prevent ARD.
  - Lower long term risk of high concentrations of sulphate generation due to hydrogeological containment of the majority of the flotation tailing. The majority of flotation tailing are stored behind a low permeability core and will remain saturated, which will limit the amount of residual sulphides in the flotation tailing exposed for potential generation of sulphate.

The key BAP features of the proposed EA approved Teigen-Treaty Cyclone Sand TMF are:

- **Corporate TSF Design Responsibility**

  Seabridge has taken a long-term planning approach to the KSM Project mine development, rather than a small initial mine plan and subsequent ad hoc design additions. In doing so, the TMF has been designed for the mine life.

  The design of the TMF, which has evolved over the EA review period, continues as the project moves towards development, and takes into account the extensive geological, seismic, hydrogeological and geomorphological site investigations and interpretations for the site.

  As part of the TMF design, design criteria were set out in terms of beach widths, rate of rise, water balance and construction material balancing. These will become part of the Quantitative Performance Objectives (QPOs) in later stages of design and ultimately incorporated into the Operations, Maintenance and Surveillance (OMS) manual.

- **Independent Tailings Review Board (ITRB) or Independent Geotechnical Review Board (IGRB)**

  Seabridge established an Independent Geotechnical Review Board (IGRB) in January 2015 to independently review and to provide expert opinion and oversight for the KSM Project's TMF and Water Storage Dam (WSD) with a focus on their structural stability and integrity throughout the design, construction, operation and closure of the project. This was following Seabridge's commitment in mid-August 2014 in light of the Mount Polley incident and their belief that such commitment was required to ensure the continued acceptance of KSM Project's design by the project's stakeholders.

  Seabridge and/or the KSM operating partner will continue to interact with the IGRB during design, construction, operations and post-closure. During design, Seabridge will host at least one IGRB meeting per annum and make the reports publically available.

- **Professional Practice and Canadian Dam Association (CDA) Guidelines**

  Extensive geological, seismic, hydrogeological and geomorphological site investigations and studies have been conducted to understand the dam foundation conditions.

  Seismic and stability assessments based on the results of foundation site investigations, the consequences of failure, and the loading conditions resulted in exceeding the minimum required factors of safety outlined by the CDA guidelines.

- **Closure should move to low risk landforms and should be consistent with First Nations values (BC First Nations Energy and Mining Council 2015)**

  The TMF closure plan was developed based on engagement with the Working Group, which includes Aboriginal groups, municipal officials, and regulatory authorities, during the EA review. The robust and resilient closure design is aimed at creating a low risk landform that will return the area back to similar hydrologic conditions.

Even with the BAT and BAP features of the Teigen-Treaty Cyclone Sand TMF design, there are remaining key risks that need to be effectively controlled through design, operations and post-closure. These are already being considered through the design process and will become part of operating controls.

- **Physical Stability**
  - Ponded water in the flotation cells will need to be kept at a minimum to meet operational and environmental objectives. Close attention to the water balance of the facility is fundamental to minimizing facility risks.
  - Impounded water increases the consequence of a hypothetical failure, particularly the CIL Residue Cell during Stage 1 (Year 0 to Year 25) when water is impounded adjacent to the cyclone sand dam.
  - Cyclone sand is erodible; management of erosion of the cyclone sand dam slopes will require erosion mitigation and control.

- **Geochemical Stability**
  - Maintaining saturation and limiting oxidation of the PAG CIL residue will require effective water management.
- **Closure**
  - Long-term erosion mitigation and control of the dam slopes will require an erosion resistant closure cover.
  - A water management trade-off between maintaining a small closure pond to achieve environmental objectives (e.g. geochemical stability of the CIL residue), and decreasing the closure pond volume to further minimize risk.

LIST OF ABBREVIATIONS

ARD	Acid Rock Drainage
ARI	Average Recurrence Interval
ASTM	American Society for Testing and Materials
BAP	Best Available Practice
BAT	Best Available Technology
BC	British Columbia
CDA	Canadian Dam Association
CIL	Carbon-in-Leach
CIP	Carbon-in-Pulp
CIM	Canadian Institute of Mining, Metallurgy and Petroleum
CN	Cyanide
CTMC	Consortium of Tailings Management Consultants
CMTs	Culturally Modified Trees
DBM	Design Basis Memorandum
EA	Environmental Assessment
EAO	Environmental Assessment Office
EC	Environment Canada
EQI	Ecological Quality Index
FOS	Factor of Safety
FMEA	Failure Mode and Effects Analysis
GARD	Global Acid Rock Drainage Guide
GHG	Greenhouse Gas
GLU	Glacio-lacustrine clay
HADD	Harmful Alteration, Disruption or Destruction
HPGR	High Pressure Grinding Rolls
ICOLD	International Commission of Large Dams
IGBR	Independent Geotechnical Review Board
IPCC	Intergovernmental Panel on Climate Change
INAP	International Network for Acid Prevention
ITRB	Independent Tailings Review Boards
KCB	Klohn Crippen Berger
MAA	Multiple Accounts Analysis
MAAT	Mean Annual Air Temperature
MAC	Mining Association of Canada
MCDA	Multiple Criteria Decision Analyses
MEND	Mining Environment Neutral Drainage
MEM	British Columbia Ministry of Energy and Mines
ML	Metal Leaching
MMER	Metal Mining Effluent Regulation
NFA	Nisga'a Final Agreement
NMD	Neutral Mine Drainage

NP	Neutralization Potential
NPAG	Non – Potentially Acid Generating
NPR	Neutralization Potential Ratio
OoM	Order of Magnitude
OPM	Ore Processing Mill
PAG	Potentially Acid Generating
PFS	Pre-Feasibility Study
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RSF	Rock Storage Facility
SD	Saline (Mine) Drainage
SPMDD	Standard Proctor Maximum Dry Density
SWE	Snow Water Equivalent
TMF	Tailing Management Framework
TSF	Tailing Storage Facility
TSS	Total Suspended Solids
TWTP	Temporary Water Treatment Plant
UBC	University of British Columbia
UCS	Unconfined Compressive Strength
WSD	Water Storage Dam
W_W	Weight of Water
W_S	Weight of Solids
W_T	Total Weight

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1 INTRODUCTION

1.1 Purpose

Klohn Crippen Berger (KCB) was commissioned by Seabridge Gold Inc. (Seabridge) to conduct a Best Available Technology (BAT) study for tailing management of the proposed gold-copper KSM Project located in north-western British Columbia (BC) (see Figure 1.1). This study is an assessment of tailing technologies, tailing facility location and management practices. It is an update to the tailing alternative study that was previously completed for the project as part of the Environmental Assessment (EA) (Rescan 2013, Appendix 33-B).

The KSM Project underwent a joint harmonized provincial and federal environmental assessment review under the BC Environmental Assessment Act and the Canadian Environmental Assessment Act (pre-2012). The review was initiated with the submission of a Project Description to the BC Environmental Assessment Office in March 2008. The Canadian Environmental Assessment Agency (CEAA) began to interact with Seabridge during the summer of 2008 and subsequently confirmed that the proposed KSM Project would need to undergo a “Comprehensive Study” EA in July 2009. EA approvals were received from the independent government agencies, with the BC Government approving the project on July 30, 2014, followed by the federal government approval which was granted on December 19, 2014.

On August 4, 2014, five days after the BC EA approval was received, the unfortunate Mount Polley incident occurred. This incident subsequently delayed the federal government’s approval of the KSM Project by at least three months until late December 2014 during which the federal government further reviewed the proposed tailing design for KSM.

The EA approved project includes combined open pit and underground deposits with an average ore processing rate of 130,000 tonnes per day (tpd). Ore will be mined from four zones of mineralization: the Mitchell, Sulphurets, Kerr and Iron Cap. Ore will be conveyed through tunnels to the tailing management area where it will be processed. The tailing is proposed to be stored behind a series of compacted cycloned sand dams located at the divide between Teigen Creek and Treaty Creek, situated within the upper reaches of the Bell-Irving River basin, which drains into the Nass River and ultimately Canadian waters of the Pacific Ocean.

Tailing facilities may pose both physical and geochemical risks that must be managed throughout the life cycle of the facilities, from design and construction, right through to long-term post-closure. The Mount Polley dam breach has heightened the awareness of tailing dam safety and, since the resulting Independent Expert Engineering Investigation and Review Panel (the Panel) recommendations regarding BAT and Best Available Practices (BAP) and their suggestion that filtered tailing as “a prime candidate” for BAT for tailing management (MPC 2015), there has been a focus on the feasibility and appropriateness of dewatering process technologies for tailing in the mining industry.

Seabridge initiated this study post the Mount Polley failure to review the proposed tailing management strategy that was submitted for the EA (Rescan 2013, Appendix 33-B), to confirm that the current plan is the most appropriate strategy to minimize the physical and geochemical risks over the life of the facility, to identify any optimizations that would decrease risk of tailing management for the KSM Project, and to comply with the Panel recommendations on BAT and BAP for tailing management.

1.2 Key Study Contributors

KCB has been a leader in tailing management since the 1960s, Appendix I-A highlights KCB's experience.

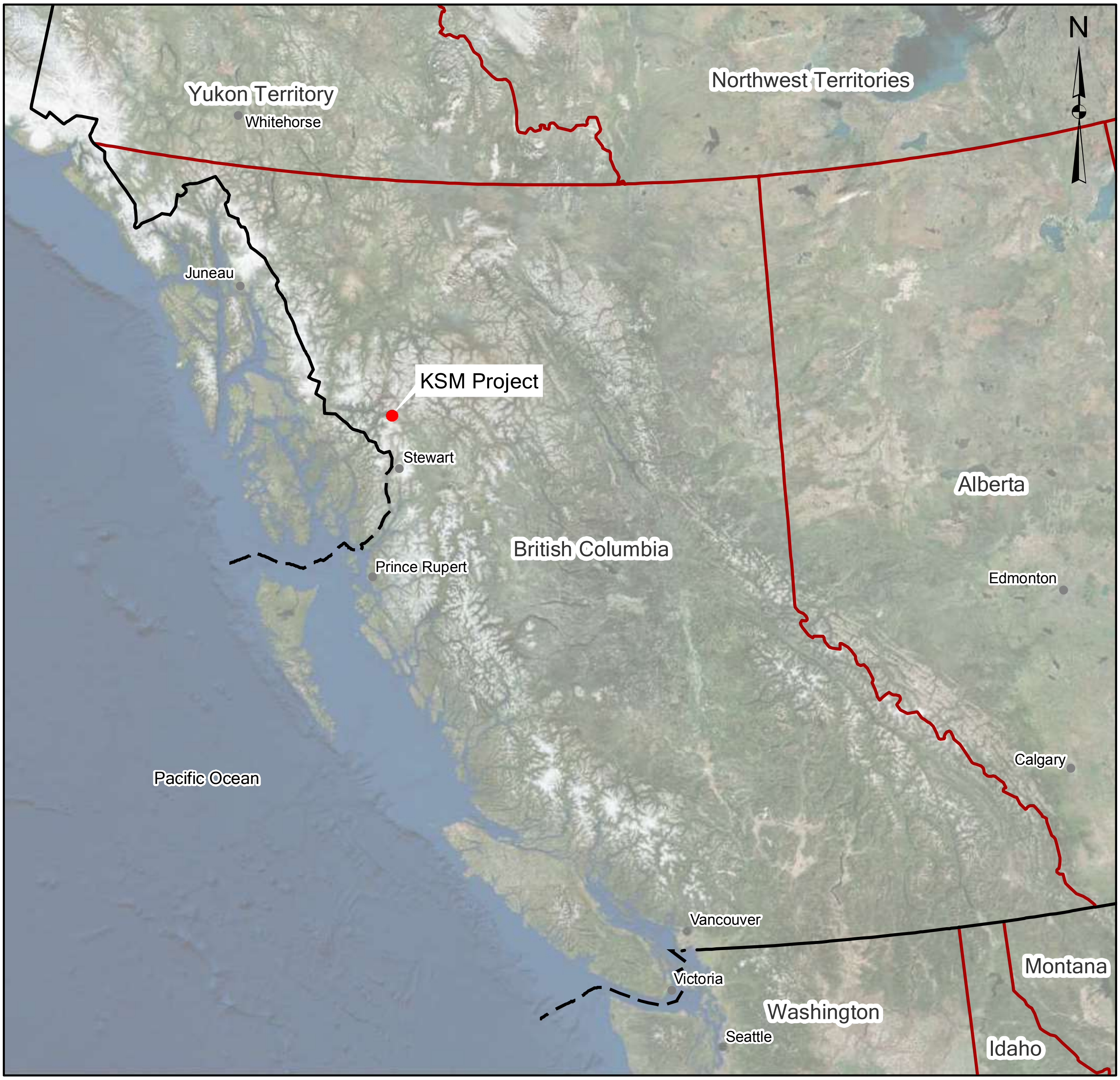
The following are the key contributors and/or provided technical input to the study:

- Kate Patterson, Tailing and Water Resources Engineer, KCB (P.Eng., M.Eng.)
- Drew Hegadoren, Geotechnical Engineer, KCB (E.I.T.)
- Graham Parkinson, Associate and Senior Geoscientist, KCB (P.Geo., P.Geoph.)
- Howard Plewes, Senior Geotechnical Engineer, KCB (P.Eng., M.A.Sc.)
- Harvey McLeod, Principal and Senior Geotechnical Engineer, KCB (P.Eng., P.Geo., M.Sc.)

1.3 List of Key References

Key information for this study has been taken from the following reports, and additional references are listed at the end of this report:

- Guidelines for the Assessment of Alternatives for Mine Waste Disposal (Environment Canada 2013).
- Application for an Environmental Assessment Certificate/Environmental Impact Statement for the KSM Project (Rescan 2013).
- KSM Project Technical Assessment of Alternative Tailing Sites (KCB 2012a).
- 2012 Engineering Design Update of Tailing Management Facility (KCB 2012c).



LEGEND

- CITY
- PROVINCIAL/STATE BOUNDARY
- INTERNATIONAL LAND BOUNDARY
- INTERNATIONAL WATERS BOUNDARY

NOT FOR CONSTRUCTION

0 500 km

NOTES:
1. PROJECTION: UTM ZONE 9N
2. HORIZONTAL DATUM: NAD 83
3. BASEDATA SOURCES: NATIONAL ROAD NETWORK (NRN), NATURAL RESOURCE CANADA. AVAILABLE: HTTP://GEOGRATIS.GC.CA (ACCESSED JUNE, 2011);
4. IMAGE SOURCE:ESRI, DIGITALGLOBE, GEOEYE, I-CUBED, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEX, GETMAPPING, AEROGRID, IGN, IGP, SWISSTOPO, AND THE GIS USER COMMUNITY

CLIENT
SEABRIDGE GOLD

Klohn Crippen Berger

PROJECT
BEST AVAILABLE TECHNOLOGY (BAT) STUDY FOR TAILING MANAGEMENT AT THE KSM PROJECT

TITLE
PROJECT LOCATION MAP

SCALE	PROJECT No.	FIG No.
AS SHOWN	M09480A07	1.1

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2 KSM PROJECT BACKGROUND

2.1 Proposed Mining Plan

The project plan estimates that 130,000 tpd of ore will be processed over the life of the project of approximately 51.5 years. The total quantity of tailing is estimated to be up to 2.3 billion tonnes.

The project includes two main areas: the Mine Area and the Tailing Management Area. The Mine Area includes three open pits, two underground mines, rock storage facilities, diversion structures, a water storage dam, and a water treatment facility. These structures are situated within the valleys of Mitchell Creek, McTagg Creek, and Sulphurets Creek. The Mine Area is located approximately 20 km southeast of the closed Eskay Creek Mine, and within 30 km of the BC-Alaska border, shown on Figure 2.1.

The Tailing Management Area includes the plant site (ore processing mill) and the Tailing Management Facility. Ore will be crushed at a primary crusher in the Mine Area and then transported via conveyor to the plant site in the Tailing Management Area (at the Teigen-Treaty site). Processing of ore in the plant will produce concentrate and gold ore, which will be trucked to the Port of Stewart and shipped to smelters overseas.

2.2 Tailing Properties

Two tailing streams will be produced by the plant: the bulk rougher flotation tailing[1] representing 90% of the tailing (by dry weight) and a fine, sulphide-rich CIL residue tailing comprising 10% of the tailing. The sulphide stream will be cyanide leached and then processed for gold recovery using activated carbon; this process is called Carbon-In-Leach (CIL) method[2]. A two-stage cyanide destruction circuit will be in place for the CIL circuit, initially using SO_2 air processing followed by a second stage hydrogen peroxide treatment.

The CIL residue has a high sulphide concentration (approximately 40% to 45%) and is Potentially Acid Generating (PAG). Sufficient sulphide minerals will be removed from the flotation tailing during the flotation process so that they will exhibit Non-Potentially Acid Generating (NPAG) behaviour. The remaining amount of sulphide in the flotation tailing is estimated to be less than 0.3% by weight (Rescan 2013, Chapter 10). Based on humidity cell leachate tests, the flotation tailing are predicted to not produce acidic leachate and the predicted time to onset of Acid Rock Drainage (ARD) for the CIL residue is less than five years (Rescan 2013, Chapter 10).

A summary of physical testing that have been performed on the tailing streams is included in Appendix II. Due to differences in ore properties, the flotation tailing have two different target gradations: P_{80} values of 150 µm for the first 30 years of mining and 120 µm for the remaining mine life. The target gradation for the CIL residue has a P_{80} value of 15 µm.

[1] Generally called “flotation tailing” in this report (has been referred to as rougher tailing in previous reports).
[2] Hence this stream is called “CIL residue” in this report.

The Specific Gravity, Gs, of the flotation tailing ranges from 2.75 to 2.90 depending on the source of the ore. CIL residue has a Gs of 3.45 to 3.54. The higher Gs of the CIL residue reflect the concentration of sulphides in this tailing stream.

Flotation tailing can be cycloned to produce cyclone sand for dam construction. The EA approved TMF includes double cycloning of the flotation tailing stream to produce cyclone sand. Primary or first stage cycloning will be conducted at a fixed cyclone house. Underflow sands will be diluted with water and pumped to on-dam mobile cyclone stations. Cyclone sand suitable for construction is estimated to be 33% to 40% of the cycloned flotation tailing by weight (KCB 2012c).

2.3 Project Setting

Location

The project is located within the steep and rugged terrain of the Coastal Mountains of northwestern BC. This landscape is characterized by topography that ranges in elevation from about 240 m in the Unuk River Valley to over 2300 m at nearby peaks. Glaciers and ice fields dominate the terrain to the north, east, and south of the ore deposits, and the Mine Area is situated in an area with steep slopes, high geohazards, and glacier-carved valleys. To the west, the area is bounded by the Unuk River Valley, which drains into the Pacific Ocean through Alaska (shown on Figure 2.1). The proposed TMF Area (Teigen-Treaty Valley) is located approximately 23 km northeast of the mine area in less rugged terrain. This watershed is entirely in Canadian waters and drains via Treaty Creek and Teigen Creek into the Bell-Irving River, followed by the Nass River, which ultimately drains into the Pacific Ocean.

Geology

Local topographic and geological factors considered for TMF siting are bedrock type and condition, overburden type and depth, slope characteristics and valley geometry. Bedrock and overburden affect dam foundation conditions, associated earthquake risks, and potential seepage. Steepness of slopes and valley geometry affect containment dam construction, and can magnify the risks of local geohazards such as debris chutes, rock falls, avalanches, and landslides.

Landforms and topography in the region of the project have been significantly influenced by glacial activity. The Mine Area is characterized by steep topography with loose talus resulting from rockslides and slumps. Rugged exposed rock and glaciers or ice fields at higher elevations, with significant areas of glacial deposits such as lateral and terminal moraines containing both ablation and basal till, and glacial outwash, often characterize landscapes in the region. Frequent mass wasting events result in the accumulation of colluvial deposits on and at the base of slopes. Fluvial deposits are limited, being confined to the active channels and isolated floodplains of formerly active channels.

Geology at the Mine Area and for the EA approved TMF Area has been assessed (KCB 2012a). The bedrock in the TMF area belongs to the Bowser Group of sedimentary rocks, which occur to the east and north of the Mine Area, which provide a good foundation for dams and tailing impoundment seepage control. To the west and south of the Mine Area, the sedimentary and metasedimentary bedrock largely consists of fissile argillites, limestones and schists, which have higher and more variable permeability than those of the Bowser Group. Glaciolacustrine clay (GLU) has not been identified at the TMF site.

Seismicity

The project is located in an area of low to moderate seismic activity with no active faults within 285 km identified in either government regional mapping, published literature or in the KCB Seismotectonic Assessment (Appendix II of KCB 2013).

Geohazards

Geohazards are effects of the local environment on the project; the following are characteristic examples (KCB 2012a):

- Areas with mountainous terrain are susceptible to snow avalanches which can prevent access for extended periods, block diversions and damage structures. Control of avalanches is possible by regularly triggering small, manageable avalanches instead of allowing large destructive avalanches to occur. Modern methods of control include fixed installations of remote controlled gas exploders that can be programmed to prevent accumulation of snow. Other mitigation methods include snow sheds for access roads and diversion structures.
- Debris flows originate in steep areas and can run out as narrow streams for distances on the scale of kilometers. They result when soil, vegetation and water are suddenly released in a steep streambed; the resulting wall of debris mobilizes more debris as the torrent advances.
- Landslides are a common feature where glaciers have receded rendering valley walls that were worn steep by the ice unstable when the ice is no longer buttressing the rock or soil slopes. The presence of tension cracks above the source zone typically gives some warning that an area may be susceptible to this type of failure.

Climate

The project lies in a transition zone between the very wet Pacific coastal region and the drier interior of BC (Rescan 2013, Appendix 33-B). The regional hydroclimate of northwestern BC is dominated by weather systems generated on the Pacific Ocean. Mean annual precipitation typically decreases with distance from the BC coast, while the orographic effect caused by mountains can lead to higher rainfall at higher elevations in some areas. These interactions between incoming weather systems and local topography produce a degree of spatial variability in snowfall and rainfall.

The average annual rainfall across the project area is high, ranging from 1390 mm at the Teigen weather station to 1650 mm at the Sulphurets weather station (KCB 2012a). Most precipitation in the region falls between September and February, with the driest months being June and July. In the winter, much of the precipitation falls as snow. For example, the Unuk River-Eskay Creek Station typically has its highest precipitation in December, with 99% falling as snow.

Seasonal temperature can vary widely in the project area, ranging from about +30°C to -30°C. Mean monthly temperatures range from +10°C to -10°C (see Appendix III-B). During winter, the air is generally unstable and there is a strong temperature gradient in the valleys (Rescan 2013, Appendix 33-B). Moderate to strong winds occur in all seasons at high elevations.

Hydrology

Hydrological factors such as catchment size, precipitation, runoff, and groundwater affect the water flows in and out of a TMF Area, influencing water quality, surplus water, and flood risks. There are four main flow periods for watersheds in the project area:

- Winter (November to April) is characterized by low-to-negligible stream flow.
- Spring/freshet period (April to May/July) typically has high flow rates due to snowmelt and often contains the peak annual flow.
- Summer (July to August/mid-September) is often characterized by steadily decreasing high-to-moderate flows, augmented by precipitation and snowmelt. In glaciated catchments (such as at Sulphurets Creek) flows can continue to rise throughout summer.
- Fall (mid-September to November), watersheds typically experience moderate-to-high flows, with the high flows corresponding to storm events.

High seasonal water flows are typical in the region, and climate change may affect the future water regimes in the region over the project life by way of slightly increased annual precipitation, increased annual average temperature (altering the distribution between snow and rain) and increased melt of permanent snowfields and glaciers (UBC 2014, BCMFR 2010).

Aquatic Habitat and Life

Fresh water systems near the project contain habitat such as riparian zones, wetlands, and stream channels that support aquatic life, including several species of fish. Many streams, particularly those contained within the Teigen and West Teigen valleys, are subject to frequent avalanches and landslides. As a result, channel formation and fish habitat are subject to repeated natural disturbance factors. In addition, aquatic biological activity is limited due to naturally occurring metal leaching (ML) and ARD near the existing mineral deposits and in other rugged areas with rock exposure (Rescan 2013, Appendix 33-B).

All of the potential TMF sites assessed in this study drain or partially drain to the Bell-Irving River system, which provides habitat for Chinook salmon, coho salmon, sockeye salmon, steelhead trout, rainbow trout, bull trout, Dolly Varden, and mountain whitefish. One of the potential TMF sites drains into the Unuk River system; downstream the Unuk River provides spawning routes for Pacific salmon and steelhead trout, as well as habitat for cutthroat trout, rainbow trout, bull trout, Dolly Varden, and mountain whitefish.

Rescan/ERM have conducted baseline studies on fish at the KSM project since 2008 (Rescan 2013, Appendix 15-A). Figure 2.2 illustrates the distribution of the fish species for the TMF candidate sites based on the baseline data. Salmon species have been found in lower Treaty Creek and lower Teigen Creek; however, none have been found within the EA approved Teigen-Treaty TMF area.

Terrestrial Wildlife

The region encompassing the KSM Project is occupied by many terrestrial wildlife species including grizzly bears, mountain goats, moose, waterfowl, raptors, migratory songbirds, western toad, and a variety of small and medium-sized mammals. Large wildlife such as deer and caribou are rare in the vicinity of the project due to the rugged topography; however, bear and mountain goats are more common (Rescan 2013, Appendix 33-B). Habitats differ from high quality habitat (along HWY 37) to low quality, high elevation and glaciated areas.

Species with conservation status that occur in the general area include grizzly bear, fisher, wolverine, and western toad (B.C. Conservation Data Centre 2011).

2.4 Previous Alternatives Assessment

Under the Fisheries Act, the capacity to use a natural fish-bearing waterbody as a TMF is only possible through obtaining a regulatory amendment to have the proposed waterbody designated as a tailing impoundment area and listed under Schedule 2 of the Metal Mining Effluent Regulations (MMER).

A project proponent must undergo a predetermined process when considering TMF alternatives that would trigger a Schedule 2 Amendment. This process must:

1. prepare an environmental assessment (EA);
2. prepare a TMF alternatives assessment, which may or may not be included within the EA document;
3. prepare a fish habitat compensation plan for consideration; and
4. participate in public and Aboriginal engagement discussing the proposed Schedule 2 Amendment.

To address step 2 of the Schedule 2 Amendment, an Assessment of Alternatives for the KSM Project Tailing Management Facility (Rescan 2013, Appendix 33-B) was completed in 2011 to 2012 and included in the EA in 2013 (further referred to as the 2013 Alternatives Study). The executive summary of this report is included in Appendix I-B.

The focus of the 2013 Alternatives Study was to assess locations for conventional tailing facilities (including cyclone sand, in-pit and lake disposal facilities). Tailing dewatering technologies were not the focus of this study because such technology had been eliminated from consideration early in the study due to the technical complexities associated with proposed high throughput projects (Rescan 2013, Appendix 33-B).

Seabridge followed the transparent and standardized process described in the *Guidelines for the Assessment of Alternatives for Mine Waste Disposal* published by Environment Canada (2013) and included in Appendix I-C. These guidelines delineate the alternatives assessment process required to identify, assess, evaluate, rank, and select the best overall TMF from the candidate sites and alternatives originally identified.

Seabridge conducted an initial screening of all potential tailing sites in a 50 km by 50 km area surrounding the Mine Area. Threshold criteria were used by Seabridge to exclude sites in the 2500 km^2 area that were not feasible due to basic topographic, accessibility, cost and technical limitations. This resulted in 14 potential TMF candidate sites:

1. Upper Teigen / Treaty TMF;
2. West Teigen Lake TMF;
3. Bowser Lake TMF;
4. Segmented Bowser Lake TMF;
5. Knipple Lake TMF;
6. Ted Morris Creek Valley TMF;
7. McTagg Creek Valley TMF;
8. Sulphurets Creek Valley TMF;
9. In-pit Tailing Storage TMF;
10. Burroughs Bay Submarine Disposal TMF;
11. Scott Creek Valley TMF;
12. Combined Sulphurets Creek Valley and Ted Morris Creek Valley TMF;
13. Unuk Valley TMF; and
14. Upper Treaty Creek Valley TMF.

The TMF candidates were pre-screened based on the following criteria:

- Do government policies recommend against specific deposition methods?
- Are geological foundations insufficient for safe construction and operation of containment dams?
- Do water management issues preclude safe operation of the TMF?
- Will the TMF result in negative life or project economics?
- Does the proposed facility have insufficient capacity for the entire proposed mine life?
- Are engineering issues prohibitive given current technology?
- Do geological hazards preclude safe operation of infrastructure?

Of the 14 candidate sites, four potential tailing management alternatives—one individual site and three combinations of two sites—met all the TMF siting pre-screening criteria:

1. Upper Teigen/Treaty TMF (site 1);
2. Scott Creek Valley TMF combined with West Teigen Lake TMF (site 11 and 2);

3. Unuk Valley combined with West Teigen Lake TMF (site 13 and 2); and
4. Upper Treaty Creek Valley combined with West Teigen Lake TMF (site 14 and 2).

These final four alternatives were designed to a conceptual level and characterized under four main areas: environmental, technical, socio-economical and economical.

A Multiple Accounts Analysis (MAA) was completed as per Environment Canada's Guidelines on the four TMF alternatives considering four primary Accounts (i.e., environment, technical, socio-economic and economic), selected evaluation criteria (Sub-Accounts) and measurement criteria (Indicators). The value-based decision process involves the creation of scoring and weighting scales for all relevant criteria (Accounts, Sub-Accounts and Indicators). A multidisciplinary team of technical experts and working group members as established by the EA process agreed upon the Accounts, Sub-Accounts, Indicators, and scoring criteria.

The 2013 Alternatives Study MAA gave the following results:

- The most appropriate TMF alternative for the project is the disposal of tailing at the Upper Teigen-Treaty site, using containment dams constructed from cyclone sand. This decision was based on environmental, socio-economic, technical, and economic considerations.
- The results of the sensitivity analyses showed that when economic and technical factors were removed from consideration, leaving only environmental and socio-economic considerations contributing to the overall decision analysis, the most appropriate tailing management facility for the project is still the Upper Teigen-Treaty site.

2.5 EA Approved Cyclone Sand Tailing Management Facility

The Teigen-Treaty Cyclone Sand TMF (referred to as the Upper Teigen-Treaty site in the 2013 Alternatives Study) was identified as the preferred TMF in the 2013 Alternatives Study (Rescan 2013, Appendix 33-B). The EA approved tailing facility design is presented in the *KSM Project - 2012 Engineering Design Update of Tailing Management Facility* report (KCB 2012c). Additional details of the Teigen-Treaty Cyclone Sand TMF are provided in Appendix IV-A.

2.5.1 Description

The Teigen-Treaty site is located in a northwest-southeast trending valley that is continuous across a low drainage divide located at roughly the valley midpoint. The drainage divide results in surface waters in the northern end of the valley draining northward as a tributary of Teigen Creek (known as South Teigen Creek or Upper Teigen Creek) and surface waters in the southern end of the valley drain southward as a tributary of Treaty Creek (known as North Treaty Creek). Both Treaty Creek and Teigen Creek drain into the Bell-Irving River, which flows into the Nass River, which discharges into Canadian waters of the Pacific Ocean.

The site is located approximately 23 km northeast of the proposed Mine Area (see Appendix IV-A Figure 1.2 and Drawing D-4001). The proposed ore processing mill (OPM) site is located west of and adjacent to the north end of the TMF on a plateau at about El. 1100 metres above sea level (masl) (Appendix IV-A, Drawing D-4101). The TMF and process plant will be accessed by a new road, the proposed Treaty Creek Access Road, from Highway 37.

The proposed TMF is designed to store up to the 2.3 billion tonnes of tailing produced over the 51.5 year mine life. Tailing will be stored in three "cells" staged over the mine life. NPAG flotation tailing will be deposited in the North Cell from Year 0 to Year 25, and in the South Cell from Year 26 to Year 51.5. The PAG sulphide rich CIL residue will be in contact with cyanide during processing and will be stored in a separate, fully lined CIL Residue Cell located between the North and South flotation cells. The CIL Residue Cell will be operated during filling of both the North and South cells. At the end of operations, the CIL residue will be contained in a lined, saturated cell, located in the center of the facility, far from the outer embankment slopes.

Flotation tailing will cycloned using dual stage cyclones during the summer months to produce sand for dam construction. Cyclone sand used for dam construction will be compacted to meet stability criteria. Cyclone overflow (fines) will be deposited in the flotation cells from the cyclone sand dam crests at either end of each flotation cell resulting in a reclaim pond at the centre of the cell and long tailing beaches.

The water balance of the facility will be closely monitored to meet performance objectives including minimum beach lengths in the flotation cells and a minimum water cover over the CIL residue. Instrumentation within the dam and foundation will be installed and monitored for dam safety.

The proposed TMF will be progressively reclaimed. After the North Cell is full flotation tailing will be directed to the South Cell and the North Cell will be closed and reclaimed. A rock cut closure spillway will be constructed from the North Cell to South Teigen Creek, allowing the water pond to drain down to a reduced volume, allowing discharge to Teigen Creek and returning Teigen Creek drainage patterns closer to the pre-mining configuration. After the end of operations and when the South Cell and CIL Residue Cell closure water quality meets applicable standards, the Saddle Dam and Splitter Dam will be breached to allow water levels in the three cells to equilibrate.

During operations, water will be discharged from the facility on an annual basis via a discharge pipeline to a diffuser in Treaty Creek. TMF discharge will coincide with the natural high flow period which occurs annually between May and November.

On final closure, the majority of flows from all cells will normally report to Teigen Creek via the North Spillway, which will be upgraded for closure. The spillway invert will be lowered to minimize ponded water stored on the tailing surface. To provide redundant capacity to route the Probable Maximum Flood (PMF), the Southeast Spillway, another rock cut closure spillway, will be constructed from the South Cell to North Treaty Creek. Flow into this spillway will be controlled by a weir regulating flows to Treaty Creek. Gate and weir structures will also be provided at the North Spillway to allow routing flow as required to either South Teigen Creek or North Treaty Creek. The gates will permit regulating flow volumes to match pre-mining flow conditions and also allow shutdown of spillways for maintenance if required. At this final stage, most of the diversion channels will be decommissioned, returning South Cell drainage patterns closer to pre-mining configuration.

Upon final closure, sloped surfaces of the tailing dams will be armoured with a layer of rockfill to resist erosion and a layer of soil to promote vegetation. Tailing beaches will be protected from erosion with gravels at the pond perimeter and areas above the pond will have a closure cover of loose soil applied and will be re-vegetated.

2.5.2 Environmental Assessment Process

A significant portion of the EA review was spent evaluating the risks associated with the proposed TMF, which resulted in a significant re-design to the originally proposed facility to accommodate and mitigate the concerns of local Aboriginal groups, whom were members of the Environmental Assessment Review Working Group. The following design features were added or modified during the review process:

- A lined central cell was added to safely store and isolate the sulphide rich CIL residue under saturated conditions to prevent the onset of acid generation and mitigate the potential for downstream water quality impacts.
- The proposed discharge location for excess water from the TMF was moved from South Teigen Creek to Treaty Creek to mitigate potential water quality impacts on high value salmon habitat in Teigen Creek.
- The proposed access road to the TMF was moved from the Teigen Creek Valley to the Treaty Creek Valley to eliminate potential impacts to high value salmon habitat in Teigen Creek.

During the EA review the proposed TMF also underwent two independent reviews:

- BGC Engineering commissioned by Seabridge; and
- Brodie Engineering on behalf of the Nisga’a Nation.

Both reviews concluded that the proposed designs were appropriate.

2.5.3 Key Risks

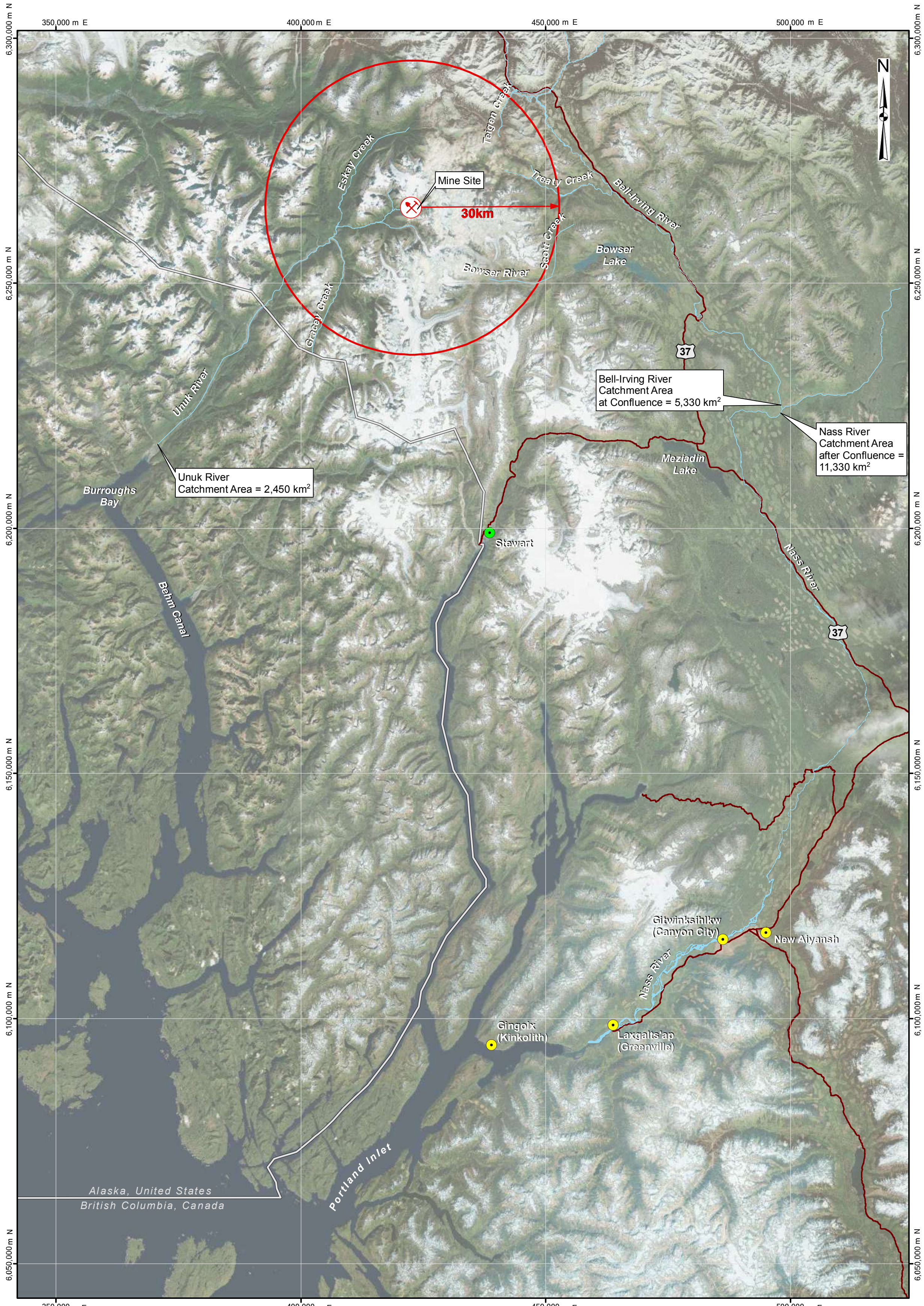
The design of the TMF has been developed over time to minimized risk. There is many beneficial features of the site and the design. Even with these features design, there are remaining key risks that need to be effectively controlled through design, operations and post-closure. These are already being considered through the design process (as described in the earlier parts of this section) and will become part of operating controls.

- **Physical Stability**
    - Ponded water in the flotation cells will need to be kept at a minimum to meet operational and environmental objectives. Close attention to the water balance of the facility is fundamental to minimizing facility risks.

    - Impounded water increases the consequence of a hypothetical failure, particularly for the CIL Residue Cell during Stage 1 (Year 0 to Year 25) when water is impounded adjacent to the cyclone sand dam.
    - Cyclone sand is erodible; management of erosion of the cyclone sand dam slopes will require effective erosion mitigation and control.
- **Geochemical Stability**
    - Maintaining saturation and limiting oxidation of the PAG CIL residue will require effective water management.
- **Closure**
    - Long-term erosion mitigation and control of the dam slopes will require an erosion resistant closure cover.
    - A water management trade-off between maintaining a small closure pond to achieve closure land use objectives and decreasing the closure pond volume to minimize further risk.

Water management risks will be mitigated by calibrating and maintaining a water balance throughout the mine life to facilitate forecasting and management of the water volume in the flotation tailing and CIL residue cells, allowing the impounded water to be reduced while still meeting the requirements for mill supply and CIL residue submersion.

Erosion risks are mitigated by the 3H:1V slopes of the outer dams, and will be further mitigated on closure by a soil and rockfill cover on the dam slopes. The cyclone sand dams will be monitored throughout the life of the facility for erosion features, which will be repaired should they develop.



LEGEND

- COMMUNITY
- DISTRICT MUNICIPALITY
- HIGHWAY
- RIVER
- CANADA / U.S. BORDER

SCALE: 0 25km

NOT FOR CONSTRUCTION

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

NOTES:
1. PROJECTION: UTM ZONE 9N
2. HORIZONTAL DATUM: NAD 83
3. BASEDATA SOURCES: DIGITAL GAZETTEER, GEOBC. AVAILABLE: HTTP://GEOBC.GOV.BC.CA/BASE-MAPPING/ATLAS/BCNAMES/GAZ.HTML (ACCESSED NOVEMBER, 2011)
4. IMAGE SOURCE: ESRI, DIGITALGLOBE, GEOEYE, I-CUBED, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEX, GETMAPPING, AEROGRID, IGN, IGP, SWISSTOPO, AND THE GIS USER COMMUNITY

CLIENT	PROJECT
SEABRIDGE GOLD	BEST AVAILABLE TECHNOLOGY (BAT) STUDY FOR TAILING MANAGEMENT AT THE KSM PROJECT
Klohn Crippen Berger	TITLE: PROJECT LOCATION AND STUDY AREA

SCALE	PROJECT No.	FIG No.
AS SHOWN	M09480A07	2.1

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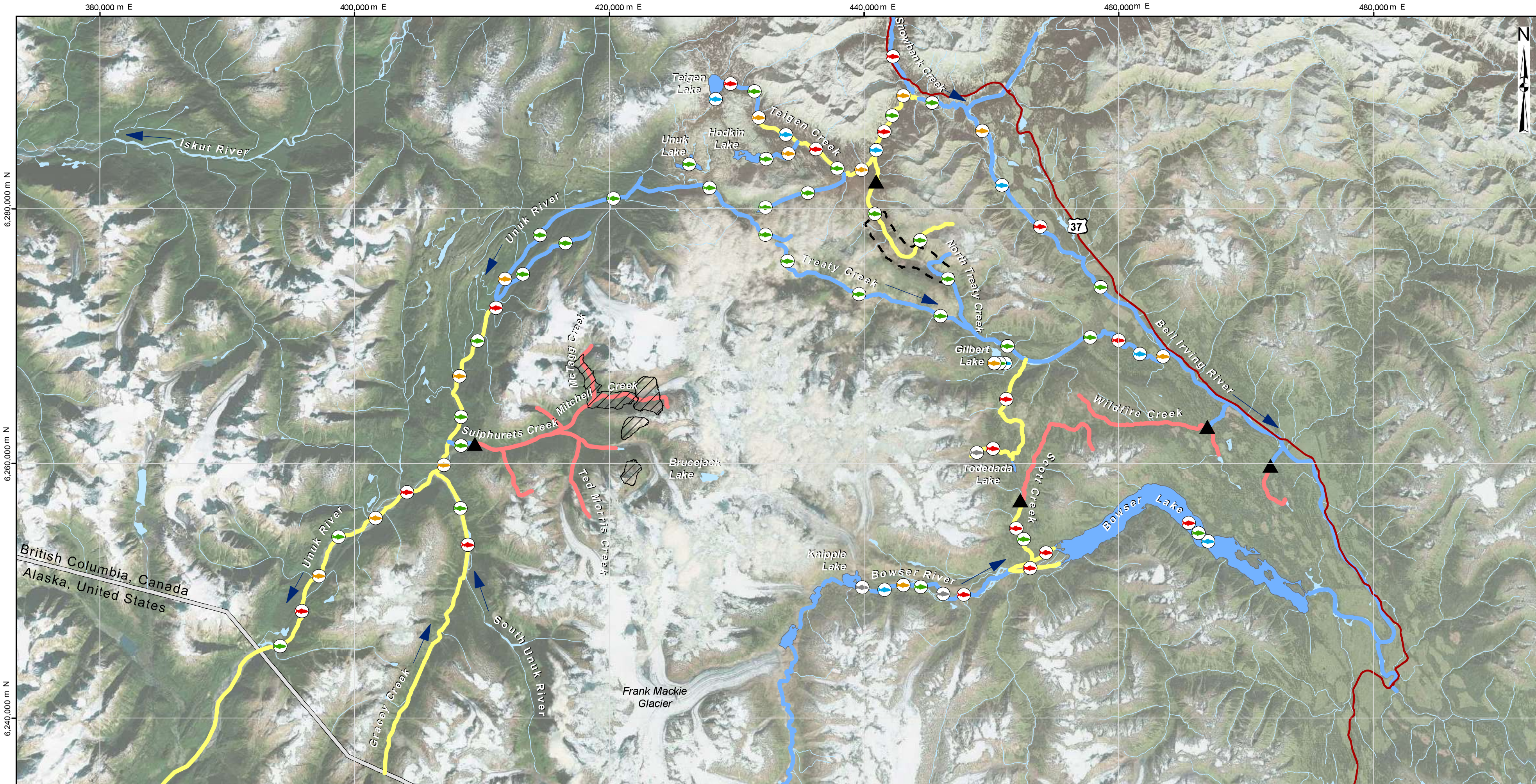

LEGEND

MINE AREA
TMF AREA

FISH SPECIES
SALMON
STEELHEAD TROUT
BULL TROUT
DOLLY VARDIN
MOUNTAIN WHITEFISH

STREAM TYPE
SPAWNING
FISH BEARING
NON-FISH BEARING
FISH BARRIER

HIGHWAY
CANADA / U.S. BORDER
RIVER

SCALE: 0 10km

NOTES:
1. PROJECTION: UTM ZONE 9N
2. HORIZONTAL DATUM: NAD 83
3. BASEDATA SOURCES: CANVEC, NATURAL RESOURCE CANADA. AVAILABLE: HTTP://GEOGRATIS.GC.CA (ACCESSED 2011)
4. BASELINE FISHERIES DATA: ERM 2014, RESCAN 2013, RESCAN 2012
5. IMAGE SOURCE: ESRI, DIGITALGLOBE, GEOEYE, I-CUBED, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEX, GETMAPPING, AEROGRID, IGN, IGP, SWISSTOPO, AND THE GIS USER COMMUNITY

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CLIENT
SEABRIDGE GOLD
Klohn Crippen Berger

PROJECT
BEST AVAILABLE TECHNOLOGY (BAT) STUDY FOR TAILING MANAGEMENT AT THE KSM PROJECT

TITLE
FISH BEARING STREAMS IN STUDY AREA

SCALE	PROJECT No.	FIG No.
AS SHOWN	M09480A07	2.2

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3 ASSESSMENT FRAMEWORK

3.1 General

The Best Available Technology (BAT) Study for Tailing Management of the KSM Project is separated into three parts:

- **Part 1:** BAT and BAP Review and Assessment of Filtered Tailing for the KSM Project
- **Part 2:** Tailing Management Alternatives Assessment
- **Part 3:** BAT Study Conclusions

3.2 Part 1 - BAT and BAP Review and Assessment of Filtered Tailing for the KSM Project

This portion of the BAT study goes beyond a traditional alternatives assessment, as was previously presented within the KSM EA (Rescan 2013, Appendix 33-B), to assess the practicality and risks associated with alternative tailing technologies specific to the KSM Project scale and location with the following components:

1. **Review Best Available Technology (BAT) and Best Available Practice (BAP)**

   A review of the history and definitions of BAT and BAP and applicability to the KSM Project.

2. **Review and Assess Tailing Technologies**

   A review of the equipment and physical limitations of tailing technologies and assessment of their applicability to the KSM Project.

3. **Review Case Histories**

   A review of existing and proposed projects employing alternative tailing technologies and a comparison of these projects to the KSM Project.

4. **Assess Feasibility of Filtered Tailing for the KSM Project**

   - Laboratory testing: this task included the following laboratory tests on KSM tailing: index testing, solid-liquid separation testing, and strength loss versus moisture content testing.
   - Filter plant and conveyor design: a conceptual level design and layout of a filter plant and stacking conveyor system at the preferred potential KSM TMF site.
   - Seepage and stability: seepage and stability analyses to assess the drainage requirements and stability of a filtered tailing pile at the preferred potential KSM TMF site.
   - Assessment of operability: this task assessed the climate at the KSM site and filter tailing placement procedures required to achieve a suitable tailing moisture content for compaction of the structural zones and trafficability of the pile surface.

5. **Risk Review**

A risk review was conducted to identify key risks associated with the proposed cyclone sand TMF and a filtered TMF. Contributors included:

- Seabridge Gold Inc.:
  - Peter Williams
  - Brent Murphy
  - Jim Smolik (by phone)
- KSM Project Independent Geotechnical Review Board (IGRB):
  - Andy Robertson
  - Jim Obermeyer
  - Ian Hutchison
  - Terry Eldridge (by phone)
- Klohn Crippen Berger:
  - Harvey McLeod
  - Howard Plewes
  - Graham Parkinson
  - Bob Chambers
  - Arvind Dalpatram
  - Kate Patterson
  - Drew Hegadoren
- Tetra Tech:
  - Jianhui Huang

3.3 Part 2 – Tailing Management Alternatives Assessment

Environment Canada's *Guidelines for the Assessment of Alternatives for Mine Waste Disposal* (Environment Canada 2013) (included in Appendix I-C) was used as the framework for the alternatives assessment; the process involves seven steps to select a TMF site by systematic analysis and elimination, as illustrated in Figure 3.1. The steps are further described below.

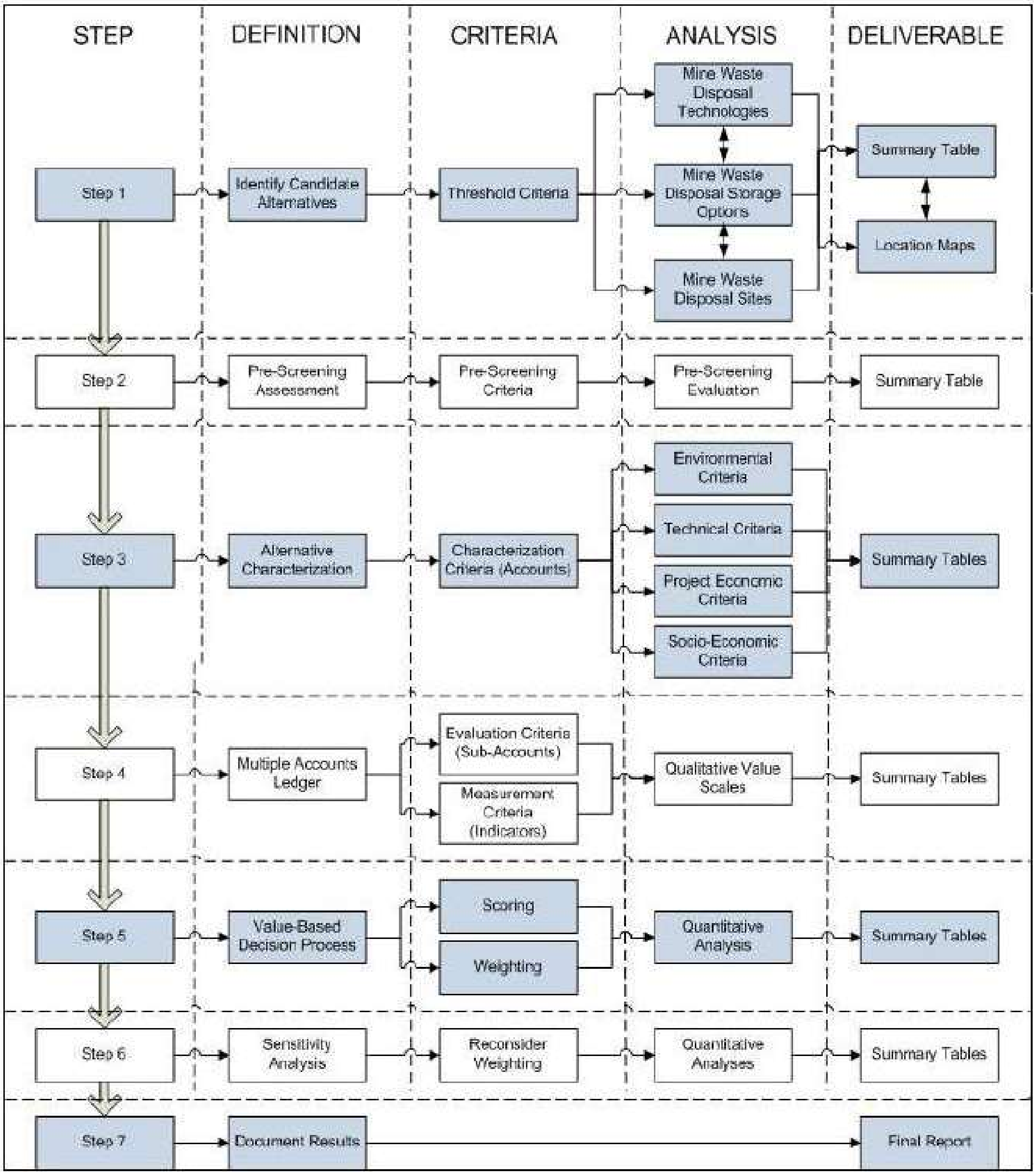


Figure 3.1 Environment Canada Guidelines for the Assessment of Alternatives for Mine Waste Disposal Framework (Environment Canada 2013)

Step 1: Identify Candidate Alternatives

This step is to identify preliminary TMF candidates (technology and location) near the Mine Area deemed feasible based on basic physiographic and technical threshold criteria. Sites that do not meet these criteria are eliminated. Step 1 involves the following activities:

- Identify candidate alternatives (technology, configurations, etc.) for potential TMF site locations.

- Establish basic threshold criteria based on topographic/geologic conditions, accessibility, and established technological precedent.
- Analyze candidates based on the threshold criteria.
- Eliminate candidates that do not meet the threshold criteria.
- Prepare a summary table and maps of remaining alternatives.

Step 2: Pre-screening Assessment

This step further narrows down the number of alternatives by applying a critical flaw assessment to eliminate alternatives that are undesirable or not feasible due to one specific trait. A critical flaw may be a fatal flaw, but isn't necessarily required to be. It could be an item that is associated with a high risk of major consequences and therefore wouldn't be further considered. Analyzed deficiencies are based on legislative, physiographic, and technical site selection criteria; no values-based criteria are applied as a critical flaw. Step 2 involves the following activities:

- Develop a list of project-specific pre-screening criteria (or critical flaws, which are characteristics so unfavourable that, if taken individually, would eliminate a site as a candidate).
- Conduct a pre-screening evaluation (critical flaw analysis) of the alternatives remaining from Step 1 using the project-specific site selection criteria.
- Eliminate candidates that do not meet the pre-screening selection criteria.
- Prepare a summary table that outlines the selection process.

Step 3: Alternative Characterization

Step 3 produces a thorough characterization of the candidate TMF alternatives not eliminated in the previous step. The goal of Step 3 is to identify parameters as a basis for further evaluation of the remaining candidates. Step 3 involves the following activities:

- Develop a list of thorough descriptive parameters (characterization criteria) for the remaining alternatives based on the following five broad categories (Accounts):
  - Environmental;
  - Technical;
  - Project Economic;
  - Socio-economic; and
  - Risks and Potential Impacts (this Account has been added to assess the comparative risks associated with conventional tailing facilities and filtered tailing facilities).
- Characterize remaining alternatives based on the characterization criteria.
- Prepare summary tables listing the descriptive characterization criteria for each Account.

Step 4: Multiple Accounts Ledger

Step 4 involves systematic evaluation of the characterization criteria developed in Step 3 based on a valuation system developed from professional judgment of relevant experts. Step 4 involves the following activities:

- Develop evaluation criteria (Sub-Accounts) to help differentiate among the characterization criteria identified in Step 3.
- Develop Indicators (also called measurement criteria or sub-sub-accounts) to allow qualitative and quantitative measurement of the benefit or loss associated (impact) with the Sub-accounts for each remaining alternative.
- Conduct a Multiple Accounts Analysis (MAA) by developing and applying qualitative value scales to analyze the evaluation and measurement criteria.
- Prepare summary tables: table of Sub-Accounts with rationale behind each, and an expansion of the Sub-accounts table that includes Indicators.

The MAA is the recommended decision-making tool under Environment Canada's guidelines, and involves developing a Multiple Accounts Ledger to facilitate evaluation. A Multiple Accounts Ledger is an explicit list of all the identified impacts associated with each TMF alternative, which generates a clear and measurable description of those impacts.

A Multiple Accounts Ledger was developed for the 2013 Alternatives Study's MAA (Rescan 2013, Appendix 33-B). To be consistent, this ledger was used as the basis for this updated assessment. Additional Sub-accounts and Indicators were added in consultation with relevant experts and Seabridge to address the differences between tailing dewatering technologies.

Step 5: Values-based Decision Process

Step 5 involves a final value-based evaluation to identify the preferred TMF candidate. This is done by scoring and weighting the Accounts, Sub-Accounts and Indicators developed in Step 4, and applying a quantitative analysis to develop weighted merit ratings for each TMF candidate. Step 5 involves the following activities:

- Develop a qualitative values-based weighting scale for every Indicator.
- Apply a values-based weighting factor to every Account, Sub-Account and Indicator develop a base case from weightings.
- Conduct a quantitative analysis for each candidate to generate weighted merit ratings (MAA).
- Prepare a summary table listing the final values-based weighting for the candidates to identify the best potential TMF candidate.

The value based scoring criteria and weighting factors from the 2013 Alternatives Study's MAA (Rescan 2013, Appendix 33-B) were also used as a starting point for the updated assessment. The additional Sub-Accounts and Indicators were scaled and weighted based on consultation with relevant experts and Seabridge.

Step 6: Sensitivity Analysis

Step 6 considers different value systems when weighting Accounts, Sub-Accounts, and Indicators. Step 6 involves the following activities:

- Develop alternate ranking systems based on professional judgment and stakeholder input.
- Re-analyze the data using a MAA as presented in Step 5.
- Prepare a summary table of the results.

Step 7: Document Process

Step 7 involves transparently reporting on the TMF alternatives analysis process using the preceding steps, and consists of producing a report documenting each of the steps and their results.

3.4 Part 3 - BAT Study Conclusions

This part summarizes the key conclusions and recommendations of the BAT study for tailing management at the KSM Project.

PART 1 - BAT AND BAP REVIEW AND ASSESSMENT OF FILTERED TAILING FOR THE KSM PROJECT

4 BEST AVAILABLE TECHNOLOGY AND BEST AVAILABLE PRACTICE

4.1 Introduction

Following the breach of the tailing facility at the Mount Polley copper and gold mine on August 4, 2014, the Province of British Columbia, together with local First Nations, established an Independent Expert Engineering Investigation and Review Panel (the Panel) to investigate the cause of the incident (MPC 2015). The Panel was asked to provide recommendations on actions that could be taken to ensure that similar failures do not occur at other mine sites in British Columbia. The BAT and BAP recommendation sections of this report are included in Appendix I-D.

The Panel (on page 121 of MPC 2015) recommended that the BAT for tailing management focus on the goal of ensuring the physical stability of tailing, and is based on three components derived from first principles of soil mechanics:

1. Eliminate surface water from the impoundment.
2. Promote unsaturated conditions in the tailing with drainage provisions.
3. Achieve dilatant conditions throughout the tailing deposit by compaction.

The chief goal of applying BAT is to achieve physical and geochemical stability for operations and closure. The Panel acknowledged the importance of geochemical stability of tailing and the potentially adverse effects of eliminating water covers and/or promoting unsaturated conditions on potentially acidic or neutral leaching tailing, but noted that “No method for achieving chemical stability can succeed without first ensuring physical stability: chemical stability requires above all else that the tailings stay in one place” (MPC 2015).

Given this, the Panel identified filtered tailing (also known as “dry” stack, however, tailing is never completely dry) as “a prime candidate” for BAT for tailing management and recommended that:

> *“BAT should be actively encouraged for new tailings facilities at existing and proposed mines. Safety attributes should be evaluated separately from economic considerations, and cost should not be the determining factor.”*

Regarding costs analysis, the Panel noted that:

> *“Cost estimates for conventional tailings dams do not include the risk costs, either direct or indirect, associated with failure potential. The Mount Polley case underscores the magnitude of direct costs for cleanup, but indirect losses—notably in market capitalization—can be even larger. Nor do standard costing procedures consider externalities, like added costs that accrue to the industry as a whole, some of them difficult or impossible to quantify. Full consideration of life cycle costs including closure, environmental liabilities, and other externalities will provide a more complete economic picture. While economic factors cannot be neglected, neither can they continue to pre-empt best technology.”*

The Chief Inspector of Mines Report on the Mount Polley dam breach (MEM 2015) identified water management as one of the contributing factors to the breach, highlighting the importance of water management as part of tailing dam safety.

Following the aftermath of questions from the publication of the Panel report, Dr. Dirk van Zyl (Professor, University of British Columbia) (2015) wrote a letter to the Minister of Energy and Mines, the Honourable Bill Bennett, and provided the following comment:

> *"In my opinion, BAT is not a single technology; it's selection is based on a site-specific risk management process with the outcome of a stable and resilient tailings deposit."*

Dr. van Zyl's letter was made publically available in the Juneau Empire and is included in Appendix I-E of this report.

A Tailings Workshop was held on March 20, 2015; this was a joint initiative between the BC First Nations Energy and Mining Council (FNEMC) and the Province of British Columbia. The purpose of this workshop was to convene First Nations leadership and community members, senior officials and Ministers representing the Province of British Columbia, mining industry experts, and the Mount Polley Expert Review Panel to seek a communal understanding on how to achieve the shared vision of safe and responsible mining for BC (FNEMC 2015). The outcomes and recommendations of this workshop were numerous and echoed the Panel report. It also highlighted the need for applicable technologies and practices and a focus on low risk closure plans for TMFs.

4.2 Definition of Best Available Technology (BAT) and of Best Available Practice (BAP)

4.2.1 BAT

For purposes of this study the definition of BAT means the combination of technologies, designs and management strategies that most effectively reduce the physical, geochemical, ecological and social risks associated (within a tolerable risk limit) with tailing management during all stages of operation and closure. BAT also includes consideration of cultural, heritage, economic values and site specific conditions. BAT includes site selection considerations, technologies and design features that provide a resilient and robust tailing facility during operations and post-closure. BAT should be implemented at every stage of the tailing life cycle.

Selection of a BAT should take into account the tailing properties (both physical and geochemical), the tailing disposal site conditions and the project specific requirements. Technologies selected for tailing may differ depending on the minerology, gradation, clay content, type of tailing, and if the tailing are PAG or NPAG, etc. Furthermore, separating PAG and NPAG tailing streams and adopting separate management strategies can aid in preventing oxidation and the onset of ARD. Technologies will differ depending on the disposal site conditions (e.g., topography, climate, geology, geohazards, etc.) and project conditions (e.g., tonnage rate, ore variability, economics, permitting requirements, etc.).

4.2.2 BAP

Dam safety requires multiple levels of defense (MPC 2015). The Panel made recommendations that have implications and suggested improvements for corporate responsibility, enhanced regulatory capacity, expanded technical review, and improvements in professional practice. These include:

- **Corporate Governance** - understanding and appreciation of tailing management at the corporate level. Implement and audit the project's environmentally responsible tailing management strategy.
- **Corporate TSF Design Responsibility** - proper tailing management planning and declaration of and adherence to Quantitative Performance Objectives (QPOs).
- **Independent Tailings Review Board (ITRB)** - Establishment of ITRB and real consideration of recommendations.
- **Ministry of Energy and Mines (MEM)** - MEM should be provided QPOs which they can use to monitor tailing facility performance.
- **Professional Practice** - improved understanding of geological, geomorphological, hydrogeological and seismotectonic conditions of tailing facility sites.
- **Canadian Dam Association (CDA) Guidelines** - target factors of safety that consider consequences of failure; loading conditions used; and strength parameters used.

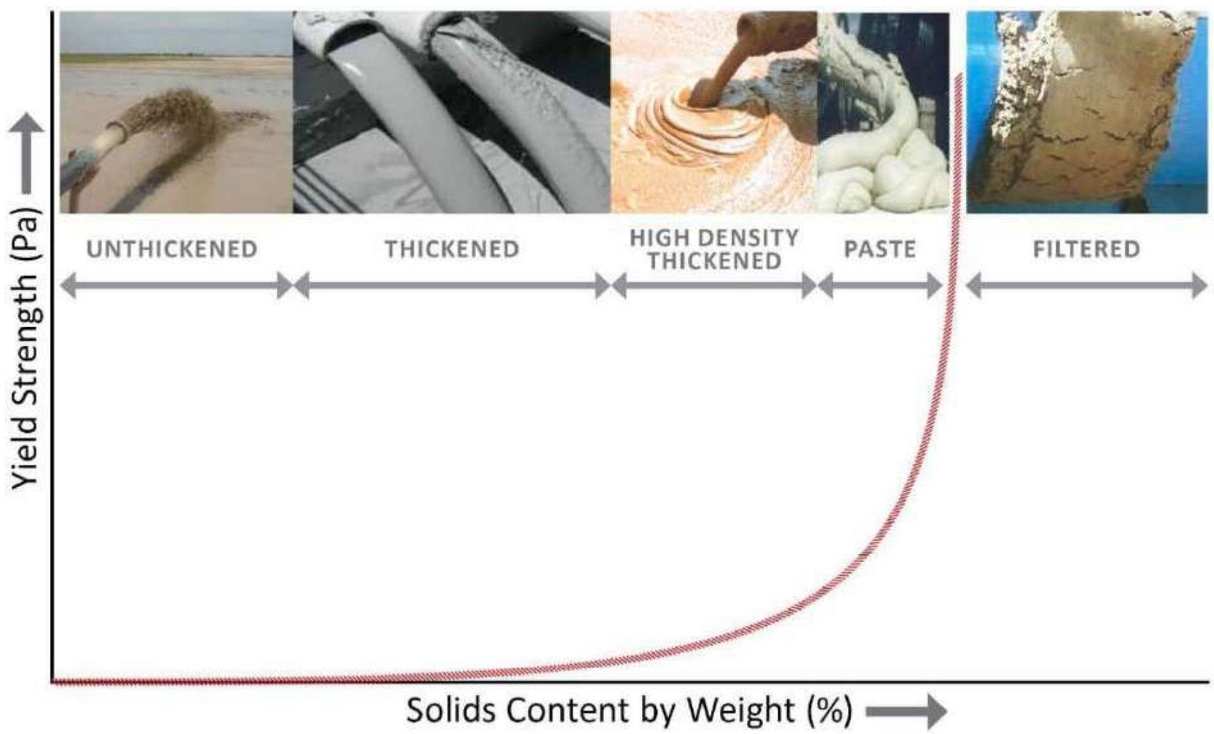
For purposes of this study the definition of BAP means the management systems and operational procedures developed considering current engineering and governance practices to ensure that tailing storage facilities are designed, constructed, operated, maintained, monitored and closed to meet dam safety objectives. Responsible parties include mining companies (owner/operators), regulators, consultants, professional licensing and regulatory associations, the Canadian Dam Association (CDA), etc.

4.3 Dewatering Tailing as a BAT

Thickeners and/or filters can be used to remove water from tailing before it is sent to the storage facility. Different states of dewatered tailing can be characterized by their yield stress, which is the applied stress that must be exceeded in order to make the tailing flow like a fluid, or their inability to act as a fluid. The different states are shown in Figure 4.1 and compared in Table 4.1. Cycloning can also be used to dewater tailing; the coarse underflow is discharged from the cyclone at a higher solids content than the inflow and is more readily dewatered, although the fine cyclone overflow must still be managed separately and may be more difficult to dewater than the original inflow.

Only by filtering can produce an unsaturated material (tailing voids hold both water and air) prior to deposition. Tailing produced by other processes are over-saturated (as a mixture of tailing and water) when deposited and future saturation (moisture content at which there is no air in the tailing voids) or desaturation (decrease in moisture content that introduces air in the tailing voids) of tailing relies on climatic, water management and other design factors. For example, in an arid climate saturated tailing deposited in thin lifts can become desaturated through evaporation. Moreover, in a wet climate, it is possible that initially unsaturated filtered tailing could become saturated through precipitation infiltration. Hence, the goal of achieving the Panel's second recommendation for BAT (i.e., promote unsaturated conditions in the tailing with drainage provisions) can be very difficult and may only be possible under specific site conditions.

Also it is important to note that unthickened tailing naturally settle to similar densities as thickened and paste tailing and that only by filtering and compacting are higher densities achieved.



Photograph reference: Fourie 2015 and Jewell and Fourie 2015

Figure 4.1 The Dewatering Tailing Continuum

Table 4.1 States of Dewatered Tailing

Dewatered State	Yield Stress Range[1] (Pa)	Process Equipment	Degree of Saturation During Transportation	Transport Method
Unthickened	~0	None - product of the processing plant with no additional de-watering effort	> 100%	Pumped in slurry pipeline using centrifugal pumps
Thickened	<30	Conventional or high rate thickeners and flocculants	> 100%	Pumped in slurry pipeline using centrifugal pumps
High Density Thickened	<100[2]	High density or high compression thickeners and flocculants	> 100%	Pumped in slurry pipeline using centrifugal pumps
Paste	>100[2]	Deep cone thickener or a combination of thickening and filtering	>= 100%	Pumped in slurry pipeline using positive displacement pumps
Filtered	Not applicable – acts as a solid	Vacuum or pressure filters	< 95%	Trucks or conveyors

Notes:
1. Based on thickener type ranges from Jewell and Fourie 2015.
2. The yield stress boundary between high density thickened slurry and paste varies based on material characteristics.

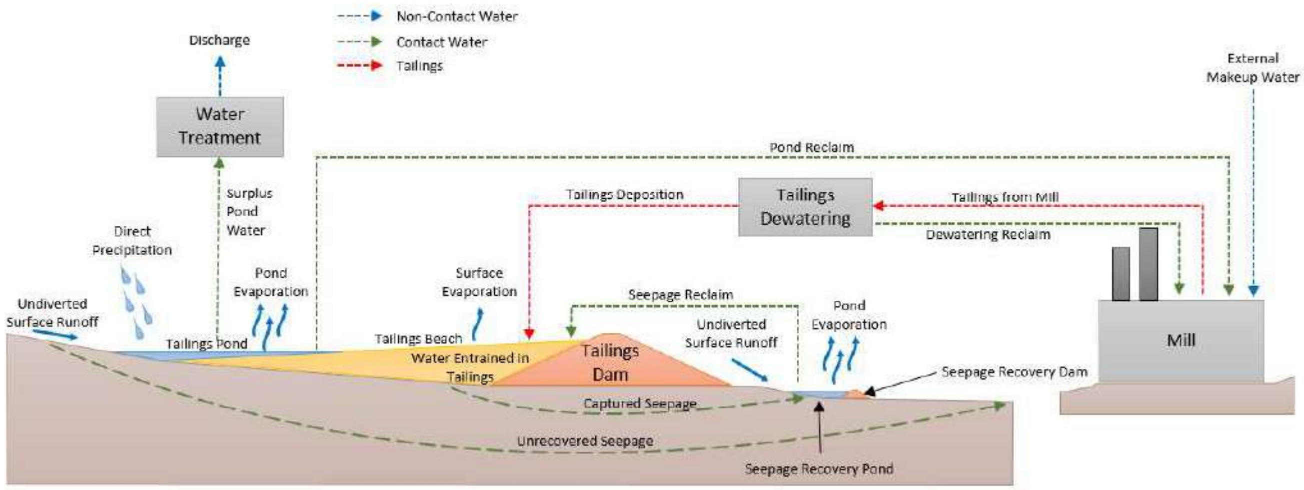
4.4 Role of Water and Risk Reduction

Water management is arguably the most important aspect of tailing management, both from the viewpoint of physical stability as well as geochemical stability. Proper management of water is required throughout construction, operations and closure. Poor water management has been a root cause or contributing factor to past tailing storage facility dam safety incidents (USCOLD 1994, ICOLD 2001); water can also exacerbate failures by mobilizing impounded tailing. For example, lack of the physical management of water was cited by the MEM Chief Inspector's Review of the Mount Polley failure (MEM 2015) as one of the root causes of the breach. Poor water management is also the leading cause of adverse geochemical effects on the receiving environment.

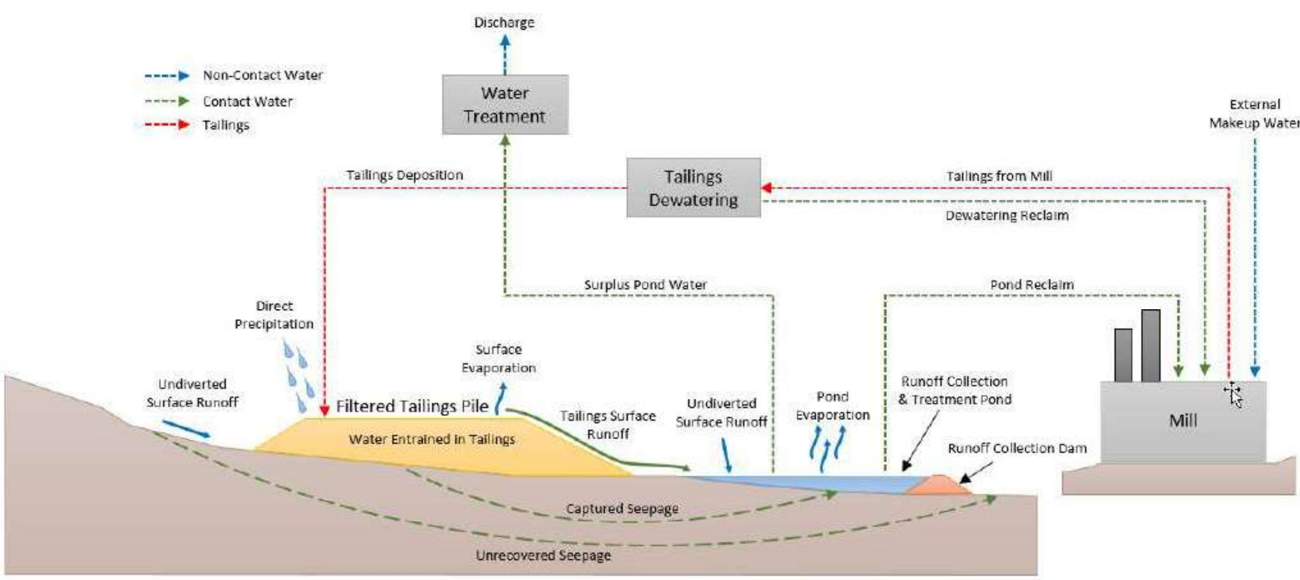
Typical configurations for conventional tailing facilities (a facility that impounds a water pond used for reclaim to the mill), and filtered tailing facilities are shown in Figure 4.2. This figure illustrates where water is stored for each type of tailing facility. The amount of water removed during processing (not sent to the tailing facility) is illustrated graphically in Figure 4.3. The ratio of tailing and water produced in the mill is the same for all dewatered tailing types. Therefore, each dewatered tailing types has the same amount of water that needs to be managed. Figure 4.3 represents the amount of solids, the amount of water entrained in the tailing after initial settling, the amount of water that would be released from the tailing at the tailing facility and the water reclaimed that would not be sent to the tailing facility. The values are typical for coarser tailing, like the flotation tailing, and do not include water entering the TMF from precipitation or surface runoff which must also be managed.

The quantity of water that must be stored on the mine site is a function of site and project conditions, however, the amount of water storage on the tailing facility is dependent on the type of facility. Table 4.2 summarizes where the water is stored for each type of facility and what the key water management concerns are for the facility types. Water can be stored in a pond on the tailing surface for conventional facilities. Typically, water is not stored on the tailing surface for filtered facilities, however, external collection ponds are required for surface water and sediment collection.

At the KSM site direct precipitation and surface runoff onto the TMF is a significant portion of the total water that must be managed at the tailing facility, particularly for a filtered tailing pile, limiting the effectiveness of tailing dewatering technologies for mitigating water management challenges.



Conventional or Thickened Tailing Facility (Majority of Water Managed in the TMF)

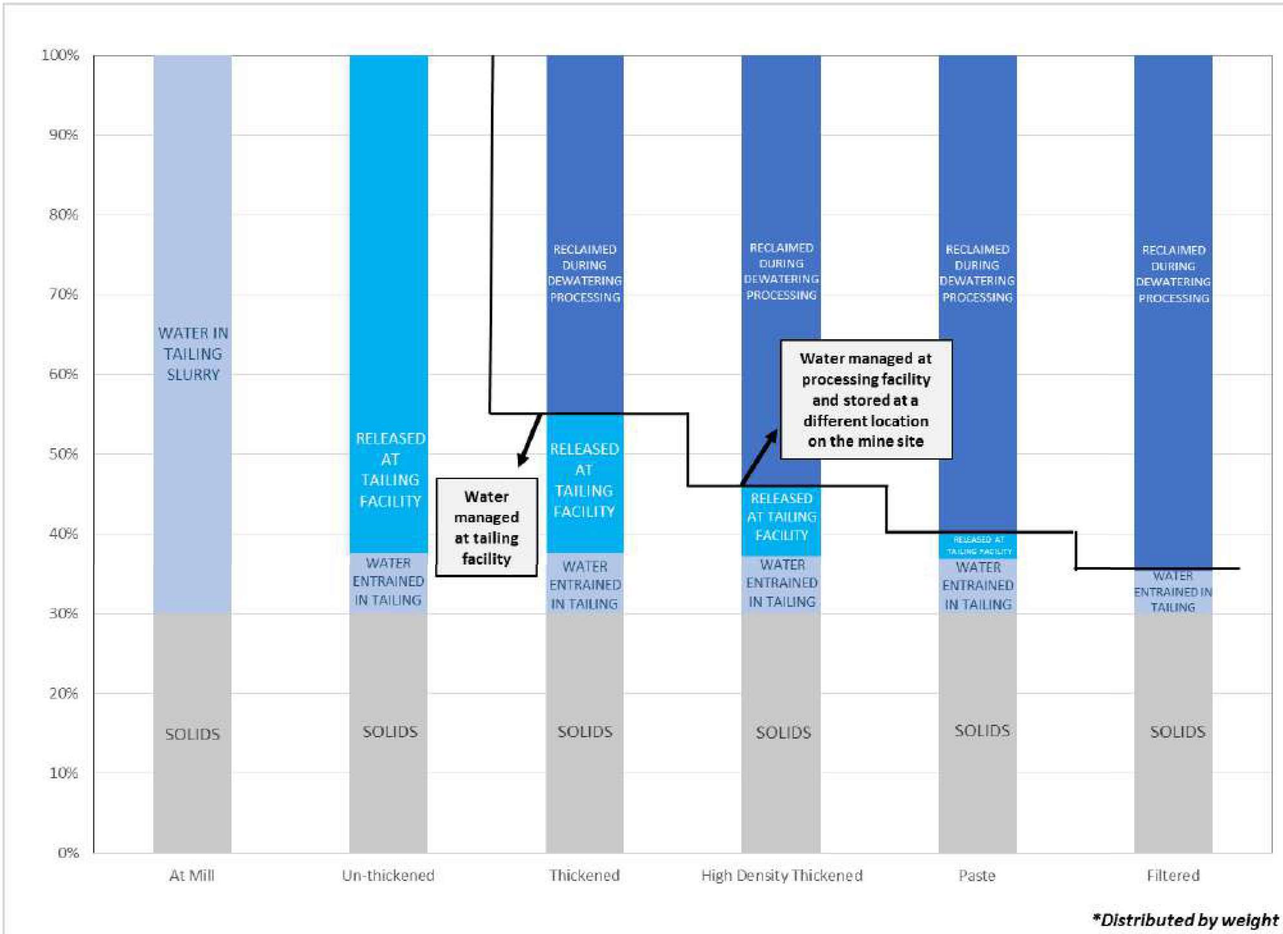


Filtered Pile Tailing Facility (Majority of Water Managed External to the TMF)

Figure 4.2 Water Management for Conventional and Filtered Tailing Facilities

Table 4.2 Location for Water Stored for Different Types of Tailing Facilities

Type of Tailing Facility (see Figure 4.2)	At Tailing Facility		At a Separate Water Storage Facility		Geochemical Management
	Storage Requirements	Possible Concerns	Storage Requirements	Possible Concerns	
Conventional Tailing (unthickened)	▪ Majority of water	▪ High consequence of failure if pond volume is released	▪ Not required	▪ Not applicable	▪ Can limit ARD ▪ Can increase neutral mine drainage (NMD) or saline drainage (SD) ▪ Large volume of water to be treated if ARD occurs
Thickened Tailing	▪ Potentially lower pond volume at tailing facility than un-thickened	▪ Consequence of failures somewhat reduced if the amount of ponded water on tailing facility is reduced relative to un-thickened	▪ Potentially required for a portion of process water	▪ Consequence of failure of water management pond, if applicable	▪ Moderately increased risk of ARD ▪ Moderate risk of NMD or SD ▪ Increased risk of dusting ▪ Large volume of water to be treated if ARD occurs
Filtered Tailing	▪ Minimal requirement	▪ Erosion control and sediment management ▪ High consequence of failure if collection dam pond volume is released	▪ All water	▪ Consequence of failure of water management pond ▪ Sediment management	▪ Increased risk of ARD and increased risk of ARD at other locations if erosion and transport occurs ▪ Moderate risk of NMD or SD ▪ Risk of dusting ▪ Large volume of water to be treated if ARD occurs



Note: Typical numbers are presented for coarse tailing with similar properties to the KSM flotation tailing. The amount of water reclaimed during dewatering processing would be lower for the CIL residue.

Figure 4.3 Comparison of Water Recovery for Dewatered Tailing States

One of the recommendations from the Panel report on the Mount Polley Tailings Storage Facility breach was to eliminate surface water from tailing impoundments, thus reducing the consequence of potential tailing dam failures by removing a mobilizing mechanism (the water). Conversely, to limit oxidation and prevent ARD, keeping PAG tailing submerged with an appropriate water cover, often greater than 1 m deep is one of the recommended strategies (INAP 2014). In some instances, maintaining a large surface water pond on a tailing facility to reduce geochemical risk intuitively conflicts with reducing the consequence of a potential dam breach. However, the reduced consequence of a potential failure by removing water on the tailing facility needs to be evaluated with all the risks of this strategy. If significant risks are incurred by removing water on the tailing facility the overall risk profile for that strategy may not be favourable.

The overall objective of tailing management is risk reduction. The BAT and BAP should be tools to reduce the risks associated with the tailing facility. Risk is defined as the product of likelihood and consequence; hence, likelihood and consequence should both be considered during selection of BAT and BAP. The overall risk profile of alternative tailing facilities should be taken into account when deciding on a tailing management strategy.

Therefore, BAT must consider processing and designs that are most suitable for a project and climate that enhance physical, geochemical, biophysical and social stability, thereby reducing the overall risk and moving to zero tailing failures. Therefore, BAT cannot be “one-size-fits-all” as it needs to be specific to the climate, geology, geomorphology and sensitivity of the downstream receptors of the tailing facility site, the tailing characteristics, and the social situation of the project as clarified by Dr. van Zyl’s letter (van Zyl 2015).

4.5 Tailing Technologies

A high level assessment of tailing technologies associated with processing and dewatering tailing was done for the KSM Project to determine if the technologies could be considered BAT. The technology advantages and disadvantages for the KSM Project are summarised in Table 4.3. Additional details on the technologies are provided in Appendix V.

Table 4.3 Review of Potential Tailing Technologies Applied to the KSM Project

Technology	Advantages	Disadvantages
Dewatering		
Unthickened	▪ Suitable solids content for cycloning to produce cyclone sand for dam construction material ▪ Applicable for conventional tailing facilities that impound water, allowing PAG CIL residue to be deposited sub-aqueously and kept saturated	▪ More water reports to the tailing facility and requires management ▪ Conventional tailing facilities impound water with tailing which may increase the consequence of failure
Thickened and High Density Thickened (Use of thickeners or cyclones to remove water from tailing slurry)	▪ Less water reporting to tailing facility compared to un-thickened ▪ Applicable for conventional tailing facilities that impound water, allowing CIL residue to be deposited sub-aqueously and be kept saturated	▪ Conventional tailing facilities impound water which may increase the consequence of failure
Paste (Use of thickeners and/or filters to remove water from tailing slurry)	▪ No advantages for the KSM Project	▪ No precedence for the KSM Project scale and costlier than un-thickened or thickened with no added benefits ▪ Paste deposited in a conventional tailing facility would impound water which may increase the consequence of failure ▪ Paste deposited as a central discharge would create significant erosion and seismic stability concerns
Filtered (Use of thickeners and filters to remove water from tailing solids, providing a partially saturated product)	▪ Filtered tailing facility would not continually impound water; it may impound water during intense storm events while the water is attenuated and routed from the surface	▪ Scale of filter plant is unprecedented and will be challenging. Filter plant downtime would likely result in unplanned shut-down of mining and milling. Target moisture content will not always be achieved due to ore variability and operational difficulty resulting in significant placement challenges ▪ Conveyor placement at the KSM tailing production rate in a wet, cold climate is unprecedented and presents significant challenges. Topography of the region is mountainous which requires complex conveyor layouts and staging ▪ Placement and compaction of tailing in a wet, cold climate will be challenging. Strict quality control during placement and potential re-handling of out-of-spec tailing may be required ▪ Drainage of the facility is critical to stability and will require significant underdrains and potential internal slope drains ▪ De-saturated CIL residue will likely generate acid and therefore surface runoff and seepage will have poor water quality and require treatment ▪ 2.1 Bt of de-saturated flotation tailing will cause elevated sulphate loadings and likely require water treatment ▪ An external water management facility will be required for collection of runoff and seepage water from the facility and provide storage capacity for mill reclaim and seasonal release. For the Teigen-Treaty Filtered TMF alternative a 135 m high collection dam is required
Particle Segregation		
Cycloning (Use of hydro-cyclones to provide separation of the coarse underflow and a fine overflow. The coarse underflow can be used for dam construction)	▪ Provide dam construction material that would decrease storage requirements for the tailing facility and minimize borrow area disturbances ▪ Provide dam construction material that is free draining, meets filter criteria for the tailing and glacial till cores, and consequently mitigates the risk of internal erosion of dam fill	
Segregation during milling / Sulphide flotation (Separation of target minerals using flotation cells to create multiple tailing streams)	▪ Separation of PAG minerals from NPAG minerals to minimize amount of PAG tailing that require special management	
Alternate Disposal		
Subaqueous (Depositing tailing subaqueously)	▪ Deposition of CIL residue sub-aqueously and maintaining a water cover will limit oxidation and prevent ARD	▪ Requires ponded water on tailing surface which may increase the consequence of failure
In-pit/Backfill (Depositing tailing within an exhausted open pit or backfilling an underground operation)	▪ Not applicable for the KSM Project: the pit geometries and mining schedule are not conducive to using a mined out pit for tailing storage	
Tailing and mine rock (waste rock) co-disposal (Depositing tailing within mine rock void space or layering tailing and mine rock)	▪ Not applicable for the KSM Project: the storage in the mine rock voids or potential layering configurations do not supply sufficient storage capacity for tailing management	

5 APPLICATION OF FILTERED TECHNOLOGY TO THE KSM PROJECT

5.1 Introduction

A detailed assessment of using filtered tailing for the KSM Project was completed as part of the BAT study to focus on meeting the changed societal expectations to consider this technology following the Panel report.

Filtered tailing was introduced in Section 4.3. Filtered tailing includes using thickeners and vacuum or pressure filters to remove water from the tailing. Filtering provides the highest degree of tailing dewatering (as shown on Figure 4.1), with post-dewatering solids content by weight in the range of 75% to 89%. The ability to filter tailing is primarily influenced by the particle size and plasticity; finer and higher plasticity tailing with clays are more difficult to filter. High plasticity tailing may also result in a sticky filter cake, which is difficult to manage at the filters as well as in transport and placement.

Filtered tailing is not a fluid, and therefore must be transported to the tailing facility using conveyors or trucks.

If the filtered tailing is placed in a stand-alone facility or pile, the portions of the pile comprising the outer slopes must maintain structural stability, particularly under seismic loading conditions, and therefore need to be dewatered sufficiently to allow compaction. For the KSM Project, filtered flotation tailing would be placed in these outer structural zones during the summer months (mid-April to mid-October) when weather conditions are more favourable for placement. Tailing would be placed in an interior, non-structural zone during the winter months (mid-October to mid-April).

This section summarizes the assessment of filtered tailing in general for the KSM Project; however, some of the assessments require a conceptual TMF plan (i.e., layout, water balance, supporting facilities). In Part 2 of this study, the alternatives assessment, filtered TMF alternatives are presented. The Teigen-Treaty Filtered TMF is used in this section as an example of a potential filtered TMF for the KSM project. Further Teigen-Treaty Filtered TMF characterization is included in Appendix IV-B.

A case history review was completed for this study to examine and compare projects using dewatering technologies to the KSM Project. The case studies present project examples illustrating the advantages and disadvantages of dewatering technologies and their applicability to different types of projects. The potential benefits and lessons learned from the case studies are included throughout this section. Select project examples, observations and lessons learned are further described in Appendix III-A. As climate has a large impact on the feasibility and selection of tailing management technologies, Appendix III-B contains a climate assessment, as part of the case study review, for select projects comparing their climates to the climate at the KSM site.

5.2 Filter Plant Design

5.2.1 General

A preliminary design for a filter plant was completed for the KSM Project for a filtered TMF located at the Teigen-Treaty site (Tetra Tech 2016) and is presented in Appendix VI. The process flow schematic is shown in Figure 5.1. The filter plant is designed to dewater 130,000 tpd of tailing.

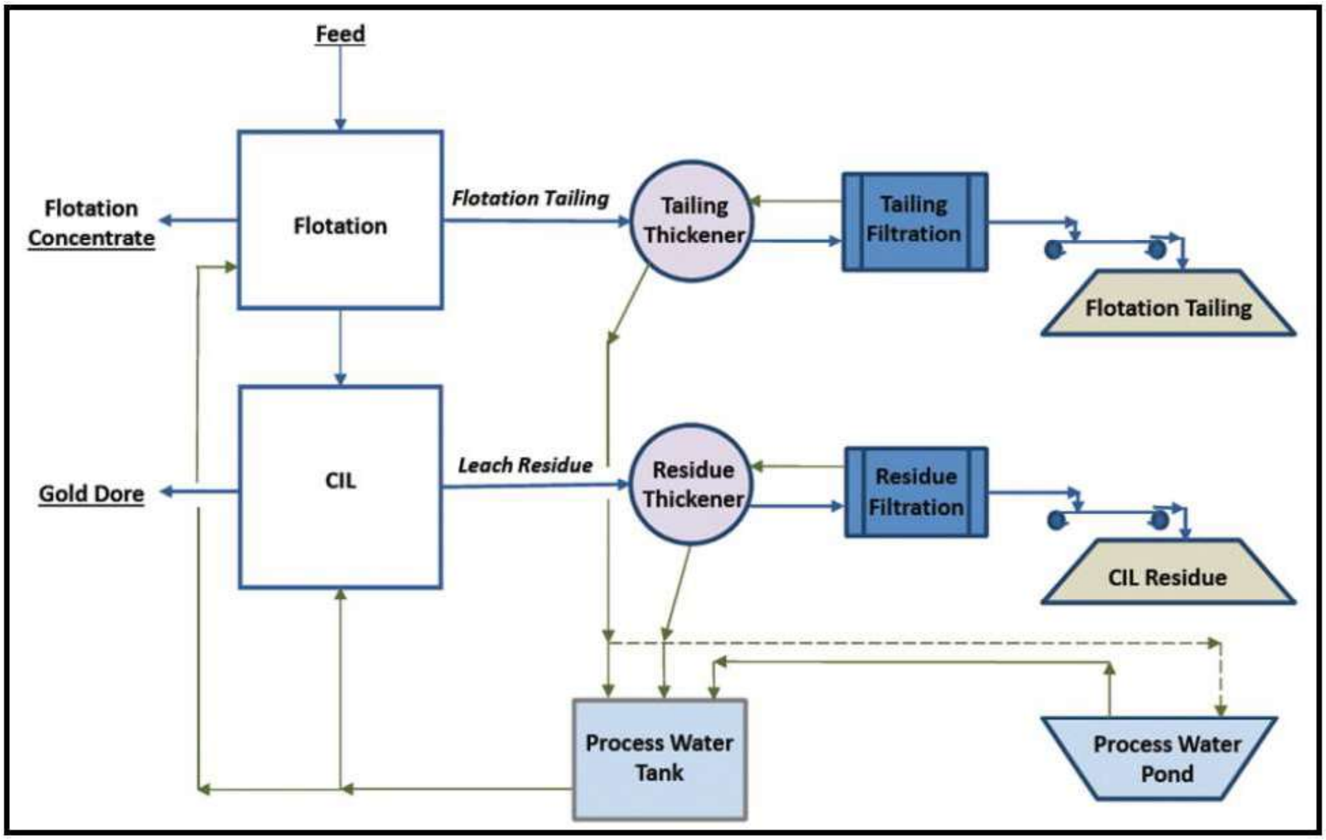


Figure 5.1 Schematic showing Relation between Mineral Processing and Tailing Production (Tetra Tech 2016 – Appendix VI)

5.2.2 Target Moisture Content

Filtered tailing piles without containment dams require structural zones, which could consist of compacted filtered tailing, that act as the containment structures. Tailing placed and compacted in structural zones needs to be placed at or close to the optimum moisture content. The optimum moisture content is the moisture content at which the tailing can be compacted to achieve maximum density. Compaction tests in a laboratory are completed to estimate the optimum moisture content of tailing (i.e. the Standard Proctor test). Results of compaction testing for the KSM tailing are provided in Appendix II and summarized in Table 5.1.

To achieve the low target moisture contents at the design tailing production rate, pressure filters are required; vacuum filters cannot reliably achieve the low target moisture content. Different filter types are further described in Appendix V.

Table 5.1 Compaction Results

Tailing	Optimum Dry Density (kg/m^3)	Optimum Moisture Content (%)	
		Weight of Water/Weight of Solids (W_W/W_S)	Weight of Water/Total Weight (W_W/W_T)
Flotation Tailing (Combined Kerr & Mitchell Rougher Ore Deposits) (1)	1860	14.0%	12.0%
CIL Residue (Combined Kerr & Mitchell) (1)	2044	17.5%	15.0%

Notes:

1. Kerr and Mitchell are ore deposits for the KSM Project and used to estimate tailing properties for the design of the TMF.

The target moisture contents (generally 1%-2% below the optimum moisture content) for the filter plant are given in Table 5.2. The target moisture content is slightly below the optimum moisture content to leave some allowance for fluctuations in plant performance and the addition of moisture from precipitation during transportation and placement.

Table 5.2 Filter Plant Target Moisture Content

Tailing	Target Moisture Content (%)	
	Weight of Water/Weight of Solids (W_W/W_S)	Weight of Water/Total Weight (W_W/W_T)
Flotation Tailing (Combined Kerr & Mitchell Rougher) (1)	13.0%	11.5%
CIL Residue (Combined Kerr & Mitchell) (1)	16.5%	14.0%

Notes:

1. Kerr and Mitchell are ore deposits for the KSM Project and used to estimate tailing properties for the design of the TMF.

5.2.3 Equipment Requirements

Filter plant design including the type of equipment, its size and capacity, the filter medium, the cake thickness and the cycle time is primarily dependent on:

- throughput;
- tailing properties:
  - particle size distribution;
  - clay content; and
  - inflow solids content.
- tailing target moisture content; and
- water chemistry.

Standard solid-liquid separation tests were performed to aid in the design of a filter plant. The results are included in Appendix VI. Selected pressure filtration results are given in Table 5.3 and Figure 5.2.

The filtered tailing moisture content ("Design Cake Moisture" in Table 5.3) is dependent on the tailing properties (gradation, clay content, mineralogy, etc.), the cake thickness, and the cycle time. Table 5.3 shows that flotation tailing from Kerr ore is more difficult to filter than that from Mitchell ore. It is possible to decrease final moisture content by decreasing the cake thickness, increasing the cycle time, or adding an air blowing step. All of these will increase the energy and equipment requirements for the filter plant.

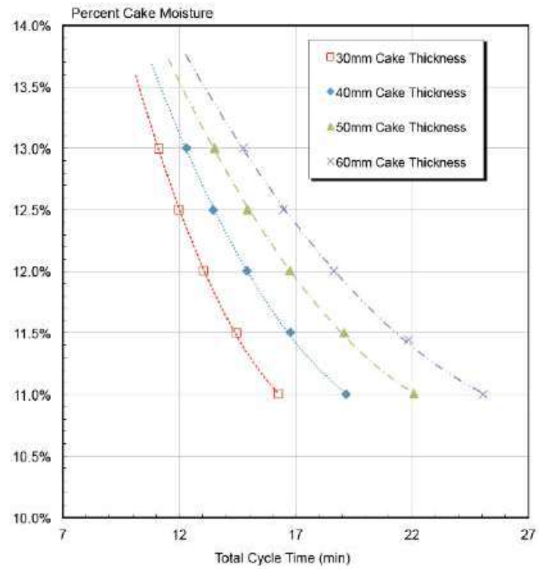
Table 5.3 Pressure Filtration Test Results

Tailing	Feed Solids Content (%)	Sizing Basis[(1)] (dry m^3/t)	Bulk Cake Density (dry kg/m^3)	Cake Thickness (mm)	Design Cake Moisture[(2)], Ww/Wt (%)	Total Cycle Time[(3)] (min)	Volumetric Production Rate[(4)] (tpd/m^3)	Area Basis Production Rate[(5)] (tpd/m^2)
Rougher Flotation Tailing Kerr	63.9	0.780	1602.2	30	14 - 17.5	9.7 – 15.5	135.4 - 174.8	2.30 – 2.97
				40	14 - 17.5	10.6 - 14.3	118.3 – 160.2	2.29 – 3.10
				50	14 - 17.5	11.4 - 16.1	104.9 - 147.8	2.46 – 3.47
				60	14 - 17.5	12.4 -18.1	93.7 – 136.1	2.57 – 3.73
Rougher Flotation Tailing Mitchell	63.2	0.782	1597.7	30	11 - 13	11.1 - 16.3	103.8 – 151.6	1.76 – 2.57
				40	11 - 13	12.3 - 19.2	88.0 – 136.9	1.70 – 2.65
				50	11 - 13	13.5 - 22.1	76.4 – 124.8	1.79 – 2.93
				60	11 - 13	14.8 - 25.1	67.3 – 114.2	1.84 – 3.13
CIL Residue (Combined Kerr & Mitchell)	54.5	0.812	1539.8	30	14.5 -16.5	12.6 - 18.3	88.7 – 129.0	1.51 – 2.19
				40	14.5 -16.5	14.4 - 22.0	73.8 – 112.9	1.43 – 2.18
				50	14.5 -16.5	16.2 - 25.8	63.1 – 100.2	1.48 – 2.35
				60	14.5 -16.5	18.2 - 29.6	54.9 – 89.6	1.50 – 2.45

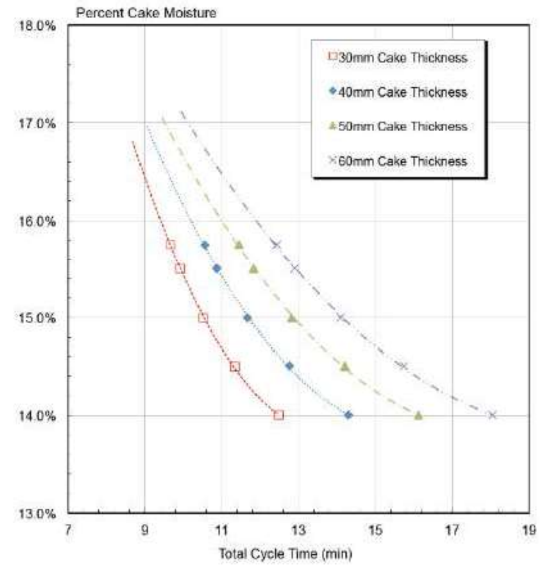
Source: Tetra Tech 2016

Notes:

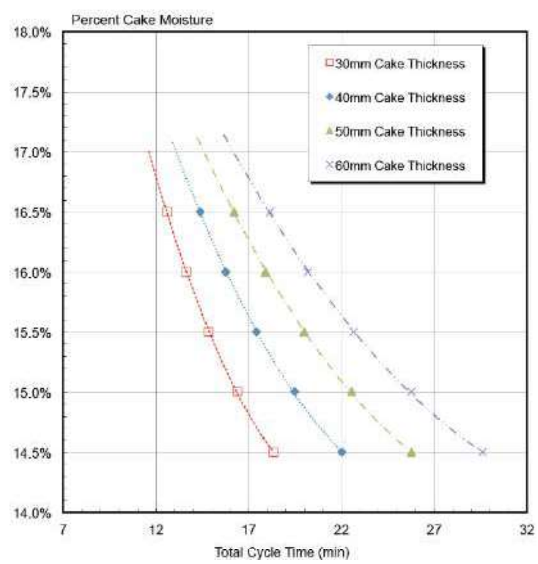
1. Filter press sizing basis in m^3/t of dry solids includes a 1.25 scale-up factor.
2. The cake moistures selected for design yielded reasonable discharge and stacking properties at reasonable dry times; % Ww/Wt = water weight/(water weight + solid weight).
3. Filter press cycle time is based on a 22-hour operating day, and includes an assumed 6.0-minute dead time for opening and closing a press.
4. Predicted volumetric production rate in metric tonnes per day of ore processed per cubic meter of available filtration volume. These values are specific to the sizing basis, cake thickness, and total cycle time values indicated.
5. Predicted area basis production rate in metric tonnes per day of ore processed per square meter of available filtration area. These values were based on the volumetric production rates indicated as well as an assumed specific chamber capacity of 0.162 m^3, 0.187 m^3, 0.228 m^3, or 0.268 m^3 depending selected chamber thickness of 35 mm, 40 mm, 50 mm, or 60 mm respectively.



A. Flotation Tailing - Mitchell



B. Flotation Tailing - Kerr



C. CIL Residue - Combined Mitchell & Kerr

Source: Tetra Tech 2016

Figure 5.2 Filtration Cake Moisture vs. Filtration Cycle Time

Based on the laboratory testing, the equipment required to filter the tailing to the target moisture contents is summarized in Table 5.4 . To achieve the target moisture content, the filtration plates will be equipped with squeezing membranes and the squeezed cakes from each filter will be further dried by blowing air prior to being discharged onto the collection conveyors. Pressure filters operate using a batch process; therefore, standby filters are required for flexibility with the batch timing.

Appendix VI includes the filter plant arrangement and a description of the operational process.

Table 5.4 Summary of Filter Plant Equipment

Tailing	Thickeners	Filters
Flotation Tailing (Combined Kerr & Mitchell Rougher)	2 x 70 m diameter high rate thickeners and flocculants (from approximately 37.5% Ws/Wt to approximately 58% Ws/Wt)	100 x 2.5 m by 2.5 m filter presses, each filter with 101 membrane plates. (includes 27 filters on standby)
CIL Residue (Combined Kerr & Mitchell)	1 x 70 m diameter high rate thickener and flocculants (included in the ore processing mill)	30 x 2.5 m by 2.5 m filter presses, each filter with 101 membrane plates. (includes 9 filters on standby)

Source: Tetra Tech 2016

5.2.4 Operating Range

A filter plant is a complex operation because of:

- operation and maintenance of the equipment, especially with the filter cloths and air blowing;
- batch processing and conveyor management; and
- ore and tailing properties variability.

As shown by the dewatering test results in Figure 5.2, the tailing samples responded differently to the dewatering procedure. The flotation tailing sample from the Mitchell deposit showed better dewatering performance, compared to the sample from the Kerr deposit. The test results from the Kerr sample suggest that tailing from the Kerr deposit may be difficult to dewater to the target moisture content within a reasonable filtration cycle time.

The moisture content required for compaction of flotation tailing structural fill is 12% (weight of water divided by total weight of water and solids - W_W/W_T). The filter plant design target would be 11.5% (W_W/W_T) but the plant would not meet this target all of the time due to ore variability (therefore tailing property variability) and operational complexity. Several of the filtered tailing case studies reported challenges with filter plants achieving target moisture contents and maintaining consistent moisture contents.

During times when the required moisture content from the filter plant is not achieved, flotation tailing would need to be place in non-structural areas. Due to the raising scheme of the pile, if these periods persist the tailing production rate (and therefore ore processing rate) would need to be reduced to allow a longer filtration cycle time unless an secondary TMF for unfiltered tailing is provided.

The flotation tailing filter plant target moisture content and expected operating range is shown in Figure 5.3. The figure illustrates how filter plant performance variability and precipitation affect the moisture content of tailing, both of which impact the ability to compact the flotation tailing adequately for geotechnical stability.

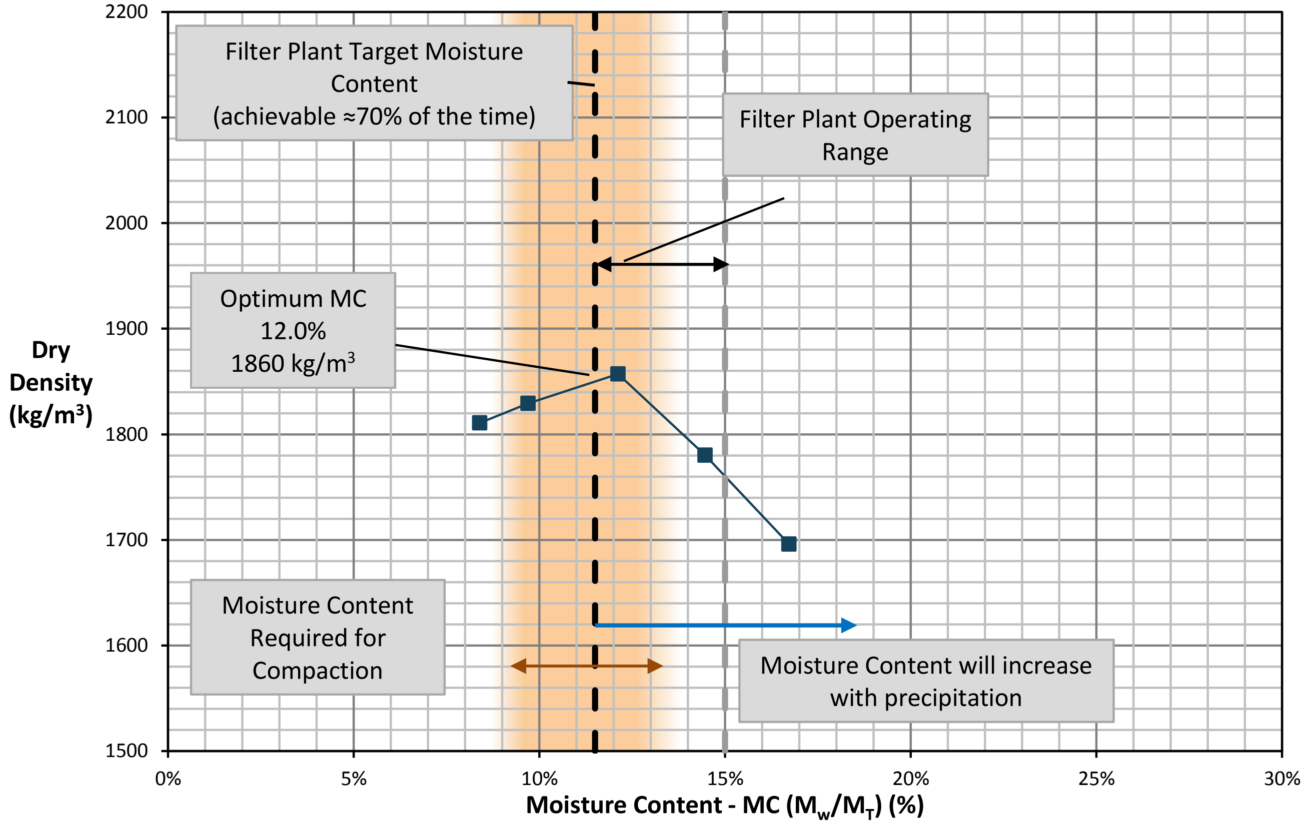


Figure 5.3 Flotation Tailing Moisture Contents

5.3 Transportation

At the scale of the KSM Project, conveyors would be more practical than trucks for transporting filtered tailing. A preliminary design for the conveyor system for the KSM Project was completed (see Appendix VI).

Filters would be arranged in groups of five. Each group would have a dedicated conveyor to collect the filter cake from the filters. These collection conveyors would feed transfer conveyors to the primary overland conveyors, which transport the tailing along the southeast side of the facility.

The filtration product from each of the overland conveyors would be discharged onto a tripper conveyor and then onto stacking tripper conveyors running across the tailing pile width. The stacking conveyors would be equipped with walking stackers that travel along the stacking conveyors' length. The tailing would be placed onto the tailing pads by the stackers according to the tailing disposal management plan. The tailing would be spread with dozers and compacted with large padfoot and smooth drum roller compactors to provide sufficient compaction for stability in the structural zones and to provide a trafficable surface for the conveyors and stackers in the non-structural zones. A standby stacking tripper conveyor equipped with a walking stacker has been provided for each structural zone as a backup unit when the other stacking tripper conveyor is shut down for maintenance; this is required to provide redundancy because of the importance of placing structural fill during the summer months.

There has not been an extensive conveyor operation at the KSM Project scale for tailing (or similar material) in a similar environment to the KSM Project. The operational complexity and climate increase the likelihood of a conveyor system shut-down and therefore an entire mine operation shut-down, as alternative temporary ore or tailing storage could not be feasibly provided for more than a day or so.

5.4 Climate Impacts and Constructability

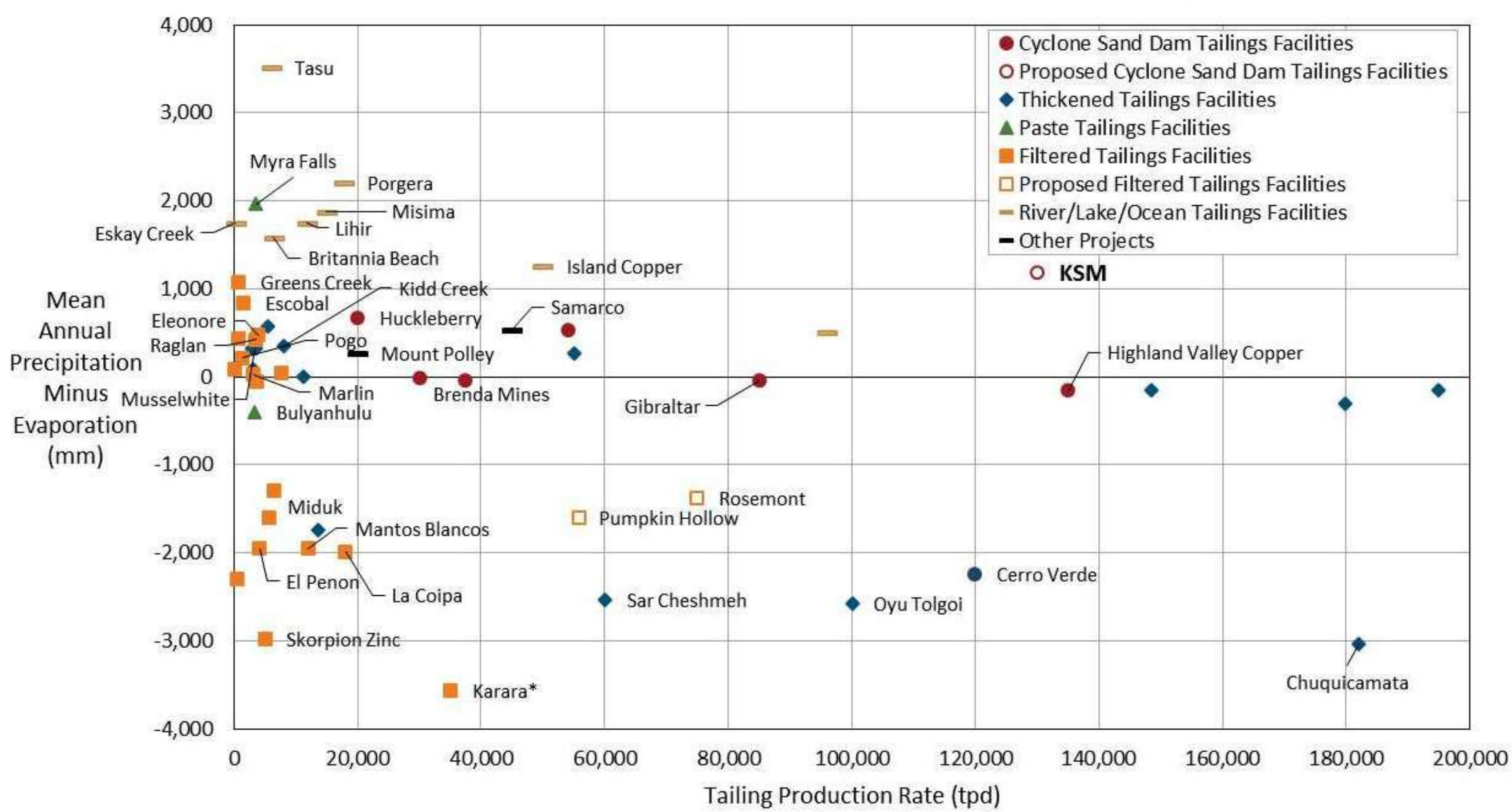
A filtered tailing facility for the KSM Project must be able to cope with adverse weather conditions including low temperatures, rain and snow. At the high KSM production rate, providing temporary storage of filtered tailing for any length of time is not considered feasible, thus operations must be able to continue in poor weather conditions. This section discusses some the concerns about the feasibility of continuing placement of filtered tailing in poor weather conditions.

5.4.1 Case History Review

As part of the case study review (Appendix III) net precipitation (annual average precipitation minus annual average evaporation) versus tailing production rate for various projects was plotted as shown in Figure 5.4. This figure illustrates the climate and tailing production rate trends for different disposal methods.

Figure 5.4 shows that operational filtered tailing projects in dry, arid climates have design tailing production rates up to 35,000 tpd; however, based on publically available information, the 35,000 tpd project has not reached its design capacity. The highest production rate that has been achieved for a filtered tailing project is on the order of 20,000 tpd. Projects have been proposed at production rates up to 75,000 tpd, but all are sited in dry, arid climates and have not yet been constructed. Operational filtered tailing facilities in wet, cold climates are few and exist up to 4,000 tpd tailing production rate; however, they typically have temporary alternate tailing storage for short periods for use during adverse weather conditions. Typically, larger mines use conventional facilities with thickened tailing where water recovery is a priority (drier climates), and unthickened tailing where water recovery is less crucial (wetter climates).

There is no precedence for filtered tailing at the scale of the KSM Project production in wet, cold environments. Precipitation and low temperatures add to operational and constructability difficulties as further described in the following sections.



*Design production capacity shown. As of 2014, the Karara project has not met this design capacity (Mining Weekly 2014)

Figure 5.4 Case Histories Net Precipitation versus Tailing Production

5.4.2 Temperature

The tailing facility must be able to operate in cold winter temperatures. Temperatures below -20°C occur annually, and lows of -28°C have been recorded at the project site.

A primary concern with low temperatures is the impact to conveying tailing. Transfer points on the conveyor system are particularly vulnerable as tailing would be prone to freezing to the sides of transfer chutes. Freezing of tailing on the conveyor belt may also result in frozen blocks of tailing which may not transfer well from one conveyor to another. In the event of a shutdown of a segment of conveyor, tailing on the conveyor may freeze solid causing problems at restart.

Frozen soil cannot be adequately compacted for structural zones of the tailing pile. It is anticipated that when the temperature drops to several degrees below zero a portion of the moisture in the tailing would freeze by the time it is transported from the filter plant, placed, spread and compacted. Furthermore, frost heave may loosen compacted soils requiring the material to be re-compacted or removed prior to continuing placement.

5.4.3 Rain

Annual precipitation often exceeds 1500 mm, with approximately half falling as rain. Periods of rain may last from days to weeks necessitating placement of tailing under heavy or continuous rainfall conditions.

During prolonged heavy rainfall it is anticipated that tailing placement will need to be limited to non-structural zones of the pile. Also, the tailing surface in the structural zone will soften, potentially creating weak layers if these layers are not remediated. After prolonged heavy rainfall, removing the top layer of soft material will be required in structural zones before placement can resume. Removed material will need to be re-filtered or placed in non-structural areas of the pile.

Rainfall will also reduce trafficability of the tailing surface for heavy equipment. Laboratory testing was conducted to assess trafficability of the tailing placed at different moisture contents (see Figure 5.5 and Appendix VII).

During storm events above 10 mm/hr, flotation tailing cannot be placed in the structural zone due to the potential increase in moisture content (even for a short period). Due to the time and effort it takes to switch between conveyors and move equipment, forecasted storm intensity of 5 mm/hr would be used as a trigger to switch to the non-structural zone. This would be a frequent occurrence in shoulder seasons (late April, May, early June, September and early October).

Although mobile conveyor systems can be designed to cope with soft ground to some degree, the weight of the equipment combined with the vibration of the conveyor system is likely to result in considerable settlement in soft conditions (during prolonged wet periods). The mobile conveyors may become stuck, or differential settlement of the tracks may result in the conveyors twisting, potentially damaging the equipment. Consequentially, it is anticipated that ongoing construction of roads over the tailing surface for the mobile conveyors to travel on will be required for a significant portion of the pile.

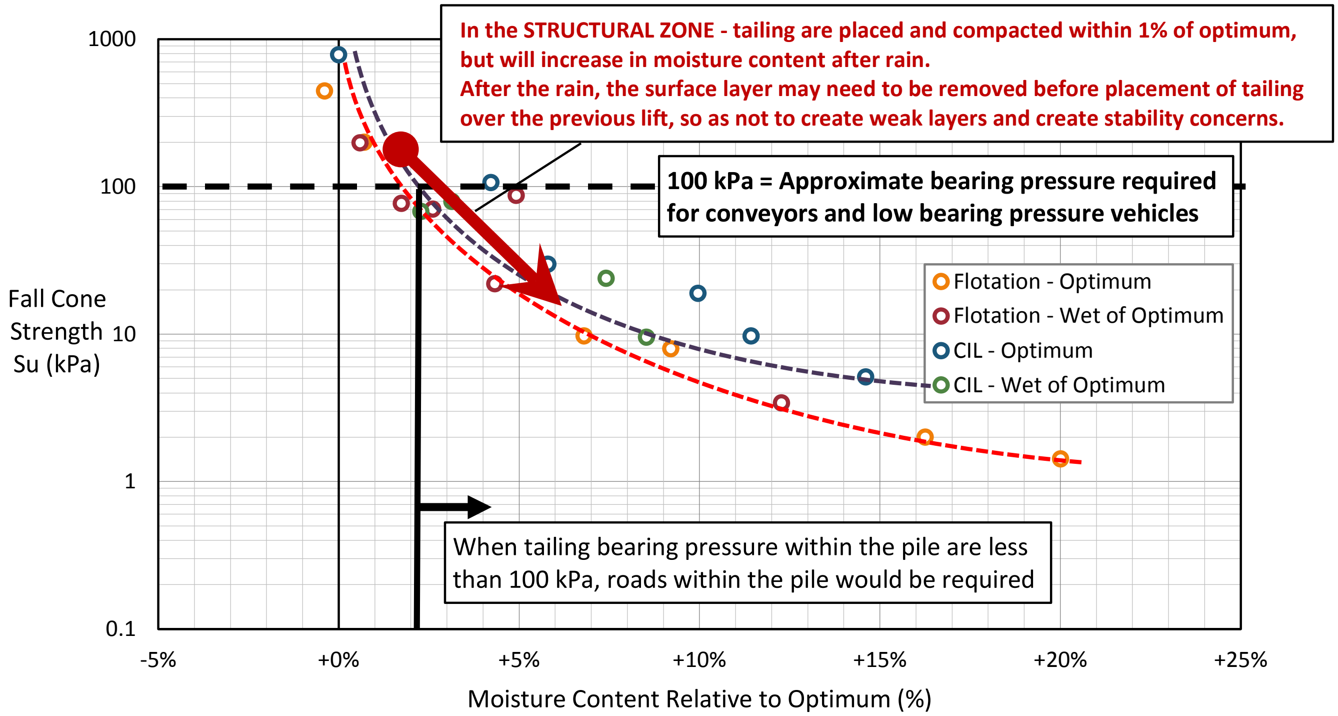


Figure 5.5 Results of Trafficability Testing

5.4.4 Snow

Annual snowfall at the KSM site exceeds 800 mm snow-water equivalent (SWE), and consolidated snow depths regularly exceed 2 m. Trafficability on the tailing pile could be affected by the accumulation of snow. Snow incorporated into the tailing pile may also result in weak layers and settlement. Blowing snow may create significant ice buildup on equipment, potentially interfering with operation. Snow avalanches are also a concern as equipment must be able to access the entire pile for placement.

At the minimum, snow must be removed to allow equipment to access the placement area, as well as allow the mobile conveyor system to traverse the pile. Snow must be stored on the pile as transporting large snow volumes in excess of 1 km to the TMF perimeter is not practical; also the snow is considered contact water and must be contained within the TMF catchment.

Snow must not be incorporated into the structural zones of the tailing pile, as thick snow layers would result in settlement and potential weak zones. If the snow has not melted by the time tailing must be placed in the structural zones, the snow must be removed.

During spring freshet, the melting snow would leave the tailing pile surface wet and soft. In structural portions of the pile, the soft surface layer would need to be removed before further placement of material in the compacted zone.

5.4.5 Climate Change Considerations

Based on the International Climate Change (IPCC 2000, 2014) predictions on greenhouse gas emissions and the ClimateBC model (UBC 2014), the average annual temperature and precipitation at the KSM Project site is expected to slightly increase. Due to the predicted temperature increase of approximately 2°C to 8°C (over the next 70 years), the distribution of rainfall and snowfall will be shifted towards rainfall. As well, the snowpack may no longer form or will become shallower in combination with increased temperatures and wind speeds. Snowfall events may become rain or melt events, increasing the frequency of high flows in the winter and decreasing the spring freshet peak (BCMFR 2010). Evaporation is also predicted to increase slightly.

Even with the extreme greenhouse gas emissions scenarios (IPCC 2000, 2014), potential climate change predictions are not expected to have any advantageous effects for filtering tailing at the KSM Project site. In fact, any increase in precipitation intensities will have a negative impact on placing filtered tailing.

5.5 Seepage and Stability

Constructing a filtered tailing pile to the KSM required height and operational rate of rise requirements introduce significant concerns regarding the stability of the external pile slopes.

An assessment of the factors that would influence the pile phreatic surface and stability, and mitigation measures and construction procedures that may be necessary to meet stability criteria is included in Appendix VIII. This was a preliminary assessment to highlight significant concerns and to comment on potential methods for mitigation. For the assessment a 300 m high pile with external slopes of 3H:1V was used, which is representative of the configurations for the filtered tailing alternatives assessed in Part 2 of this study. This assessment is site independent and therefore does not consider factors such as adverse foundation geotechnical or hydrological conditions that may be present at a potential TMF site (which is the case at most of the potential TMF sites and would need to be accounted for in design). It also does not consider the inclusion of weak layers in the structural area due to precipitation and poor quality control.

Post-earthquake seismic stability was found to be the primary controlling condition for pile stability. Tailing placed in structural zones must be adequately compacted to create dilatant conditions at the stress levels that would be experienced within the pile. To achieve dilatant conditions, the moisture content of tailing placed in structural zones must be controlled and any frozen or soft, saturated tailing on the surface must be removed before placement of subsequent lifts. During periods of rainfall, controlling moisture content would require rapid compaction of tailing after placement to limit rewetting of the tailing. Rainfall in excess of 5 mm/hr will require halting placement in the structural zones until the weather improves. As a single continuous weak layer could reduce the stability of the tailing below an acceptable level, good construction and quality control practices throughout the life of the pile would be integral to pile stability.

The phreatic surface and pore water pressures within structural portions of the tailing pile must be kept low for stability, as to not generate high pore water pressures. Maintaining a low phreatic surface also reduces potential for strength loss during seismic events as compacted, non-saturated materials are typically not prone to liquefaction; although, with the high degree of saturation in the tailing pile above the phreatic surface, strength loss within the unsaturated tailing under seismic conditions is still a significant concern. As the low hydraulic conductivity of the fine grained flotation tailing (as compared to cyclone sand) would result in slow drainage, lowering the phreatic surface in structural zones of the pile would require substantial underdrains and potentially internal drains. In addition to infiltration though the filtered tailings, the underdrains would need to collect upwelling groundwater to limit artesian pressures, and therefore pore pressures, in the pile foundation. As it is not realistic to install drainage elements in an existing pile, they would have to be constructed as the pile in constructed and oversized to account for uncertainties in the design and potential long-term plugging, degradation and settlement.

5.6 Water Management and Geochemistry

As described in Section 4.4, water management for filtered tailing facilities differ from conventional facilities.

During the filtering process, water is recovered and re-used in the mill. However, if the site has a positive water balance and seasonal storage is required, as is the case with the KSM Project, additional water storage facilities are necessary. A water management plan and water balance was completed for the Teigen-Treaty Filtered TMF (Appendix IV-B and Appendix X). Two collection ponds are required to collect pile runoff and seepage water. As part of the EA conditions, water is to be stored seasonally and released during freshet to mimic natural flows. To meet this water management objective, a 135 m high main collection dam would be required, with capacity to store 10.8 Mm^3 of water. A conventional facility would have the capacity to attenuate the seasonal flows, minimizing the size of the downstream seepage dams (20 m to 40 m high) that are required.

Conventional facilities have reclaim water ponds within the tailing impoundment where fine tailing particles settle. During storm events runoff from the beach will collect in the reclaim water pond and tailing particles brought into suspension will settle out. Filtered facilities do not have this feature. Runoff from a filtered pile will be high in suspended tailing particles that will settle out in the external collection pond. During review of the filtered tailing facility case histories, it was noted that erosion control is challenging during rain events and sediment control in collection ponds requires constant maintenance.

Managing high intensity storm events on large filtered tailing facilities is difficult as filtered tailing facilities, by design, typically do not have substantial flood attenuation capacity. The objective during high intensity storms would be to prevent runoff on the top surface of the pile from flowing over the outer embankment crests and eroding the structural zones of the pile. This would be achieved by sloping the pile near the embankments towards the interior of the pile. The interior of the pile would be sloped to direct runoff towards collection ditches at the side of the pile, which would route runoff to the toe of the pile via a spillway portion of the collection ditch. As the collection ditch would not realistically be able to pass peak flows from high intensity storm events, the pile surface would have to be graded in such a way that a significant volume of water could be stored on top of the pile without overtopping the structural zones during extreme precipitation events. This storage would only be used when the capacity of the collection ditch is exceeded, and would attenuate high intensity peak flows. The placement scheme would need be carefully managed to maintain this capacity throughout the life of the facility. Therefore, during extreme precipitation events there will be water ponded on the surface of the tailing impoundment temporarily.

CIL residue is considered PAG and if filtered and stored in a filter pile it will not be saturated and will be exposed to oxidation. Management to avoid oxidation of the CIL residue and therefore generation of acid would be challenging and would require more frequent, thinner lifts to bury the CIL residue quickly. If roads are constructed within the CIL residue area they would act as a conduit for water and oxygen, increasing the likelihood of acid generation.

The CIL residue supernatant also contains a small amount of cyanide. The EA approved cyclone sand TMF has a central CIL residue pond, which allows for further CN destruction. If the CIL residue is filtered, the trace amount of CN in the filtered tailing pore water won't be destroyed and some will ultimately report to runoff and seepage.

The flotation tailing contains less than 0.3% sulphides by weight (Rescan 2013, Chapter 10). Although the flotation tailing are considered NPAG, they have the potential to generate sulphate when exposed to oxygen. Filtered flotation tailing will be unsaturated and generate high sulphate concentrations in seepage water.

5.7 Progressive Reclamation

Due to the high erosion potential of filtered tailing in a high rainfall environment, progressive reclamation is considered essential. Even with 3H:1V external slopes, the large sloped areas would be highly susceptible to erosion.

An advantage of filter tailing facilities is that progressive reclamation of the outer slopes is often possible, provided the staging of the facility allows for placement of material to the ultimate outer slopes as the pile is constructed.

5.8 Other Considerations

Other considerations for filtered tailing for the KSM Project are:

- Large fleets of equipment and labour are required for filtered tailing operations.
- Large volumes of external borrow are required throughout the life of the facility for pile drainage and interior access roads. This will result in additional surface disturbance outside the pile footprint.
- Staff safety concerns for placing filtered tailing during the winter. Conveyance, spreading, and compaction are required for the operation of a filtered tailing facility 24 hours a day at all times of the year. Cyclone sand dam construction operations would only be required during summer months. There is greater exposure to operations staff to blizzard and avalanche conditions for a filtered tailing facility.

- Dust management over a larger surface area of fine grained tailing potentially resulting in additional environmental impacts to vegetation.
- High capital and operating costs.
- Higher power usages and increased production of greenhouse gases.

5.9 Risk Review

The overall objective of applying BAT and BAP to tailing management is to reduce risk. Risk is defined as the product of likelihood and consequence.

A high level risk review workshop was conducted to identify the high risk items that differentiate a cyclone sand TMF from a filtered TMF, to assist Seabridge in designing and operating the lowest risk TMF.

To focus the risk review, two TMF designs consisting of a filtered and non-filtered tailing management scheme were compared for the Teigen-Treaty site (the preferred site from the 2013 Alternatives Assessment (Rescan 2013, Appendix 33-B)). The first is the Teigen-Treaty Cyclone Sand TMF, which was identified as the preferred TMF in the 2013 Alternatives Study (Rescan 2013, Appendix 33-B) and has been EA approved, and is further described in Appendix IV-A. The second is the Teigen-Treaty Filtered TMF and is further described in Appendix IV-B.

The key risks identified in the workshop are given in Table 5.5.

Table 5.5 Key Differentiating Risks Associated with Cyclone Sand TMF and Filtered TMF for the KSM Project

	Cyclone Sand TMF		Filtered TMF	
	Risk	Potential Mitigation	Risk	Potential Mitigation
Operational Physical Risk	▪ Impounded water on the tailing surface during operations increases the consequence of a hypothetical tailing dam failure	▪ Minimize the water ponded on the tailing surface	▪ Substantial drainage requirements and the likelihood of drainage failure increases the likelihood of slumping failure of tailing facility ▪ Risk of piping or overtopping failure of the collection dam	▪ Oversize pile drains and monitor phreatic surface within the pile ▪ Robust design of dam zoning and spillway
Operational Geochemical Risk	▪ Potential for water quality in the CIL residue pond to not be suitable for use in the mill	▪ Water treatment	▪ De-saturated CIL residue will generate acid ▪ De-saturated 2.1 Bt of flotation tailing (that contain ≈0.3% sulphides) will generate higher sulphate loadings ▪ The water quality in the collection ponds will not be suitable for discharge	▪ Minimize seepage from the collection dams with impermeable cores, cut-offs, pump-back wells and downstream seepage dams ▪ Water treatment
Post-Closure Physical Risk	▪ Impounded water on the tailing surface post closure increases the consequence of hypothetical tailing dam failure ▪ Erosion of cyclone sand dam	▪ Design the closed tailing dam as a landform that does not impound water ▪ Rockfill cover and long-term monitoring and maintenance	▪ Substantial drainage requirements and the likelihood of drainage failure increases the likelihood of slumping failure of tailing facility ▪ Erosion of filtered tailing slopes	▪ Oversize pile drains and monitor phreatic surface within the pile post-closure ▪ Progressive reclamation with rockfill cover and long-term monitoring and maintenance
Post-Closure Geochemical Risk	▪ Closure cover and water management strategy may not be sufficient to keep CIL residue saturated, CIL residue could oxidize and generate acid ▪ Low potential of closure pond water quality not meeting discharge criteria	▪ Design closure cover to keep CIL residue saturated ▪ Limit seepage from the CIL residue pond (liner and cut-offs) ▪ Potential for water treatment	▪ De-saturated CIL residue will generate acidic seepage. De-saturated flotation tailing will generate seepage with high sulphate concentrations ▪ The likelihood of the seepage water quality in the collection ponds will not be suitable for discharge is increased	▪ Long-term water treatment

PART 2 – TAILING MANAGEMENT ALTERNATIVES ASSESSMENT

6 ALTERNATIVES ASSESSMENT (EC GUIDELINE STEP 1 AND STEP 2)

6.1 Introduction

Part 2 of this study consists of a TMF alternative assessment for the KSM Project and is an assessment of tailing technologies, tailing facility location and management practices. It is an update to the 2013 Alternatives Study that was previously completed for the project as part of the EA (Rescan 2013, Appendix 33-B).

TMF locations for conventional tailing facilities were assessed previously in the 2013 Alternatives Study. The EA approved Teigen-Treaty Cyclone Sand TMF selected in the previous study was included in this assessment, while conventional cyclone sand tailing facilities at other sites were not re-assessed.

This study assessed the locations listed below for possible storage of dewatered tailing technologies (thickened, paste or filtered), co-disposal with mine rock and storing CIL residue in a separate facility. Not all the locations assessed were consistent with the 2013 Alternatives Study; the locations were chosen based on applicability to the tailing technology.

The framework for this assessment is based on Environment Canada's *Guidelines for the Assessment of Alternatives for Mine Waste Disposal* (Environment Canada 2013) to be consistent with the previous assessment. The framework is further described in Section 3.3.

Step 1 and Step 2 of the Environment Canada's Guidelines include identifying candidate alternatives for potential TMFs. The assessment for Step 1 and Step 2 for this study is described in detail in Appendix IX. Section 6 provides of summary of Steps 1 and 2.

As part of the previous 2013 Alternatives Study (Rescan 2013, Appendix 33-B) KCB conducted a technical assessment of the alternate TMF sites (KCB 2012a). Part of this study reviewed alternate tailing management strategies to surface disposal. The assessment concluded that surface disposal was required for the KSM Project.

The potentially suitable strategies for the KSM Project are surface storage in: conventional tailing facility, thickened or paste tailing facility, filter tailing facility, and co-disposal with mine rock. The strategies that were found to be unsuitable for the KSM Project were in-pit disposal, underground backfill, lake disposal, and ocean disposal. Further discussion on the reasoning behind these are included in Appendix IX.

6.2 Location

This study assessed the following sites considering use of dewatered tailing technologies:

1. Upper Unuk Valley;
2. Unuk Valley Terrace;
3. Tom Mackay Lake Terrace;

4. South Unuk Valley;
5. Ted Morris Creek Valley;
6. McTagg Creek Valley;
7. Sulphurets Creek Valley;
8. West Teigen Lake;
9. Teigen-Treaty Valley;
10. Upper Treaty Valley;
11. Knipple Lake;
12. Bowser Lake; and
13. Scott Creek Valley.

Preliminary location screening identified the following sites for consideration of storing tailing using alternative technologies: Teigen-Treaty Valley, Scott Creek Valley, Upper Treaty Valley, Unuk Valley Terrace, and McTagg Valley. The other sites were discarded at this stage for various reasons including deposition in a fish bearing lake, insufficient capacity, accessibility, sterilizing mineral deposits, and no perceivable advantage of re-evaluating the site with a new technology. Further details on the preliminary location assessment are given in Appendix IX.

The technologies assessed for the sites were:

1. cyclone sand (only the preferred candidate from the 2013 Alternatives Study);
2. high density thickened;
3. paste;
4. filtered;
5. co-disposal with mine rock; and
6. conventional (for storing CIL residue only).

6.3 TMF Alternatives (EC Guidelines Step 1)

Thirty-one conceptual TMF alternatives at the five potential sites were developed for the assessment. The design basis for the assessment is based on the 2012 PFS (KCB 2012c) and is used for preliminary layouts. Additional design criteria were developed based on laboratory testing and the anticipated TMF consequence category under the CDA guidelines (CDA 2013). Some design basis parameters were updated for the alternative characterisation layouts (Section 7).

The 31 alternatives include multiple configurations for some sites, where appropriate, including cross valley fills, side hill stacking, different pile heights and different pile geometries to assess the feasibility of different placement schemes. The 31 alternatives are described and shown on figures in Appendix IX.

TMF alternatives are identified using the following syntax:

[**Location**]-[**Management Method**]-[**Alternative Number**]-[**Tailing Type**]

Example: **TT-F-3-CIL**

Identifier	Description
Location	
TT	Teigen-Treaty Valley
UT	Upper Treaty Valley
SC	Scott Creek Valley
UN	Unuk Valley
MT	McTagg Valley
MA	Mine Area
Management Method	
C	"Conventional" unthickened slurried tailing deposited in a surface impoundment
F	Filtered tailing stacked in a pile
P	Paste tailing
CD	Co-disposal of tailing and mine rock
CP	Co-placement of tailing and mine rock
Tailing Type	
CIL	Labeled if alternative is for storage of CIL tailing only (label not included for flotation/combined alternatives)

6.4 Critical Flaw Assessment (EC Guidelines Step 2)

6.4.1 General

An initial screening on the 31 alternatives was done to eliminate alternatives that have identifiable critical flaws. A critical flaw in this assessment is defined as a flaw so unfavourable that it alone is sufficient to eliminate the alternative from further consideration for tailing disposal in the context of the KSM Project. Explanations of reasons identified for removing alternatives from further consideration are summarized in the following section.

6.4.2 Criteria

Required Pile or Embankment Height Exceeding 400 m

There is little or no precedent for fill or dam heights exceeding 400 m. In fact, the highest sand dams, which are more comparable to a filtered tailing pile, have been reported to have been constructed to 200 m high along the dam centerline (Barrera et al 2011) and approximately 250 m toe to crest. The highest existing filtered tailing pile is at the La Coipa Mine in Chile and is estimated to be in the range of 100 m to 150 m from toe to crest (estimated from GoogleEarth™); however, the maximum thickness is closer to 70 m (AMEC 2008). Also La Coipa is located in an arid climate with very low precipitation and is not subject to the erosive forces of frequent rain and snowmelt. The highest filtered tailing pile in a high rainfall, low evaporation environment similar to KSM is the Greens Creek mine in Alaska, which is approximately 40 m high.

A greater fraction of precipitation falling on compacted tailing will flow over the surface rather than infiltrate (due to the fine grain nature of tailing compared to waste rock or the cyclone sand of embankment dams) leading to erosion control difficulties which rapidly become more severe with higher piles. Generally, with higher embankments, longer sloped surfaces are exposed creating erosion control concerns during operations and post-closure. Because risk of erosion increases with increasing slope height due to the increased energy involved and increasing slope area as there is more area susceptible to erosion, a preliminary evaluation of the relative erosion risk of different filtered options can be estimated using the formula:

$$Relative\ Erosion\ Risk \approx Slope\ Height \times Slope\ Area$$

Measuring from the toe to the crest is a measurement of drop in elevation, which is generally indicative of erosive energy of runoff on over the dam face on a filtered tailing pile. This height can also be measured on an existing dam as it does not rely on knowledge of the topography before dam construction. Measuring maximum embankment height on the centreline is similar to measuring the maximum dam thickness, which influences the stress levels that the fill at the base of the dam is subject to, which in turn influences overall dam stability. In this study, embankments with a height of greater than 400 m using either method of measurement are considered critically flawed.

Insufficient Capacity

The target tailing capacity for the KSM Project is 2.3 billion tonnes, which would ideally be stored in a single facility (Environment Canada 2013). It is recognized that combinations of options could be used to provide the required capacity, however the benefits of such combinations would have to offset the disadvantages of storing tailing in separate facilities at different locations. These disadvantages were examined in the 2013 Alternatives Study (Rescan 2013, Appendix 33-B), and include increased tailing footprint, greater infrastructure footprint and greater water management requirements. No combinations of options have been identified in this study that would result in significant benefits over using a single facility. Alternatives with insufficient capacity to store the required tailing volume have thus been removed.

Required Structural Fill Volume Exceeds 50% of Flotation Tailing Volume

Fill comprising the outer slopes of filtered tailing piles forms a structural zone and requires a more stringent compaction specification for structural stability. Due to seasonal and climate constraints at KSM, it is anticipated that only 50% of filtered flotation tailing can be adequately compacted to comprise the structural fill required in outer embankments. The structural zone placement season would be approximately from mid-April to mid-October when there is limited snow on the ground and the conditions are somewhat drier.

No Suitable Runoff/Seepage Collection Pond Location

Each of the conceptual tailing management facilities assessed will require collection ponds downslope of the facility to collect, seasonally store and treat runoff and seepage. Collecting runoff/seepage water in a sump with little storage and pumping it to a pond elsewhere is not considered an acceptable solution as a pump or power failure would result in an environmental release if there is insufficient storage to contain storm flows until operation of the system is restored. Alternatives without suitable area and geometry to construct an appropriately sized runoff collection pond (e.g. if constructing a runoff collection pond would require obstructing a major water course) have thus not been carried forward.

Reliance on Tailing Paste Slopes as Structural Fill

Paste deposition of tailing has potential to create steep, unstable slopes due to the low viscosity of the material. Large paste slopes above a tailing dam create the potential for a slope failure that could overtop the dam, which is considered an unacceptable risk. Configurations that would result in steep paste slopes above a tailing dam have not been carried forward.

6.4.3 Results

Seventeen of the alternatives were eliminated leaving 14 alternatives. However, based on similarities between alternatives, only five were progressed to the next step. Alternative TT-F-2 was further divided into an Option 1 (filtered CIL residue) and an Option 2 (thickened CIL residue) for a total of six alternatives to be carried forward. A summary of the results of the critical flaw assessment is provided in Table 6.1. Reasoning for not carrying 9 of the 14 alternatives that passed the critical flaw assessment are provide in Appendix IX.

Table 6.1 Critical Flaw Assessment Summary

Alternative	Critical Flaws
Teigen-Treaty Valley	
"Conventional" Slurried Tailing in Surface Impoundment	
TT-C-1	▪ Carried forward for further assessment
TT-C-2	▪ Passed critical flaw assessment, not carried forward due to similarities with another alternative
Filtered Tailing	
TT-F-1	▪ Passed critical flaw assessment, not carried forward due to similarities with another alternative
TT-F-2	▪ Carried forward for further assessment
TT-F-3	▪ Passed critical flaw assessment, not carried forward due to similarities with another alternative
TT-F-3-CIL	▪ Structural fill volume exceeds 50%
TT-F-4	▪ Pile height exceeds 400 m ▪ Structural fill volume exceeds 50%
TT-F-4-CIL	▪ Structural fill volume exceeds 50%
TT-F-5	▪ Pile height exceeds 400 m ▪ Insufficient capacity ▪ Structural fill volume exceeds 50%
TT-F-6	▪ Pile height exceeds 400 m ▪ Structural fill volume exceeds 50%
TT-F-7	▪ Pile height exceeds 400 m ▪ Insufficient capacity
TT-F-7-CIL	▪ Pile height exceeds 400 m
TT-F-8-CIL	▪ Insufficient capacity ▪ No suitable downslope location for runoff collection ponds ▪ Structural fill volume exceeds 50%

Alternative	Critical Flaws
High Density Thickened Tailing	
TT-HDT-1	▪ Passed critical flaw assessment, not carried forward due to no advantages over another alternative
TT-HDT-2	▪ Passed critical flaw assessment, not carried forward due to no advantages over another alternative
TT-HDT-3	▪ Passed critical flaw assessment, not carried forward due to no advantages over another alternative
Paste Tailing	
TT-P-1	▪ Reliance on tailing paste slopes as a structural material
Upper Treaty Valley	
Filtered Tailing	
UT-F-1	▪ Passed critical flaw assessment, not carried forward due to similarities with another alternative
UT-F-2	▪ Carried forward for further assessment
UT-F-3	▪ Pile height exceeds 400 m ▪ Structural fill volume exceeds 50%
UT-F-4	▪ Insufficient capacity ▪ Inadequate space available for runoff collection ponds below tailing pile ▪ Pile height exceeds 400 m ▪ Structural fill volume exceeds 50%
UT-F-4-CIL	▪ Insufficient capacity
Scott Creek Valley	
Filtered Tailing	
SC-F-1	▪ Carried forward for further assessment
Unuk Valley	
Filtered Tailing	
UN-F-1	▪ Carried forward for further assessment
McTagg Valley/Mine Area	
Filtered Tailing	
MT-C-1-CIL	▪ Passed critical flaw assessment, not carried forward due to storage area used for PAG mine rock storage
MT-F-1	▪ Large stored water volume on closure unless a permanent diversion tunnel is maintained ▪ Pile height exceeds 400 m ▪ Insufficient capacity ▪ Structural fill volume exceeds 50%
MT-F-2	▪ Pile height exceeds 400 m ▪ Insufficient capacity ▪ Structural fill volume exceeds 50%
MT-F-3	▪ Pile height exceeds 400 m
MT-F-3-CIL	▪ Passed critical flaw assessment, not carried forward due to storage area used for PAG mine rock storage
Co-disposal of Tailing and Mine Rock	
MA-CD-1	▪ Insufficient capacity
Co-placement of Tailing and Mine Rock	
MA-CP-1	▪ Insufficient capacity

*Alternative naming convention is described in Section 6.3

Notes on highlighting:

Green indicates alternative passed critical flaw assessment

Red indicates alternative did not pass critical flaw assessment

Orange indicates alternative passed critical flaw assessment but was not carried further due to a similarity with another alternative.

6.5 TMF Alternatives to be carried forward to Step 3

The alternatives carried forward to Step 3 are:

TT-C-1 – Teigen-Treaty Cyclone Sand Tailing Management Facility

This alternative was carried forward for the following reasons:

- Relies on robust technologies (cycloning) and construction methods (compaction of sand during summer months) proven in similar climates, in similar geologic settings and at similar throughputs thereby reducing operation uncertainty and potential for adverse events.
- Provides robust water management capabilities for managing flood flows because it does not rely on pumping or release short term. Provides storage for PMF.
- The valley sides generally have more shallow slopes than other sites considered allowing perimeter diversions and access to be established and maintained, as well as allowing a liner to be installed beneath the CIL residue cell.
- Required structural zones are limited to the cyclone sand dam fill, which can be compacted using established techniques even in a wet climate. A relatively small percent of the overall tailing facility is required to be structural, allowing engineering and quality control efforts to be focused in that area.
- The deposition pattern results in long tailing beaches between the dams and ponds in the flotation tailing cells.
- CIL residue is deposited subaqueously in a lined impoundment to prevent acid generation and limit seepage, both during operations and post-closure.
- Allows for re-establishing existing downstream flow patterns post-closure.
- Has redundant spillways, contained and saturated CIL residue, decreasing water treatment requirements over time, a robust closure cover and no reliance on diversion channels post-closure.

TT-F-2 – Teigen-Treaty Filtered Tailing Management Facility

This alternative was carried forward for the following reasons:

- Has a relatively small catchment with no large, concentrated flows onto the pile footprint.
- Confinement by the valley sides reduces the perimeter embankment requirements and allows for the CIL residue to be contained within a central area of the pile.
- The valley sides in the pile footprint generally have more shallow slopes than layouts that make use of the steeper sided south Teigen-Treaty Valley or the East Valley Catchment, allowing perimeter diversions and access to be established and maintained, as well as allowing a liner to be installed beneath the CIL Residue Cell.

- The regular, rectangular shape of the pile allows for conveyor deposition using a less operationally complex and more reliable configuration than irregularly shaped filtered tailing options would require.

UT-F-2 – Upper Treaty Filtered Tailing Management Facility

This alternative was carried forward for the following reasons:

- If the upstream flows are diverted using a tunnel, it has a relatively small undiverted catchment.
- Confinement by the valley sides reduces the perimeter embankment requirements and allows for the CIL residue to be contained within a central area of the pile.
- The regular, rectangular shape of the pile allows for conveyor deposition using a less operationally complex and more reliable configuration than irregularly shaped filtered tailing options would require.
- Upper Treaty Creek currently has reduced water quality due to mineralization in the area, resulting in lower aquatic habitat value.

SC-F-1 –Scott Creek Filtered Tailing Management Facility

This alternative was carried forward for the following reasons:

- Access to the area is already established via the Brucejack Mine access road.
- Confinement by the valley sides reduces the perimeter embankment requirements and allows for the CIL residue tailing to be contained within a central area of the pile.

UN-F-1 –Unuk Valley Terrace Filtered Tailing Management Facility

This alternative was carried forward for the following reasons:

- Has a smaller catchment than other filtered options reducing water management requirements, and has no large, concentrated flows flowing into the pile footprint.
- Diversion channels are only required on one side of the pile, reducing closure diversion maintenance.

7 ALTERNATIVE CHARACTERIZATION (EC GUIDELINE STEP 3)

7.1 General

The alternative characterization describes the six TMF alternatives short-listed by the critical flaws assessment (Step 2). Two options (filtration and thickening) for handling the CIL residue were considered for the Teigen-Treaty Filtered TMF (TT-F-2) to assess if any optimizations could be made to the design to improve the ability to manage CIL residue, and to provide an area to deposit flotation tailing that is not sufficiently dewatered (due to weather conditions or filter plant down time) for placement in the filtered tailing portion of the facility.

The characterizations for the alternatives can be found in the following appendices:

- Appendix IV-A - Teigen-Treaty Cyclone Sand TMF (TT-C-1) Characterization.
- Appendix IV-B - Teigen-Treaty Filtered TMF (TT-F-2) Characterization (including Option 1 – filtered CIL residue and Option 2 – thickened CIL residue).
- Appendix IV-C - Upper Treaty Filtered TMF (UT-F-2) Characterization.
- Appendix IV-D - Unuk Valley Terrace Filtered TMF (UN-F-1) Characterization.
- Appendix IV-E - Scott Creek Filtered TMF (SC-F-1) Characterization.

7.2 Design Basis

7.2.1 Design Criteria

The basic design criteria adopted for design of the alternative TMFs used for the alternatives characterization step (Step 3) are similar to those laid out in the pre-screening assessment (Appendix IX) and updated based on laboratory testing. The designs were further refined to facilitate comparison by including key features such as water management infrastructure, conveyor layouts, grading of the tailing surface, staging, and alignments for supporting infrastructure including access roads and ore transport tunnels.

7.2.2 Tailing Characterization

A summary of the geotechnical laboratory testing and results for the KSM tailing are included in Appendix II. The specific gravity, tailing distribution, moisture contents, in situ dry density and saturation for the different tailing are summarized in Table 7.1. This information was used to assess the water balance (presented in Appendix X), placed tailing density and filter plant requirements to further refine the alternatives.

Table 7.1 Tailing Properties and Processing Solids Concentration

Tailing Type	Specific Gravity[1]	Percent of Total Tailing Stream[2] (%)	Filter Plant Target Moisture Content[3] (%, W_W/W_T)	Solids Content (W_S/W_T) (%)			In Situ Dry Density[4] (t/m^3)	Saturation at Placement[5] (%)
				From Ore Processing Plant	After Thickener	After Filtering		
Filtered Flotation Structural	2.88	26	11.5	37.3	58	88.5	1.79	61.5
Filtered Flotation non-Structural		61	11.5	37.3	58	88.5	1.61	47.5
Filtered CIL Residue	3.53	13	14	54.5	55	86	1.77	57.8
Thickened CIL Residue			n/a	54.5	n/a	n/a	1.60	100

Notes:

1. From Pocock Industrial Inc. Testing (Appendix VI).
2. Average percent of tailing needed for structural fill based on average staging plan for options TT-F-2, UT-F-2 and SC-F-1. UN-F-1 requires 65% of the tailing to be placed in the structural area.
3. Filter Plant target moisture content (Appendix VI).
4. Based on compaction testing, summarized in Appendix II.
5. Does not account for increase in moisture content due to precipitation.

7.3 Alternatives Characterization Summary

The Teigen-Treaty Cyclone Sand TMF includes two flotation tailing cells surrounding one lined CIL residue cell contained by cyclone sand dams.

The other alternatives are filtered tailing facilities which include a lined filtered CIL residue cell encapsulated in filtered flotation tailing. The external slopes are considered structural zones and will be compacted for geotechnical stability.

Two options for the Teigen-Treaty Filter Pile TMF (TT-F-2) were considered; both have the same footprint and ultimate configuration. Option 1 includes filtering both the flotation tailing and the CIL residue as described above. For Option 2, the CIL residue will be sent to the facility as thickened slurry. The lined CIL residue cell will require a small reclaim pond with flood storage.

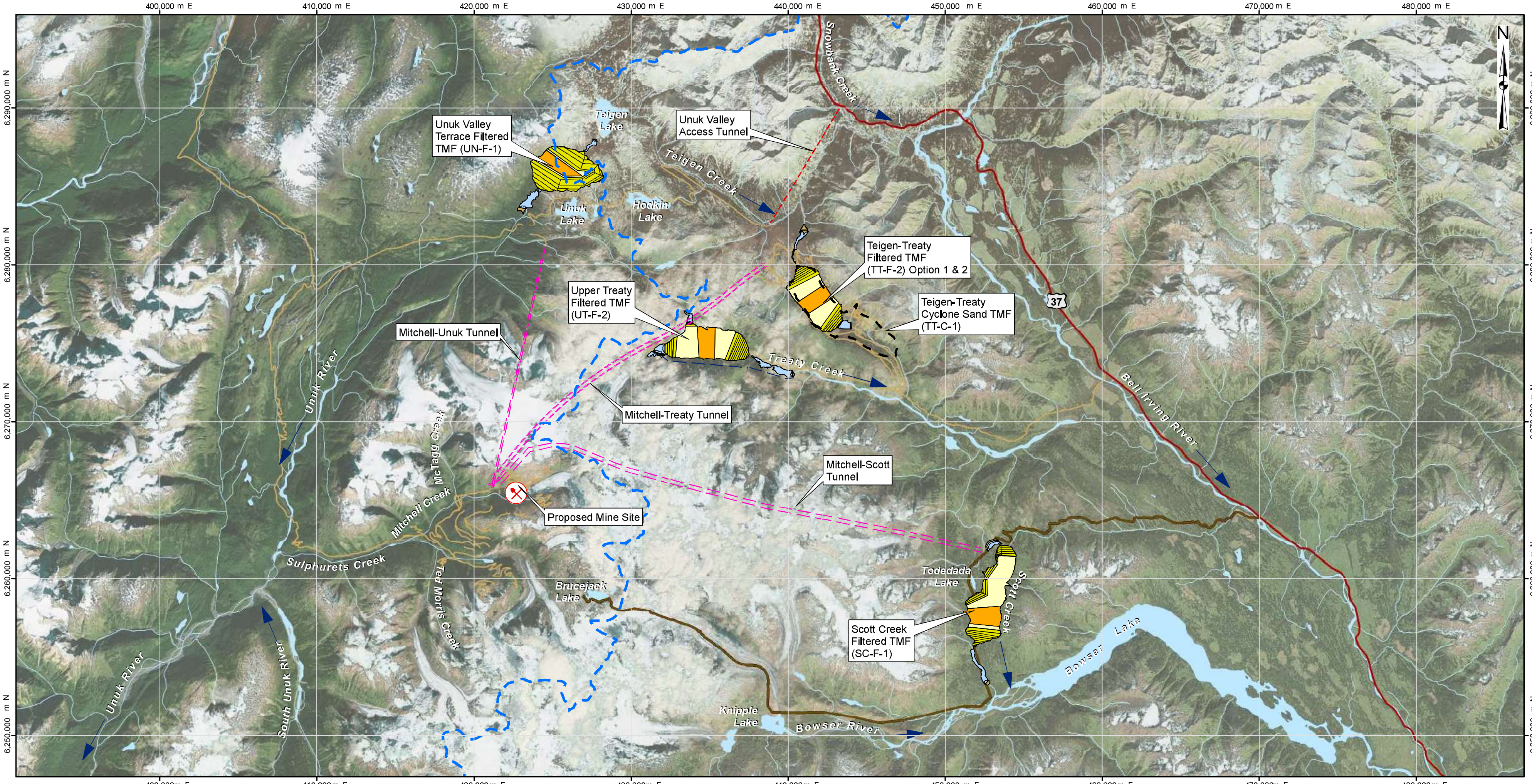
Key features of the alternatives are summarized in Table 7.2. A high-level bill of quantities and comparative cost estimate for the alternatives is provided in Appendix XI.

Table 7.2 Summary of Alternative Key Features

Item	Unit	Teigen-Treaty Cyclone Sand TMF (TT-C-1)	Teigen-Treaty Filtered TMF (TT-F-2) Option 1 Filtered CIL Residue	Teigen-Treaty Filtered TMF (TT-F-2) Option 2 Thickened CIL Residue	Upper Treaty Filtered TMF (UT-F-2)	Unuk Valley Terrace Filtered TMF (UN-F-1)	Scott Creek Filtered TMF (SC-F-1)
Areas							
Total Catchment Area	km^2	60.7	37.9	37.9	114.8	28.6	76.9
Undiverted Catchment Area (Disturbed Area)	km^2	21.0	11.2	11.2	12.2	14.2	16.1
Tailing Footprint Area	km^2	13.5	8.8	8.8	9.2	9.8	10.8
Tailing Dams/Embankments							
Maximum Dam/Embankment Height (Toe to Crest)	m	280	350	350	365	400	342
Maximum Dam/Embankment Height (Thickness)	m	239	301	301	339	329	291
Fraction of Flotation Tailing Required for Structural Fill	%	12%	32%	32%	27%	73%[1]	27%
Water Management Infrastructure							
Number of Collection Dams	ea	3	3	3	2	2	2
Maximum Collection Dam Height (Toe to Crest)	m	35	131	130	71	180	66
Maximum Collection Dam Fill	Mm^3	0.4	6.2	6.2	3.5	4.5	3.1
Total Collection Dam Fill	Mm^3	0.6	6.4	6.4	4.5	4.9	5.4

Notes:

1. The percent of structural fill required exceeds the critical flaw requirement of 50% from the EC Guideline's Step 2; however, this alternative was kept in the MAA to determine if that critical flaw was the only factor that made the alternative unfavourable.



LEGEND

PROPOSED MINE SITE

TMF OPTION
- COLLECTION DAM
- POND
- STRUCTURAL ZONE
- NON-STRUCTURAL ZONE
- CIL RESIDUE

- DRAINAGE DIVIDE
- BRUCEJACK ACCESS ROAD
- PROPOSED ACCESS ROAD
- HIGHWAY
- CREEK / RIVER

- FLOW DIRECTION

PROPOSED TUNNELS
- ORE TRANSPORT TUNNEL
- WATER DIVERSION TUNNEL
- ROAD ACCESS TUNNEL

NOTES:
1. PROJECTION: UTM ZONE 9N
2. HORIZONTAL DATUM: NAD 83
3. BASEDATA SOURCES: MAJOR WATERSHEDS BC, IMAPBC AVAILABLE: MAPS.GOV.BC.CA/ESS/SV/IMAPBC (ACCESSED OCTOBER, 2015)
4. IMAGE SOURCE: ESRI, DIGITALGLOBE, GEOEYE, I-CUBED, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEX, GETMAPPING, AEROGRID, IGN, IGP, SWISSTOPO, AND THE GIS USER COMMUNITY

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Klohn Crippen Berger

PROJECT: BEST AVAILABLE TECHNOLOGY (BAT) STUDY FOR TAILING MANAGEMENT AT THE KSM PROJECT

TITLE: TAILING MANAGEMENT FACILITY ALTERNATIVES

SCALE	PROJECT No.	FIG. No.
AS SHOWN	M09480A07	7.1

8 MULTIPLE ACCOUNTS ASSESSMENT (EC GUIDELINE STEP 4 TO STEP 6)

8.1 Introduction

A MAA was completed for the 2013 Alternatives Study (Appendix 33-B, Rescan 2013). The MAA was updated as part of this study to assess the additional TMF alternatives in comparison to the proposed Teigen-Treaty Cyclone Sand TMF (KCB 2012c, Appendix IV-A).

The MAA process is Step 4 through Step 6 of the Environment Canada's *Guidelines for the Assessment of Alternatives for Mine Waste Disposal* (Environment Canada 2013), see Figure 3.1 and Appendix I-C. The steps are briefly described below:

Step 4: Multiple Accounts Ledger

Step 4 involves systematic evaluation of the characterization criteria developed in Step 3 based on a valuation system developed from professional judgment of relevant experts. The Multiple Accounts Ledger identifies the differentiating characteristics for the TMF alternatives. The Multiple Accounts Ledger consists of three elements: Accounts (main categories), Sub-Accounts (evaluation criteria) and Indicators (measurement criteria).

A Multiple Accounts Ledger was developed for the 2013 Alternatives Study MAA (Rescan 2013, Appendix 33-B). To be consistent, the ledger was used as the basis for this updated assessment. An additional Account was added to the MAA to review the risks and potential impacts for the TMF alternatives. Additional Sub-Accounts and Indicators were also added in consultation with the judgement of relevant experts and Seabridge to address the differences between tailing dewatering technologies.

Step 5: Values-based Decision Process

Step 5 involves a final value-based evaluation to identify the preferred TMF candidate. This is done by scoring and weighting the Indicators developed in Step 4, and applying weightings to the Sub-Accounts and Accounts for each TMF candidate and compare the results to determine the preferred TMF.

The value based scoring criteria and weighting factors from 2013 Alternatives Study's MAA (Rescan 2013, Appendix 33-B) were also used as a starting point for this updated assessment. The additional Sub-Accounts and Indicators were scaled and weighted based on consultation with relevant experts and Seabridge.

Step 6: Sensitivity Analysis

Step 6 considers different value systems when weighting Accounts, Sub-accounts, and Indicators. Sensitivity analysis addresses that there may be opposing value systems when deriving Indicator, Sub-account, and Account weightings.

8.2 Step 4 – Multiple Accounts Ledger

8.2.1 Evaluation Criteria (Sub-Accounts)

Environment Canada's Guidelines recommend that all Sub-Accounts are impact driven, differentiating, relevant in the context of the evaluation, understandable, non-redundant and independent of judgement.

The Sub-Accounts used in this MAA are shown in Table 8.1 and were based on those developed in the 2013 Alternatives Study's MAA (Rescan 2013, Appendix 33-B), shown as un-highlighted items in Table 8.1. Additional Sub-Accounts were added with consideration of the guidelines above and consultation with subject matter experts; the additions are highlighted in green in Table 8.1.

8.2.2 Measurement Criteria (Indicators)

In order to compare Indicators between multiple alternatives in a MAA, they must be measureable. The Indicators used in the 2013 Alternatives Study's MAA (Rescan 2013, Appendix 33-B) prepared for the EA were used as the basis for this assessment, and additional Indicators were added to define differences between the alternatives using different technologies. The Indicators are listed in:

- Table 8.2 Environment Account
- Table 8.3 Technical Account
- Table 8.4 Project Economics Account
- Table 8.5 Socio-Economic Account
- Table 8.6 Risks and Potential Impacts Account

The Indicators were measured on a six-point scale to provide sufficient range to differentiate without implying more detail than is known. The Indicator scoring scales were based on the MAA developed in the 2013 Alternatives Study's MAA (Rescan 2013, Appendix 33-B). Some Indicators were modified from the 2013 Alternatives Study to better define the differences between filtered and cyclone sand TMFs; Indicators where the weighting was modified are highlighted orange in Table 8.1 to Table 8.6. The Indicator scoring scales are given in Appendix XII-A. A summary of the basis for the Indicator related to wetlands is provided in Appendix XII-B. A summary of the alternative characterization and the Indicator scores are given in Appendix XII-C. The results are provided in Appendix XII-D. A summary of the basis for the Indicators related to terrestrial toxicology are given in Appendix XII-E. A summary of the basis for the Indicator related to the consequence of a hypothetical seismic (slumping) failure is provided in Appendix XII-F.

Table 8.1 Evaluation Criteria and Supporting Rationale for the MAA

Account	Standard Account Weighting	Evaluation Criteria (Sub-Account)	Rationale
Environmental	6	Aquatic Habitat Loss	Alternatives with greater effects to aquatic habitat would be less desirable due to the high ecological importance of aquatic habitat and the corresponding riparian ecosystems
		Direct Loss Fisheries	Alternatives with greater effects to fisheries values would be less desirable due to effects on traditional use and wildlife values. Options with sufficiently high fisheries values may be difficult to permit
		Downstream Fisheries	Alternatives with higher downstream fisheries values would be less desirable due to potential effects on traditional use and wildlife values in the case of a chronic or catastrophic containment dam failure
		Terrestrial Habitat Loss	Alternatives that affect rare ecosystems or high quality habitat for valued or at-risk wildlife species would be less desirable due to higher associated costs to biodiversity and traditional use values
		Surface Water Hydrology and Surplus Water Balance	Alternatives with greater potential effects to surface water hydrology would be less desirable due to potential downstream effects
		Groundwater Quantity And Quality	Alternatives with greater potential effects to groundwater quality and quantity would be less desirable due to potential downstream effects
		Pond Water Quality	Alternatives with poor water quality that will be released to the environment would be less desirable due to greater potential effects
		Air Emissions	Alternatives with minimal air emissions effects are preferred
Technical	3	Technical Precedence	Alternatives that use technologies with demonstrated technical precedence are preferred
		Water Management	Alternatives with smaller catchment areas and extents of upstream glaciation will have smaller volumes of runoff to manage which reduce engineering requirements and risks associated with excess flows
		Containment Infrastructure	Higher and more complex containment infrastructures are generally less desirable because of the engineering risks associated with size. Proposed containment dams may be near, or may exceed, the maximum safe height given current engineering technologies
		Foundation Conditions	Alternatives with more challenging foundation conditions pose greater engineering challenges and high risks to the long-term safety of any containment infrastructure, and are thus generally less desirable
		Processing, Construction, Operating And Closure Requirements	Alternatives with higher construction, operating and closure requirements are generally less desirable from a cost perspective, and would have higher long-term risk of failure
Project Economics	1.5	Comparative Costs	Alternatives with lower overall costs are more preferred
Socio-Economic	3	Aboriginal Interests	The existing aboriginal and treaty rights of the aboriginal peoples of Canada are recognized and affirmed in Section 35 of Canada's Constitution Act. Alternatives that do not conflict with aboriginal and treaty rights are preferable
		Commercial Land Uses	Existing commercial land uses make an important contribution to economic livelihoods and economic diversity in the region. It would be less desirable to affect areas which have direct commercial use values by local stakeholders
		Employment	The project region is characterized by boom and bust economic cycles, and employment opportunities may, at times, be limited. Alternatives with higher and more secure employment requirements would likely be viewed favourably by the public
		Archaeology	The project region is characterized by a long history of habitation by Aboriginal peoples. Alternatives that have a lower archaeological importance are preferable
		Health and Safety	Alternatives that reduce the potential for health and safety hazards are preferred
Risks and Potential Impacts[1]	4	Consequence of Physical Failure	Alternatives with a predicted minimal release of tailing and water during hypothetical failures are preferred
		Likelihood of Physical Failures	Alternatives that are less likely to have physical failures are preferred
		Risk of Geochemical Failure	Alternatives with that have the greatest potential for water quality to meet guidelines on-site are preferred
		Post Closure Water Management	Alternatives with a minimal storage of water on site and on the tailing facility post-closure are preferred to reduce the consequence of a hypothetical failure

Notes:
1. Not directly assessed in Rescan 2013. Weighted based on KCB's professional judgement.

Notes on cell highlighting:
No highlighting - indicators from the 2013 Alternatives Study's MAA (Rescan 2013, Appendix 33-B);
Orange - indicator and scaling have changed from the 2013 Alternatives Study's MAA; and
Green - new Accounts/Sub-Accounts/Indicators that were not assessed in the 2013 Alternatives Study's MAA.

Table 8.2 Multiple Account Ledger – Environment Account

Sub-Account	Sub-Account Weighting	Indicator	Indicator Weighting	Indicator Parameter	Unit
Aquatic Habitat Loss	3	Ecological Quality Index of Affected Wetlands	6	Index	unitless
		Lake Surface Area Directly Affected	2	Area	ha
		Stream Length Directly Affected	5	Distance	km
		River Length Directly Affected	3	Distance	km
Direct Loss Fisheries	6	Number of Fish Species Directly Affected	1	Value	#
		Extent of HADD (harmful alteration, disruption or destruction) to Fish Habitat	6	Value	km^2
Downstream Fisheries	1	Distance from Toe of Containment or Collection Dam to First Occurrence of Downstream Salmon	1	Distance	km
		Downstream Chinook Salmon Values	6	Value	#
		Downstream Sockeye Salmon Values	6	Value	#
		Downstream Coho Salmon Values	6	Value	#
Terrestrial Habitat Loss	3	Presence of Rare and Endangered Ecosystems	6	Value	#
		Presence of Rare and Endangered Plant Species	6	Value	#
		Presence of High Value Grizzly Bear Habitat	2	Area	ha
		Presence of High Value Mountain Ungulate Habitat	5	Area	ha
		Presence of High Value Moose Habitat	3	Area	ha
		Presence of High Value Marten Habitat	1	Area	ha
		Presence of Rare and Endangered Wildlife Species, Excluding Grizzly Bear, Mountain Ungulates, Moose and Marten	6	Value	#
		Potential Toxicological Effects to Terrestrial Wildlife - Proximity to High-Value Habitat	3	Value	#
		Potential Toxicological Effects to Waterbirds	3	Value	#
		Pond Water Quality Effects on Migratory Birds	3	Value	#
Surface Water Hydrology and Surplus Water Balance	5	Potential Impacts to Downstream Sediment Transport	3	Value	#
		Potential Runoff Loss Using Watershed Area (to Salmon Habitat)	3	Value	#
		Average Annual Contact Water to be Discharged to the Environment	6	Volume	Mm^3
Groundwater Quantity And Quality	5	Changes to Groundwater Quantity	3	Value	#
		Changes to Groundwater Quality	3	Value	#
Pond Water Quality	5	The Operational Pond Water Quality Compared to the Discharge Water Quality Guidelines	6	Value	#
Air Emissions	2	Fugitive Greenhouse Gases (GHG)	2	Value	#
		Potential Quality of Dust from Flotation Tailing	3	Value	#
		Potential Quality of dust from CIL Residue	6	Value	#
		Potential Quantity of Dust from Flotation Tailing	3	Area	ha
		Potential Quantity of Dust from CIL Residue	6	Area	ha

Notes on cell highlighting:

No highlighting - indicators from the 2013 Alternatives Study's MAA (Rescan 2013, Appendix 33-B);
Orange - indicator and scaling have changed from the 2013 Alternatives Study's MAA; and
Green - new Accounts/Sub-Accounts/Indicators that were not assessed in the 2013 Alternatives Study's MAA.

Table 8.3 Multiple Accounts Ledger - Technical Account

Sub-Account	Sub-Account Weighting	Indicator	Indicator Weighting	Indicator Parameter	Unit
Technical Precedence	6	Precedence for Scale of Tailing Processing	6	Value	#
		Precedence for Scale and Climatic Conditions for Tailing Transportation	4	Value	#
		Precedence for Scale and Climatic Conditions for Tailing Placement	6	Value	#
		Precedence for Embankment or Pile Height	4	Value	#
Water Management	6	Total Catchment Size	6	Area	km^2
		Undiverted Catchment Size	6	Area	km^2
		Glacierized Area in Catchment	4	Area	km^2
		Number of Diversion Dams Required	3	Value	#
		Diversion of Main Channel Required	3	Value	yes/no
		Feasibility of Diversion Construction	4	Value	#
Tailing Containment Infrastructure	4	Number of Containment Dams Required	2	Count	#
		Total Embankment Volume	2	Volume	Mm^3
		Number of Facilities	6	Value	#
Foundation Conditions	3	General Foundation Conditions	6	Value	#
		Earthquake Foundation Conditions	4	Value	#
Processing, Construction, Operating And Closure Requirements	6	Reliability of Tailing Processing	6	Value	#
		Reliability of Tailing Transportation	4	Value	#
		Ease of Construction	4	Value	#
		Ease of Operation	4	Value	#
		Closure Requirements	6	Value	#

Notes on cell highlighting:

No highlighting - indicators from the 2013 Alternatives Study's MAA (Rescan 2013, Appendix 33-B);
Orange - indicator and scaling have changed from the 2013 Alternatives Study's MAA; and
Green - new Accounts/Sub-Accounts/Indicators that were not assessed in the 2013 Alternatives Study's MAA.

Table 8.4 Multiple Accounts Ledger – Project Economics Account

Sub-Account	Sub-Account Weighting	Indicator	Indicator Weighting	Indicator Parameter	Unit
Comparative Costs	1	Capital and Sustaining costs	6	Cost	B$
		Operating Costs	3	Cost	$/t
		Net Present Value (NPV) Initial Closure Costs	2	Cost	M$
		Long-Term Water Treatment Costs	5	Value	#

Notes on cell highlighting:

No highlighting - indicators from the 2013 Alternatives Study's MAA (Rescan 2013, Appendix 33-B); and
Green - new Accounts/Sub-Accounts/Indicators that were not assessed in the 2013 Alternatives Study's MAA.

Table 8.5 Multiple Accounts Ledger - Socio-Economic Account

Sub-Account	Sub-Account Weighting	Indicator	Indicator Weighting	Indicator Parameter	Unit
Aboriginal Interests	6	Cultural and/or Spiritual Significance of Site	6	Value	#
		Importance for Traditional Land Use Activities	6	Value	#
		Importance as Aboriginal Access Route	5	Value	#
		First Nations Asserted Territories Overlapped	4	Value	#
		Nisga'a Nation Treaty Lands Overlapped	4	Count	#
Commercial Land Uses	3	Number of Traplines	5	Value	#
		Number of Guide Outfitting Licenses	5	Count	#
		Number of Commercial Recreation Tenures	3	Count	#
Employment	3	Local Contracting and Employment Effects Resulting Directly from Containment Dams	-	Value	#
Archaeology	6	Archaeologic Importance	-	Value	#
Health and safety	4	Number of Personnel Required for Outside Winter Operations (24 hours/day)	4	Count	#
		Potential Exposure to Geohazards	6	Count	#
		Potential for Traffic Accidents	3	Value	#

Notes on cell highlighting:

No highlighting - indicators from the 2013 Alternatives Study's MAA (Rescan 2013, Appendix 33-B); and

Green - new Accounts/Sub-Accounts/Indicators that were not assessed in the 2013 Alternatives Study's MAA.

Table 8.6 Multiple Account Ledger – Risks and Potential Impacts

Sub-Account	Sub-Account Weighting	Indicator	Indicator Weighting	Indicator Parameter	Unit
Consequence of Physical Failure	6	Volume of Water Released during a Hypothetical Overtopping Failure of the TMF	4	Volume	Mm^3
		Volume of Tailing Released during a Hypothetical Overtopping Failure of the TMF	4	Volume	Mm^3
		Volume of Water Released during a Hypothetical Overtopping Failure of the Collection/Seepage Dam	4	Volume	Mm^3
		Consequence of a Hypothetical Seismic (Slumping) Failure	4	Value	#
		Mobility of Tailing (Desaturation and Compaction)	2	Value	#
		Management Strategy for High Sulphide Tailing	3	Value	#
		Erosion Potential (Surface Area of Slope X Height of Embankment/Pile)	3	Area	ha
Likelihood of Physical Failure	6	Integrity of Structural Zone	6	Value	#
		Complexity and Resiliency of Contact Water Management Systems	5	Value	#
		Dam Safety Design Flood	3	Value	#
Risk of Geochemical Failure	6	Mass of Flotation Tailing Subject to Potential Oxidation (ML/ARD)	4	Mass	Mt
		Mass of CIL Residue Subject to Potential Oxidation (ML/ARD)	6	Mass	Mt
Post-Closure Water Management	4	Water Stored on the Tailing Surface Post-Closure	4	Volume	Mm^3
		Water Stored at the Toe of the Tailing Facility Post-Closure	2	Volume	Mm^3
		Requirement for Long-Term Water Treatment Post-Closure	4	Value	#

Notes on cell highlighting:
No highlighting - indicators from the 2013 Alternatives Study's MAA (Rescan 2013, Appendix 33-B); and
Green - new Accounts/Sub-Accounts/Indicators that were not assessed in the 2013 Alternatives Study's MAA.

8.3 Step 5 – Values Based Decision Process

8.3.1 Account Weighting

An additional Account was added to the MAA to review the risk and potential impacts for the TMF alternatives. Based on the recommendations from the Environment Canada's Guidelines, the standard Account weightings were used for the original four Accounts. The Risk and Potential Impacts Account was given a weighting of 4 because of its importance for dam and public safety.

The Account weightings are presented in Table 8.1.

8.3.2 Sub-Account Weighting

The Sub-Accounts for each Account were assigned a weighting to identify its significance within the Account. The Sub-Accounts from the 2013 Alternatives Study (Rescan 2013, Appendix 33-B) have the same weightings unless noted otherwise. The weightings of the additional Sub-Accounts are based on the professional judgment of relevant experts.

All Sub-Accounts were weighted on a 6-point scale, with 6 being the most significantly valued and 1 being the least. The Sub-Accounts weightings are given in Table 8.2 to Table 8.6.

8.3.3 Indicator Weighting

The Indicators for each Sub-Account were assigned a weighting based on their significance within the Sub-Account. The Indicators from the 2013 Alternatives Study (Rescan 2013, Appendix 33-B) have the same weightings unless noted otherwise. The weighting of the additional Indicators are based on the professional judgment of relevant experts. All Indictors were weighted on a 6-point scale, with 6 being the most significantly valued and 1 being the least.

The Indicator weightings are given in Table 8.2 to Table 8.6.

8.3.4 Quantitative Analysis

Quantitative analyses were performed for the Accounts, Sub-Accounts and Indicators developed in the 2013 Alternatives Study (Rescan 2013, Appendix 33-B) and for this updated MAA with the additional Accounts, Sub-accounts and Indicators. The results of the quantitative analysis are given in Appendix XII-D. The results of the standard Account weighting from is presented in Table 8.7.

The quantitative analysis results of the values-based decision are based on the following equations:

$$Indicator\ Merit\ Score\ (S_I\ x\ W_I) = Indicator\ Value\ (S_I)\ x\ Indicator\ Weight\ (W_I) \quad (1)$$

$$Sub - account\ merit\ score = \sum(S_I\ x\ W_I) \quad (2)$$

$$Sub - account\ merit\ rating = R_s = \sum\{S_I\ x\ W_I\} / \sum W_I \quad (3)$$

$$Account\ merit\ rating = R_A = \sum\{R_s x W_S\} / \sum W_S \quad (4)$$

$$Alternative\ merit\ rating = A = \sum\{R_A x W_A\} / \sum W_A \quad (5)$$

Table 8.7 Multiple Accounts Analysis Results (Standard Account Weighting)

		Teigen-Treaty Cyclone Sand TMF (TT-C-1)	Teigen-Treaty Filtered TMF (TT-F-2) Option 1	Teigen-Treaty Filtered TMF (TT-F-2) Option 2	Upper Treaty Filtered TMF (UT-F-2)	Unuk Valley Terrace Filtered TMF (UN-F-1)	Scott Creek Filtered TMF (SC-F-1)
Only 2013 MAA[1] Accounts, Sub-Accounts and Indicators	Alternative Merit Rating[2] (A)	4.5	3.4	3.5	2.9	2.8	2.8
	Ranking[3]	1	3	2	4	5	6
All Accounts, Sub-Accounts and Indicators	Alternative Merit Rating[2] (A)	4.8	3.1	3.3	2.8	2.7	2.7
	Ranking[3]	1	3	2	4	5	6

Notes:
1. Assessment of Alternatives for KSM Project Tailing Management Facility (Rescan 2013, Appendix 33-B)
2. Alternative merit rating is based on a 6-point scale: 6 being the most favourable and 1 being the least favourable.
3. Ranking is the comparison of the alternatives based on the merit rating: 1 ranking the highest (most preferred alternative) and 6 ranking the lowest (least preferred alternative).

The Teigen-Treaty Cyclone Sand TMF resulted in the highest merit rating (4.5) in the 2013 Alternatives Study's MAA and 4.9 in this updated MAA and is therefore ranked the highest. The next closest alternatives (however, scoring much less) were the Teigen-Treaty Filtered TMF options (Option 1 and Option 2).

Relevant observations from these results are:

- The Teigen-Treaty Cyclone Sand TMF scored the highest for all of the Accounts. It has the lowest impact on environmental considerations, is the most technically feasible to construct, operate and close in a safe manner, has the fewest associated socio-economic concerns and is the best strategy to manage overall risk throughout the life of the project.
- The Teigen-Treaty site is the preferred site; all other sites scored lower.
- The Teigen-Treaty Filtered TMF Option 2 (storage of thickened CIL residue) is preferred over the Teigen-Treaty Filtered TMF Option 1 (storage of filtered CIL residue), but still scored much lower than the Teigen-Treaty Cyclone Sand TMF.

8.4 Step 6 – Sensitivity Analysis

Sensitivity analysis was performed to address the potential for opposing value systems when deriving Indicator, Sub-Account and Account weightings.

Eight Account sensitivity analyses were performed and the weightings and results for these scenarios are presented in Table 8.8 and Table 8.9, respectively.

Table 8.8 Multiple Accounts Analysis Sensitivity Account Weightings

Scenario	Environment	Technical	Project Economics	Socio-Economic	Consequence of Failure
Standard Account weighting	6	3	1.5	3	4
Only the Environmental Account	1	0	0	0	0
Only the Technical Account	0	1	0	0	0
Only the Project Economics Account	0	0	1	0	0
Only the Socio-economic Account	0	0	0	1	0
Only the Risk and Potential Impacts Account	0	0	0	0	1
No Project Economics Account (all remaining weightings being as in the standard Account weighting)	6	3	0	3	4
No Risks and Potential Impacts Account (all remaining weightings being as in the standard Account weighting)	6	3	1.5	3	0
All Accounts have equal weighting (all remaining weightings being as in the standard Account weighting)	1	1	1	1	1

Table 8.9 Multiple Accounts Analysis Sensitivity Results

Scenario		Teigen-Treaty Cyclone Sand TMF (TT-C-1)	Teigen-Treaty Filtered TMF (TT-F-2) Option 1	Teigen-Treaty Filtered TMF (TT-F-2) Option 2	Upper Treaty Filtered TMF (UT-F-2)	Unuk Valley Terrace Filtered TMF (UN-F-1)	Scott Creek Filtered TMF (SC-F-1)
Standard Account Weighting	Alternative Merit Rating ($A = \Sigma\{R_A \times W_A\}/\Sigma W_A$)	4.8	3.1	3.3	2.8	2.7	2.7
	Ranking	1	3	2	4	5	6
Only the Environmental Account	Account Merit Rating ($R_A = \Sigma\{R_S \times W_S\}/\Sigma W_S$)	4.8	3.3	3.4	3.2	2.8	3.1
	Ranking	1	3	2	4	6	5
Only the Technical Account	Account Merit Rating ($R_A = \Sigma\{R_S \times W_S\}/\Sigma W_S$)	5.4	2.8	3.1	2.2	2.4	2.7
	Ranking	1	3	2	6	5	4
Only the Project Economics Account	Account Merit Rating ($R_A = \Sigma\{R_S \times W_S\}/\Sigma W_S$)	5.4	1.6	1.9	1.6	1.0	1.2
	Ranking	1	3 (tie)	2	3 (tie)	6	5
Only the Socio-economic Account	Account Merit Rating ($R_A = \Sigma\{R_S \times W_S\}/\Sigma W_S$)	4.2	3.6	3.4	2.7	3.0	2.1
	Ranking	1	2	3	5	4	6
Only the Risks and Potential Impacts Account	Account Merit Rating ($R_A = \Sigma\{R_S \times W_S\}/\Sigma W_S$)	4.7	3.3	3.5	3.2	3.1	3.1
	Ranking	1	3	2	4	5	6
No Project Economics Account	Alternative Merit Rating ($A = \Sigma\{R_A \times W_A\}/\Sigma W_A$)	4.8	3.3	3.4	2.9	2.8	2.9
	Ranking	1	3	2	4	5	6
No Risks and Potential Impacts Account	Alternative Merit Rating ($A = \Sigma\{R_A \times W_A\}/\Sigma W_A$)	4.9	3.1	3.2	2.7	2.6	2.6
	Ranking	1	3	2	4	6	5
All Accounts Have Equal Weighting	Alternative Merit Rating ($A = \Sigma\{R_A \times W_A\}/\Sigma W_A$)	4.9	2.9	3.1	2.6	2.5	2.5
	Ranking	1	3	2	4	5	6

Notes:

1. Merit rating is based on a 6-point scale: 6 being the most favourable and 1 being the least favourable.
2. Ranking is the comparison of the alternatives based on the merit rating: 1 ranking the highest (most preferred alternative) and 6 ranking the lowest (least preferred alternative).

Relevant observations from the MAA sensitivity results are:

- The Teigen-Treaty Cyclone Sand TMF scored the highest for all of the sensitivity scenarios and is therefore the preferred alternative. In particular, the Teigen-Treaty Cyclone Sand TMF scored significantly higher in the Technical Account.
- The other Teigen-Treaty site alternatives always rank 2 to 3 and is therefore the preferred site.
- The Teigen-Treaty Filtered TMF Option 2 (storage of thickened CIL residue) is preferred over the Teigen-Treaty Filtered TMF Option 1 (storage of filtered CIL residue), except when taking into consideration only the Socio-economic Account, due to the higher scoring in the employment Sub-Account.

PART 3 - BAT STUDY CONCLUSIONS

9 CONCLUSIONS

The three main conclusions from Part 1 and Part 2 of the BAT Study for tailing management for the KSM Project are:

Conclusion 1: The Teigen-Treaty site is the Preferred TMF site

Based on the 2013 Alternative Study's MAA (Rescan 2013, Appendix 33-B) and the updated MAA from this study, the Teigen-Treaty site is the most appropriate TMF location because it has:

- more favorable foundation conditions and hydrogeological containment;
- a small upstream catchment;
- less high value and less sensitive fisheries and terrestrial habitat;
- fewer geohazards; and
- more favorable storage to structural fill ratios.

Conclusion 2: Filter tailing technology is not practical for the KSM Project

Filter technology is not practical for the KSM Project because:

- Scale of filter plant is unprecedented.
- Filter plant complexity will result in significant unscheduled downtime which would result in frequent shut-down of mining and milling.
- Target moisture content for the tailing will not always be achieved due to ore variability and operational difficulty, causing significant placement challenges and potential pile stability concerns.
- Conveyor placement of the KSM tailing production rate in a wet, cold climate is unprecedented and will present significant challenges. Topography of the region is mountainous which provides difficulty for conveyor arrangements.
- Placement and compaction of tailing in a wet, cold climate will be challenging. Strict quality control and potential re-handling of tailing will be required. Ponding of water during extreme precipitation events will be required and increase the risk of failure.
- Drainage of the facility is critical to stability and will require significant underdrains and potential internal slope drains. Adequate drainage will be more challenging in areas of upwelling groundwater (which is the case at several of the potential TMF sites).
- De-saturated CIL residue will generate acid. Surface runoff and seepage will have poor water quality and will require long term water treatment.
- Small percentage of sulphides in de-saturated flotation tailing will cause elevated sulphate loadings and require management.

- A 135 m high external collection dam with the capacity of 10.8 Mm^3 will be required for collection of runoff and seepage water from the facility to store for mill reclaim and seasonal release. Water quality in this facility is expected to be poor due to the oxidation of tailing. This facility would need to be located further downstream than a conventional TMF seepage dam in Teigen Creek, where there is less hydrogeological containment, creating a larger overall disturbance area of the TMF and resulting in poor quality seepage.
- Perpetual post-closure water treatment of seepage water will likely be required because of the oxidation of tailing.

Conclusion 3: The Teigen-Treaty Cyclone Sand TMF is the Preferred Management Strategy for the KSM Project Tailing

Based on the results of the MAA, the Teigen-Treaty Cyclone Sand TMF is the most appropriate TMF alternative. The Teigen-Treaty Cyclone Sand TMF scored the highest for each Account. It has the lowest environmental impact, is the most technically feasible to construct, operate and close in a safe manner, and has the fewest associated socio-economic concerns.

The key BAT features of the proposed Teigen-Treaty Cyclone Sand TMF are:

- **Site Selection**
  - Located at a catchment divide, therefore able to minimize upstream catchment area for flood management.
  - Favourable geology and foundation conditions for stability and hydrogeological containment.
  - Good storage capacity to dam volume ratio therefore able to minimize footprint.
  - Area is exposed to fewer geohazards compared to the surrounding region.
  - No high value fish habitat (i.e. food fishery) within the footprint of the facility.
- **Design Features Providing Physical Stability**
  - Compacted NPAG centerline raised cyclone sand dams with low permeability cores provide a dense, gradient controlled, free draining and de-saturated containment structure.
  - Over 50 years of precedence constructing centerline raise sand dams in the mining industry. Raising of these structures is simpler than other types of dams, minimizing the risk of human error.
  - Dams are designed with 3H:1V downstream slopes which results in Factors of Safety (FOS) that exceed CDA guidelines (CDA 2013).
  - Cyclone sand dams are not as prone to piping failures as other dam types, such as zoned rockfill dams, as cyclone sand is filter compatible with the glacial till core and tailing.

- Long tailing beaches between the ponds in the flotation tailing cells and the tailing dams decrease the likelihood of piping failures and catastrophic release of the pond if a hypothetical dam failure were to occur.

- **Design Features Providing Geochemical Stability**
  - De-sulphuring of the tailing by flotation so the majority of the tailing is NPAG.
  - PAG CIL residue is kept saturated in a lined cell to limit seepage and oxidation preventing ARD.
  - Flotation tailing contains <0.3% sulphides by weight. The majority of the flotation tailing will be stored behind a low permeability core and will remain at or close to saturation, which will limit sulphate generation.

- **Closure**
  - The TMF configuration allows two (redundant) spillways to be cut into rock, and allows drawing the closure pond down to a minimal volume. The redundancy adds to the resiliency of the TMF during a hypothetical failure of one of the spillways.
  - Lowering the spillway invert on final closure minimizes the pond volume stored on the tailing surface and increases the distance from the dam crests to the pond, decreasing the likelihood of a hypothetical overtopping failure and the likelihood the pond will be released during a hypothetical slumping failure of the dam.
  - At closure, the surface will be contoured to return the flow patterns similar to pre-mine conditions to achieve environmental objectives identified during the EA review process.
  - Rock cover on dam slopes will minimize erosion.
  - PAG CIL residue will be covered with flotation tailing and the phreatic surface will be maintained above the CIL residue, maintaining saturation of the CIL residue to limit oxidation and prevent ARD.
  - Lower long term risk of high concentrations of sulphate generation due to hydrogeological containment of the majority of the flotation tailing. The majority of flotation tailing are stored behind a low permeability core and will remain saturated, which will limit the amount of residual sulphides in the flotation tailing exposed for potential generation of sulphate.

The key BAP features of the proposed EA approved Teigen-Treaty Cyclone Sand TMF are:

- **Corporate TSF Design Responsibility**

  Seabridge has taken a long-term planning approach to the KSM Project mine development, rather than a small initial mine plan and subsequent ad hoc design additions. In doing so, the TMF has been designed for the mine life.

The design of the TMF, which has evolved over the EA review period, continues as the project moves towards development, and takes into account the extensive geological, seismic, hydrogeological and geomorphological site investigations and interpretations for the site.

As part of the TMF design, design criteria were set out in terms of beach widths, rate of rise, water balance and construction material balancing. These will become part of the Quantitative Performance Objectives (QPOs) in later stages of design and ultimately incorporated into the Operations, Maintenance and Surveillance (OMS) manual.

- **Independent Tailings Review Board (ITRB) or Independent Geotechnical Review Board (IGRB)**

  Seabridge established an Independent Geotechnical Review Board (IGRB) in January 2015 to independently review and to provide expert opinion and oversight for the KSM Project's TMF and Water Storage Dam (WSD) with a focus on their structural stability and integrity throughout the design, construction, operation and closure of the project. This was following Seabridge's commitment in mid-August 2014 in light of the Mount Polley incident and their belief that such commitment was required to ensure the continued acceptance of KSM Project's design by the project's stakeholders.

  The IGRB has presented a series of recommendations for Seabridge to consider during the ongoing development of the KSM Project, which are being addressed through the design.

  Seabridge and/or the KSM operating partner will continue to interact with the IGRB during design, construction, operations and post-closure. During design, Seabridge will host at least one IGRB meeting per annum and make the reports publically available.

- **Professional Practice and Canadian Dam Association (CDA) Guidelines**

  Extensive geological, seismic, hydrogeological and geomorphological site investigations and studies have been conducted to understand the dam foundation conditions.

  Seismic and stability assessments based on the results of foundation site investigations, the consequences of failure, and the loading conditions resulted in exceeding the minimum required factors of safety outlined by the CDA guidelines.

- **Closure should move to low risk landforms and should be consistent with First Nations values (BC First Nations Energy and Mining Council 2015)**

  The TMF closure plan was developed based on engagement with the Working Group, which includes Aboriginal groups, municipal officials, and regulatory authorities, during the EA review. The robust and resilient closure design is aimed at creating a low risk landform that will return the area back to similar hydrologic conditions.

Even with the BAT and BAP features of the TMF design, there are remaining key risks that need to be effectively controlled through design, operations and post-closure. These are already being considered through the design process and will become part of operating controls.

- **Physical Stability**
  - Ponded water in the flotation cells will need to be kept at a minimum to meet operational and environmental objectives. Close attention to the water balance of the facility is fundamental to minimizing facility risks.
  - Impounded water increases the consequence of a hypothetical failure, particularly the CIL Residue Cell during Stage 1 (Year 0 to Year 25) when water is impounded adjacent to the cyclone sand dam.
  - Cyclone sand is erodible; management of erosion of the cyclone sand dam slopes will require erosion mitigation and control.
- **Geochemical Stability**
  - Maintaining saturation and limiting oxidation of the PAG CIL residue will require effective water management.
- **Closure**
  - Long-term erosion mitigation and control of the dam slopes will require an erosion resistant closure cover.
  - A water management trade-off between maintaining a small closure pond to achieve environmental objectives (e.g. geochemical stability of the CIL residue), and decreasing the closure pond volume to further minimize risk.

10 CLARIFICATIONS REGARDING THIS REPORT

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