



The **BACK RIVER**
PROJECT

**FINAL ENVIRONMENTAL IMPACT STATEMENT
ADDENDUM**



February 2017

Submitted to:
Nunavut Impact Review Board
PO Box 1360
Cambridge Bay, NU X0B 0C0

BACK RIVER PROJECT

FEIS ADDENDUM

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- 20. Wildlife Mitigation and Monitoring Program Plan (Significantly Revised)
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- 30. Vegetation Monitoring Plan (New)
- 31. Conceptual Fish-out Plan (New)

4. Volume 4 Addenda: Atmospheric Environment

VOLUME ADDENDA SUMMARY

INTRODUCTION

This FEIS Addendum is being provided to the NIRB, in response to the direction received on January 23, 2017, to provide new and updated information on the topic of the Atmospheric Environment, as identified within the NIRB Hearing Decision Report (June 15, 2016) and the Ministers' Referral Letter (January 12, 2017).

For convenient reference, this FEIS Addendum follows the original FEIS heading and numbering scheme. In the interest of brevity, the volume and chapter numbers of the FEIS Addenda headers in the Table of Contents have been combined. For example, Section 6.4 in the FEIS Addendum Table of Contents corresponds to Volume 6, Chapter 4 Freshwater Water Quality in the FEIS. Where there is no new or updated information provided in the FEIS Addendum, the corresponding section number is omitted. For example, Section 6.2 and 6.3 are omitted from the FEIS Addendum Table of Contents for this reason. Wherever the original FEIS information is referenced, FEIS is used at the start of the reference (FEIS Volume 10 Chapter 19). Wherever the FEIS Addendum information supersedes the FEIS information, FEIS Addendum is used at the start of the reference (FEIS Addendum Volume 10, Chapter 21).

Volume 4 of the FEIS presents the assessment of potential environmental effects to the atmospheric environment associated with proposed Project activities following the application of mitigation and management measures. During development of the FEIS, air quality, and noise and vibration were selected as VECs. Meteorology and climate was considered a Subject of Note and all required information noted in the EIS guidelines was considered.

CONFORMITY TO EIS GUIDELINES

Sabina has reviewed the EIS Guidelines (Section 8.1.1, 8.1.2, 8.1.3) in respect of the new information provided on the topic of the Atmospheric Environment, and provided an updated Table of Conformity in FEIS Addendum Appendix V1-1A. This Table replaces the FEIS Table V1-1A.

AIR QUALITY (FEIS VOLUME 4, CHAPTER 1)

No areas of concern noted within the Final Hearing Report or the Ministers' Referral Letter. No additional information is presented.

NOISE AND VIBRATION (FEIS VOLUME 4, CHAPTER 2)

No areas of concern noted within the Final Hearing Report or the Ministers' Referral Letter. No additional information is presented.

CLIMATE AND METEOROLOGY (FEIS VOLUME 4, CHAPTER 3)

In the Final Hearing Report, the Board expressed that it was not confident that the measures proposed would be sufficient to mitigate effects related to climate change on tailings and waste rock storage areas if the climate continued to warm past the year 2100 where climate change projections are not as well understood. Sabina has prepared new or updated information to address Section 4.2 of the Final Hearing Report. This information can be found in response FHR-NIRB-4.2 under FHR-NIRB-4.2(A) - Effects of Climate Change on Tailings and Waste Rock Storage During Closure.

None of the additional information presented in the FEIS Addendum affects the conclusions presented in the Climate and Meteorology assessment (FEIS Volume 4, Chapter 3).

APPENDICES (FEIS VOLUME 4)

FEIS Appendix	Title	Summary of Change
Appendix V4-1A	Back River Project: 2011-2013 Air Quality Baseline Report	No Changes
Appendix V4-1B	Air Quality Modelling Assessment: Goose Property	No Change
Appendix V4-1C	Air Quality Modelling Assessment: Marine Laydown Area	No Changes
Appendix V4-2A	Back River Project: 2012 Noise Baseline Report	No Changes
Appendix V4-2B	Back River Project: Noise and Vibration Modelling Report	No Changes
Appendix V4-2C	Marine Laydown Area Qualitative Noise Assessment	No Changes
Appendix V4-3A	Back River Project: 2004 to 2014 Meteorology Baseline Report	No Changes
Appendix V4-3B	Climate Change Projections - Model Variation	No Changes
Appendix V4-3C	Climate Change Approach Memo	No Changes
Addendum Appendix V4-3D	Climate Change Memo	New
Addendum Appendix V4-3C	Climate Change Expert Third Party Review	New

4.3 CLIMATE AND METEOROLOGY (ADDENDA)

NIRB Section:	Section 4.2 - Climate and Meteorology	Ref No.:	FHR-NIRB-4.2
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Reference to NIRB Report:

Section 4.2 - Climate and Meteorology

Conclusions and Recommendations of the Board (Section 4.2.4):

In considering the views of the Proponent and those of parties throughout the assessment of the Project and as outlined above, the Board is not confident that the mitigation, monitoring, and adaptive management measures as proposed will be sufficient to mitigate effects related to climate change on tailings and waste rock storage areas because of the highly variable climatic conditions that may be experienced within the project area and the likelihood that covered tailings and support structures would interact with the seasonal active layer sooner and more consistently than predicted. Should the Proponent revise the project proposal for future submission, it is the Board's view that more information about long term monitoring of tailings and tailings storage structures in an Arctic environment with real world examples and discussion of any observed or anticipated climate change effects would be very helpful [FHR-NIRB-4.2(A)].

Issues Highlighted within the Ministers' Referral Letter:

On the issue of climate and meteorology, the Board expressed that it was not confident that the measures proposed would be sufficient to mitigate effects related to climate change on tailings and waste rock storage areas if the climate continued to warm past the year 2100 where climate change projections are not as well understood. However, after reviewing the Board's conclusions, it is not clear why the Board was not confident in the adequacy of the measures put forward by the proponent and interveners to manage the highly variable climatic conditions. Further, it is not clear why, when the coming to pass of any of the predictable scenarios would be detectable early with monitoring and manageable with feasible and implementable measures, the uncertainty was deemed too great. The Report requires further explanation on this point. We also find that further review of these issues is required to give parties the opportunity to address the Board's concerns and develop additional mitigations if necessary.

The Board also expressed its view that more information about tailing storage facilities in an Arctic environment would be helpful. We trust that this information would be sought through further review.

Sabina Response:

For the NIRB's convenience, a listing of the terms and conditions and commitments that were recommended during the FEIS Final Hearing by INAC and agreed to by Sabina that are relevant to the topic of climate and meteorology are provided in the table below.

Recommended Terms & Conditions and Commitments:

Type	Identifier	Suggested Text from Final Hearing	Anticipated Party Involvement
Term and Condition	INAC-T-1	The Proponent shall revise the Closure and Reclamation Plan to include an adaptive management component that documents proposed monitoring and mitigation measures to ensure long-term containment of the Tailings Storage Facility and Waste Rock Storage Areas. The revised plan shall include detail on the triggers for implementing alternative mitigation options, and shall be submitted to the Nunavut Water Board during the water licence application process.	INAC

FHR-NIRB-4.2(A) - Effects of Climate Change on Tailings and Waste Rock Storage During Closure

The Board has raised concerns and requested additional information regarding the long-term operations and closure of the waste rock and tailings facilities at the Project. Given the uncertainty associated with a changing climate, the Board identified outstanding concerns with the viability of maintaining freezing conditions beyond closure, as well as proposed mitigation strategies in event the freezing conditions could not be maintained.

Sabina would like to highlight the extensive waste rock and tailings characterization, design, and closure information that was submitted, and made available through the environmental assessment phase. Specifically, the following supporting documents, Information Requests, and Technical Comments were included:

- FEIS Appendix V2-4A: Waste Management Multiple Accounts Analysis Report
- FEIS Appendix V2-7A: Hydrogeological Characterization and Modeling Report
 - Appendix B: Goose Property Talik Thermal Modeling
- FEIS Appendix V2-7C: Site Wide Geotechnical Properties Report
- FEIS Appendix V2-7D: Geochemical Characterization Report
- FEIS Appendix V2-7E: WRSA Design Report
 - Attachment A: Waste Rock Storage Area Thermal Modeling
- FEIS Appendix V2-7G: Tailings Management System Design Report
 - Appendix G: TSF Containment Dam Thermal Modeling
- FEIS Appendix V2-7H: Water and Load Balance Report
- FEIS Appendix V4-3C: Climate Change Approach Memo
- FEIS Appendix V4-3B: Climate Change Predictions
- FEIS Volume 10: Management Plans
 - Chapter 10, Site Water Monitoring and Management Plan
 - Chapter 9, Mine Waste Rock Management Plan
 - Chapter 22, Tailings Management Plan
 - Chapter 29, Mine Closure and Reclamation Plan
- FEIS Information Request Responses (February 2016)
 - F-INAC-IR-4: Tailings Management System Containment Dam Thermal Modeling
 - F-INAC-IR-7: Waste Rock Storage Areas Management Design
 - F-NRCAN-IR-1: Thermal conditions in the Tailings Storage Facility
 - F-GN-IR-2: Tailings Management and Climate Change Modelling
- FEIS Technical Comment Responses (March 2016)
 - F-INAC-TC-7: TMS Thermal Modeling Thawing n-Factor
 - F-INAC-TC-8: TMS Containment Dam Long-Term Thermal Modeling
 - F-INAC-TC-9: Waste Rock Storage Areas Management Design Long-Term
 - F-NRCAN-TC-3: Permafrost and Terrain Stability: Design of Tailing Storage Facility (TSF) - Thermal Conditions
 - F-NRCAN-TC-4: Permafrost and Terrain Stability: Design of Tailings Storage Facility and Waste Rock Storage Area - Cover Thickness

Sabina's objectives for mine closure include the following (FEIS Volume 10, Chapter 29, Section 1.7):

- Design the mine for closure, through the identification of processes and forces that may act upon the mine components after the mine closure and reclamation so that they can be factored into the design and operation of the mine.

- Mine components that will remain after mine closure will be constructed or modified at closure to be physically stable.
- Mine components, including wastes, remaining after mine closure will be chemically stable.
- All practical efforts will be made to ensure that Project components that remain after closure will not require long-term active care.
- Reclamation will consider future use and aesthetics, and the site will be compatible with the surrounding lands once reclamation activities have been completed.

With a focus on these objectives, Sabina developed an approach to climate change (FEIS Appendix V4-3C), and a detailed description of the climate change projections and model variations in which this approach was founded (FEIS Appendix V4-3B).

To further address the concerns raised by the Board in the Final Hearing Report, Sabina commissioned an additional review of this topic by Maritz Rykaart, PhD, PEng, Practise Lead and Principal Consultant (Geotechnical) with SRK, *Back River Project: Considering Climate Change in Tailings Storage Facility and Waste Rock Storage Areas Closure Strategy* (SRK Memo; FEIS Addendum Appendix V4-3D) and a third party peer review of SRK's methodology by Janya Kelly, PhD, Air Quality and Climate Change Specialist and Sean Capstick, PEng, Principal with Golder Associates, *Climate Change Peer Review of Back River Project Waste Rock and Tailings Closure Strategy* (the Golder Memo; FEIS Addendum Appendix V4-3E); both of these documents are attached.

A summary of the key points discussed in both these new documents is provided below:

Best Practices in Arctic Cover Design

Based on the uncertainty associated with future projected climate change, the freezing conditions required for the proposed cover design is difficult to be guaranteed post closure. To address this concern, the proposed cover designs were compared to the cover designs of other mine sites in the Canadian Arctic, including their consideration of climate change, to demonstrate that best practices were being followed.

Freeze encapsulation covers are a well-established practice in northern Canada. These covers have been effectively implemented, or are proposed to be implemented, at least at eight other mines in Nunavut and the Northwest Territories, all of which have taken climate change into consideration.

- Nanisivik Mine, NU
- Mary River Project, NU
- Meadowbank, NU
- Ekati, NWT
- Diavik, NWT
- Snap Lake, NWT
- High Lake, NU (Proposed)
- Meliadine, NU (Proposed)

For a detailed benchmarking of the closure strategies used at these mines compared to the proposed strategy for the Project, see the SRK Memo, Section 4.4.

Through detailed benchmarking, the Project's proposed cover thickness was found to be the thickest compared to cover designs for existing Canadian Arctic mine sites. Based on this assessment, including support by a thermal modelling assessment, the SRK Memo states that any seasonal thawing proposed to take place under current and future projected climate conditions would be contained within the currently proposed 5m cover. With the seasonal thaw taking place within the cover, all intentionally encapsulated materials will remain frozen year round.

Monitoring Program to Observe Freezing Conditions

As part of the ongoing adaptive management plan, performance monitoring will be conducted to measure freeze encapsulation of the cover during Operations and through Closure. This cumulative monitoring will span 21 years and is sufficient monitoring time to inform the decision of whether the freeze encapsulation design needs to be modified or if an alternate mitigation strategy needs to be adopted (SRK Memo, Section 5.1).

This monitoring, along with the most recent projections of future climate change available, will inform whether the freeze encapsulation cover design requires modification through periodic updates to the thermal analysis modelling. Uncertainty is addressed both through the comparison to other existing Arctic mine sites, through the collection of thermal data that would be submitted with annual reports, and through the periodic updates to thermal analysis modelling incorporating the most up to date climate change projections available.

This process will be reviewed annually by an independent, appropriately qualified engineer. If the results deviate substantially from the expected freeze-back monitoring predictions, the variance will be investigated, and if appropriate, the closure strategy will be reviewed and discussed with regulators (SRK Memo, Section 5.3). This is a new, unsolicited commitment not previously stated in the FEIS, the technical review phase, nor the FEIS Final Hearing. This new commitment is meant to add further confidence for the Board that Sabina will ensure adequate monitoring is completed and adaptive management employed.

Mitigation Strategies in the Adaptive Management Plan

The focus of Sabina's adaptive management plan is on determining whether the freeze encapsulation cover design will be robust enough to maintain freezing conditions post-closure under the range of future climate projections, and on the steps to take if freezing conditions are unable to be maintained post-closure. A robust list of mitigation strategies is proposed based on existing strategies in place at other Canadian Arctic mines.

The primary strategy is to increase the cover thickness based on field measurements collected, updated thermal analysis modelling, assuming there is sufficient cover material on site if required. If sufficient material is not available, the storage areas may be consolidated to reduce the need for cover material.

The remaining mitigation strategies involve changing the type of cover considered (water and low infiltration geomembrane) or water treatment. The water treatment would treat the surface drainage and localized seasonal subsurface flow within the active layer emanating from the mine waste facilities.

While the proposed mitigation strategies are less sensitive to a changing climate, the cover designs will still be informed by future climate projections where appropriate, helping to address uncertainty.

Requirements for Additional Mitigation Strategies

Based on Sabina's adaptive management plan, the Project addresses the viability of maintaining freezing conditions post-closure and the uncertainty associated with climate change projections. In addition, as part of demonstrating best practices, the Project provides comparisons to existing Arctic mine sites where the proposed strategies are currently employed.

As part of the closure plan review process, under the Nunavut Water Board, the appropriate regulating agencies will have the opportunity to review the final closure strategy, including the comparison of the modelling and monitoring comparison used to inform the requirement for additional mitigation strategies. There will be opportunity at this point to further refine any requirements for mitigation and what mitigation strategies are being considered. Separate to

the closure plan review process, Sabina will internally review the modelling and monitoring data on a periodic basis.

The Board has stated that they require additional information to support the conclusions or reduce the uncertainty surrounding climate change. Sabina acknowledges the Boards' outstanding and remains willing and able to discuss any issues related to climate change.

With the additional information provided in this Addendum, Sabina has endeavoured to address the concerns of the Board by highlighting the industry leading approach to our waste rock and tailings closure strategy, and our commitment to adaptively manage this strategy. In addition, Sabina is offering a new, unsolicited commitment for an annual geotechnical inspection to be completed by an independent, appropriately qualified engineer.

Using an adaptive management approach, with regularly collected site data and the most current climate change modelling, Sabina is confident that we can continue to employ industry leading practices and implement appropriate mitigation measures should site conditions change in the future.

Attachment:

FEIS Addendum Appendix V4-3D. Climate Change Memo

FEIS Addendum Appendix 4V-3E. Climate Change Expert Third Party Review

ADDENDUM APPENDIX V4-3D: CLIMATE CHANGE MEMO (NEW)

Memo

To:	Matthew Pickard, VP, Environment & Sustainability,	Client:	Sabina Gold & Silver Corp.
From:	Maritz Rykaart, PhD, PEng	Project No:	1CS020.008
Cc:	Catherine Paul, Project Engineer	Date:	February 14, 2017
Subject:	Back River Project: Considering Climate Change in Tailings Storage Facility and Waste Rock Storage Areas Closure Strategy		

Executive Summary

The Nunavut Impact Review Board (NIRB) has raised concerns regarding the long term operations and closure of the waste rock and tailings facilities at the Back River Project (the Project). Given the uncertainty associated with a changing climate, NIRB identified outstanding concerns with the viability of maintaining freezing conditions beyond closure, as well as proposed mitigation strategies in the event that freezing conditions could not be maintained. This memo provides additional supporting information to address these concerns by:

- Demonstrating that best practices in the field of freeze encapsulation cover design are being followed with comparisons to existing mine sites in the Canadian Arctic;
- Committing to a monitoring program that will observe freezing conditions during the Operations and the Closure phases;
- Outlining the options that would be included as part of Sabina's adaptive management plan to overcome the uncertainties of a changing climate; and
- Providing the triggers that will require mitigation strategies under the adaptive management plan to be implemented if freezing conditions are not maintained Post-Closure.

The proposed Project freeze encapsulation cover designs rely on freezing conditions post closure; however, there is concern that future climate change projections may impact the ability to maintain freezing conditions. The Project has addressed this in a number of ways. First, the proposed freeze encapsulation cover designs were compared to the freeze encapsulation cover designs of other mine sites in the Canadian Arctic. The proposed cover thickness for the Project exceeds current best practice and is thicker than the freeze encapsulation cover designs for all existing mine sites in the Canadian Arctic; any seasonal thawing will take place in the cover and all deposited materials will remain frozen year-round.

As part of ongoing adaptive management, performance monitoring will be conducted to measure the effectiveness of the freeze encapsulation cover during Operations. This monitoring, along with the most recent projections of climate change, will inform whether the freeze encapsulation cover design requires modification through periodic updates to the thermal modeling, including modeling that will be done at the time the application for the closure permit will be filed.

If updated thermal analysis modeling shows freezing conditions are unable to be maintained Post-Closure, the mitigation strategies that are proposed will be implemented. The primary strategy is to increase the cover thickness, and there is sufficient cover material on site if required. The remaining mitigation strategies involve changing the type of cover or water treatment. These strategies have been implemented at other mines in the Canadian Arctic and are less sensitive to a changing climate.

Through Sabina's adaptive management plan, the Project addresses the viability of maintaining freezing conditions in waste rock and tailings Post-Closure and the uncertainty associated with climate change projections.

1 Introduction

1.1 Background

The NIRB identified outstanding concerns regarding the suitability of the long term closure strategy in the Project Final Hearing Report, June 2016 (NIRB, 2016); NIRB cited concerns about the long-term viability of maintaining freezing conditions when considering uncertainty associated with climate change predictions. Furthermore, the NIRB is of the opinion that Sabina did not present credible mitigation strategies in case the proposed closure strategy could not be successfully implemented.

This memo provides additional context pertaining to the proposed waste rock and tailings closure strategy.

The Project will generate two mine waste streams; waste rock and tailings. Geochemical characterization of the waste rock (FEIS Volume 2, Appendix V2-7D) has confirmed that there are two waste rock types; potentially acid generating (PAG), and non-potentially acid generating waste rock (NPAG).

Acid generation of waste rock occurs when sulfides, naturally occurring in the host rock, are exposed to oxygen after it has been mined. This exposure results in a chemical reaction called oxidization. Depending on the type and quantity of sulfides exposed, the reaction time can vary greatly, from days to decades. Acid rock drainage (ARD) occurs if water percolates through oxidized waste rock. The resultant drainage may be acidic and contain elevated concentrations of metals that are also naturally occurring in the host rock.

Tailings geochemical characterization (FEIS Volume 2, Appendix V2-7D) has demonstrated that the tailings deposited into the Tailings Storage Facility (TSF) is PAG; this facility is active for the first two years of mining.

Geochemical testing has also confirmed that reactivity of the PAG tailings and PAG waste rock material is slow (FEIS Volume 2, Appendix V2-7D), suggesting that if left exposed to the natural environment, ARD development would likely not be observed until many decades after the PAG material has been placed.

In order to delay or entirely prevent the onset of ARD, the oxidation process needs to be prevented from happening, i.e., exposure to oxygen must be restricted. Similarly, if oxidation does occur, ARD can be minimized by limiting the amount of water that percolates through the mine waste. Since the potential oxidation rate is very slow, limiting the amount of water percolating through the mine waste would lead to any seepage water staying well within accepted water quality guidelines at the designated downstream receiving environment.

Since the Project is located in the Canadian Arctic, both the waste rock and tailings will naturally freeze (FEIS Volume 2, Appendix V2-7E; FEIS Volume 2, Appendix V2-7G). This frozen state is the most likely future scenario and thus it constitutes an effective means of slowing down the oxidation rate and limiting percolation of water through the mine waste. Therefore, following rigorous thermal analysis, which takes into consideration climate change (FEIS Volume 4, Appendix V4-3C; FEIS Volume 4, Appendix V4-3B), Sabina has proposed a closure strategy for their waste rock storage areas (WRSAs) and TSF tailings, which consists of an NPAG waste rock freeze encapsulation cover of at least 5 m thick. Thus any seasonal thawing would be totally within the NPAG material maintaining all PAG material in the frozen state.

1.2 Previous Work

Waste rock and tailings characterization, design, and closure are described in detail in the Back River Project Final Environmental Impact Statement (FEIS) submitted in November 2015. Specifically, the following supporting documents, Information Requests, and Technical Comments contain the information on which the statements included in this memo are based on:

- Appendix V2-4A: Waste Management Multiple Accounts Analysis Report
- Appendix V2-7A: Hydrogeological Characterization and Modeling Report
 - Appendix B: Goose Property Talik Thermal Modeling
- Appendix V2-7C: Site Wide Geotechnical Properties Report
- Appendix V2-7D: Geochemical Characterization Report
- Appendix V2-7E: WRSA Design Report
 - Attachment A: Waste Rock Storage Area Thermal Modeling
- Appendix V2-7G: Tailings Management System Design Report
 - Appendix G: TSF Containment Dam Thermal Modeling
- Appendix V2-7H: Water and Load Balance Report
- Appendix V4-3C: Climate Change Approach Memo

- Appendix V4-3B: Climate Change Predictions
- Volume 10: Management Plans
 - Site Water Monitoring and Management Plan
 - Mine Waste Rock Management Plan
 - Tailings Management Plan
 - Mine Closure and Reclamation Plan
- FEIS Information Request Responses (February 2016)
 - F-INAC-IR-4: Tailings Management System Containment Dam Thermal Modeling
 - F-INAC-IR-7: Waste Rock Storage Areas Management Design
 - F-NRCAN-IR-1: Thermal conditions in the Tailings Storage Facility
 - F-GN-IR-2: Tailings Management and Climate Change Modeling
- FEIS Technical Comment Responses (March 2016)
 - F-INAC-TC-7: TMS Thermal Modeling Thawing n-Factor
 - F-INAC-TC-8: TMS Containment Dam Long-Term Thermal Modeling
 - F-INAC-TC-9: Waste Rock Storage Areas Management Design Long-Term
 - F-NRCAN-TC-3: Permafrost and Terrain Stability: Design of Tailing Storage Facility (TSF) - Thermal Conditions
 - F-NRCAN-TC-4: Permafrost and Terrain Stability: Design of Tailings Storage Facility and Waste Rock Storage Area - Cover Thickness
- Nunavut Impact Review Board, Final Hearing Report, Back River Gold Mine Project, NIRB File No. 12MN036, June 2016

1.3 NIRB Concerns

The NIRB, in Section 4.2.3 of their Final Hearing Report (NIRB, 2016), makes the following statement:

The Board recognizes discussions between federal departments and Sabina regarding the proposed remediation measures for the tailings storage and waste rock areas and their potential future interactions with the seasonal active layer should changes in climatic conditions continue as predicted. During the Final Hearing, the Board questioned Sabina on whether it would apply adaptive management to its model and reclamation plans if climatic conditions were to change in the future (e.g., in 20 years). Sabina clarified that to verify its predictions it would close off certain facilities and conduct tests to assess whether freeze back is occurring and would apply adaptive management measures if required. The Board acknowledges that commitments made by the Proponent sufficiently

addressed concerns raised by federal departments throughout the Review, however, the Board remains uncertain whether the proposed mitigation and monitoring measures, such as the application of a rock cover limited to five metres, would effectively mitigate impacts that could result from climate change on the tailings and rock storage areas. As such, the Board is not confident that the management measures, as proposed, could adapt to greater than expected adverse effects on these project components and maintain the pristine environmental integrity of the project area given the speed that climatic conditions can change and effects can be realized.

This leads to the NIRB reaching the following conclusions in Section 4.2.4 of their Final Hearing Report (NIRB, 2016):

In considering the views of the Proponent and those of parties throughout the assessment of the Project and as outlined above, the Board is not confident that the mitigation, monitoring, and adaptive management measures as proposed will be sufficient to mitigate effects related to climate change on tailings and waste rock storage areas because of the highly variable climatic conditions that may be experienced within the project area and the likelihood that covered tailings and support structures would interact with the seasonal active layer sooner and more consistently than predicted. Should the Proponent revise the project proposal for future submission, it is the Board's view that more information about long term monitoring of tailings and tailings storage structures in an Arctic environment with real world examples and discussion of any observed or anticipated climate change effects would be very helpful.

This memo aims to address these specific concerns and recommendations as outlined by the NIRB.

2 Waste Rock and Tailings Closure Concerns

2.1 Tailings Quantities

At the Project, the life-of-mine ore production is about 19.8 Mt; this is approximately equal to the total amount of tailings that will be produced. Following a rigorous alternatives assessment, it was concluded that the most environmentally protective strategy for tailings management would be constructing a purpose-built TSF to contain the first two years of tailings production. The remaining tailings will be deposited in the exhausted open pits.

The quantity of tailings in the TSF will be 3.8 Mt (3.1 Mm³); this will be closed by placing at least a 5 m thick cover of NPAG waste rock over the entire facility. The Umwelt Tailings Facility (TF) and Goose Main TF will be closed with a permanent water cover; this is a proven mitigation strategy previously used at Canadian Arctic mines and will ensure appropriate ARD management.

2.2 Waste Rock and Overburden Quantities

At the Project, a total of 64.3 Mt of overburden and waste rock will be generated from open pit and underground operations, and divided as follows:

- Overburden = 5.3 Mt;
- NPAG waste rock = 24.7 Mt (~42%); and
- PAG waste rock = 34.3 Mt (~58%).

Waste rock and overburden will be produced during mining and will be stored in engineered WRSAs located close to each of the open pits. There will be four WRSAs; Umwelt, Llana, TSF, and Echo. Each will be closed by placing at least a 5 m thick cover of NPAG waste rock over the entire facility. At the Project, overburden testing has confirmed this material is NPAG; as such, overburden can be placed either within the frozen zone of the WRSAs, or used as a portion of the cover material.

2.3 Issue

PAG waste rock material will result in ARD, and geochemical source load predictions (FEIS Volume 2, Appendix V2-7D; FEIS Volume 2, Appendix V2-7H) have confirmed that this drainage will not meet discharge water quality criteria. As a result, a mitigation strategy to manage ARD is required.

The best mitigation strategy against ARD is to prevent it before it can develop. This can only be done by preventing the material from oxidizing in the first place, and practically can only be done by sub-aqueously depositing the material immediately after exposure. This option was considered in the rigorous mine waste disposal alternatives assessment (FEIS Volume 2, Appendix V2-4A) completed for the Project, but was not selected since it could not be done without requiring perpetual engineered water retaining structures (i.e., dams).

The Project mine waste rock is however slow to react (FEIS Volume 2, Appendix V2-7D); therefore, the onset of ARD is delayed, potentially by many decades. As a result, the next best strategy for managing ARD can effectively be adopted at the Project. This strategy entails minimizing the amount of percolation that would flow through the mine waste, such that the volume of ARD being released into the environment would be sufficiently small and would not have a detrimental effect (FEIS Volume 2, Appendix V2-7E).

2.4 Waste Rock Exposure Pathways

The Project is located in the continuous permafrost region of Canada. At the Project site, the permafrost is up to 500 m thick, and the active layer thickness averages around 1.5 m. The permafrost is also very cold, having a surface temperature below zero with an annual amplitude of between -6°C and -8°C (FEIS Volume 2, Appendix V2-7C). Climate change projections for the Project site included in FEIS Volume 5, Appendix V4-3B confirmed that continuous permafrost will continue to exist in the region in the very long term. Regional groundwater in this environment is limited to talik zones which are located beneath large natural lakes, and below the deep permafrost. Within this active layer, there is localized seasonal subsurface flow, but this is not connected to the regional groundwater system (FEIS Volume 2, Appendix V2-7A).

Meteoric water (i.e., precipitation in the form of snow and rain) falls on the mine waste rock and some portion of that will percolate into the mine waste and ultimately emerge as drainage. This drainage may appear as surface seepage at the perimeter of the mine waste facility, and will continue as surface flows to overland surface water bodies. In warmer climates without permafrost, drainage may also percolate directly to groundwater underneath the facility without emerging as surface flow; however, at the Project site, a connection between the mine waste facilities and the regional groundwater system is not present.

All of the Project WRSAs and the TSF will be constructed on permafrost (FEIS Volume 2, Appendix V2-7D; FEIS Volume 2, Appendix V2-7E; FEIS Volume 2, Appendix V2-7G), and thermal analysis has demonstrated that within a very short timeframe (less than five years) permafrost aggradation will occur into the mine waste (FEIS Volume 2, Appendix V2-7E). This means there is no hydraulic connection between the mine waste facilities and the regional groundwater system. As a result, none of the mine waste facilities have design elements that would preclude drainage to the regional groundwater since this pathway does not exist.

Therefore, to manage impacts associated with ARD from the mine waste facilities, appropriate mitigation measures should be put in place for managing surface drainage and localized seasonal subsurface flow within the active layer only.

3 Waste Rock and Tailings Closure Options

There are various options available to manage potential for ARD and Sabina has thoroughly investigated these (FEIS Volume 2, Appendix V2-7E). Although some of these options are not viable, there are several possible options that could be implemented if the most favourable option (freeze encapsulation covers) does not work as expected. Below is a summary of the options explored.

3.1 Do Nothing

Leaving the WRSAs and the TSF exposed to the environment will result in the onset of ARD, which will emerge as surface drainage and localized seasonal subsurface flow within the active layer. Geochemical source load predictions (FEIS Volume 2, Appendix V2-7D) and subsequent water and load balance modeling (FEIS Volume 2, Appendix V2-7H) have confirmed that without mitigation this drainage will not meet discharge criteria and therefore the “Do Nothing” closure option is not viable.

3.2 Water Treatment

It would be possible to effectively capture, collect, and treat all surface drainage and localized seasonal subsurface flow within the active layer emanating from the mine waste facilities. The capture and collect methods would entail conventional engineered sub-surface cut-off drains and surface collection channels and ponds. Treatment methods would similarly entail conventional metal treatment systems. This mitigation strategy is completely protective of the environment and has been used, or is currently in use, during the reclamation or progressive reclamation phase at

many northern Canadian mine sites including Lupin Mine, Con Mine, Seabee Mine, Giant Mine, Faro Mine, and Colomac Mine.

Based on geochemical source load predictions (FEIS Volume 2, Appendix V2-7D), water treatment at the Project would have to continue in perpetuity. Therefore, this mitigation strategy is not preferred, but would be an effective final mitigation strategy should all other mitigation strategies prove to be ineffective.

3.3 Relocate and/or Consolidate Waste Rock and/or Tailings

Relocating mine waste to areas where it has better environmental containment is a practical closure strategy and has been adopted at other northern Canadian mines including the Faro Mine, Con Mine, and Giant Mine.

At the Project site, this can best be achieved by relocating PAG material to a natural lake, such that it can be completely submerged and thereby permanently stop ongoing oxidation. This was considered as a proactive mitigation strategy as part of the mine waste disposal alternatives assessment (FEIS Volume 2, Appendix V2-4A) and was in part rejected as the preferred option because Sabina's current understanding is there are no suitable natural lakes in close proximity to the Project. The only way to achieve this would therefore be to construct water retaining structures that would have to be maintained in perpetuity. In addition, placement of PAG mine waste into a natural lake may require listing of the lake under Schedule II of the Metal Mining Effluent Regulations (MMER).

Alternatively, mine waste can be returned to the mined out open pits, which will be flooded into and beyond closure time frames. Sabina is already maximizing this strategy by using open pits as they become available for tailings. At the end of mine life, accounting for the current in-pit water and tailings disposal, additional capacity is available in exhausted open pits that could be used to relocate PAG material. This means a substantial portion of the PAG material on surface could be relocated to these open pits and flooded with a permanent water cover of at least 5 m to mitigate any ongoing ARD concerns.

While this mitigation would be effective, it would be costly to implement, and would have to be carefully evaluated following a rigorous trade-off analysis against other mitigation strategies presented herein.

3.4 Cover System

3.4.1 Concept

Engineered covers are a proven technology to manage PAG mine waste. The cover system is designed to perform specific functions to allow management of the ARD such that the stated closure objectives can be met, which in the case of the Project would be to ensure that all mine waste drainage meets water quality discharge criteria.

3.4.2 Oxygen Reducing Cover

An oxygen reducing cover over the mine waste facilities will prevent or slow down ongoing oxidation. As mentioned in Section 1.1, complete prevention of oxidation is likely not possible, and therefore the attainable and suitable goal would be to slow down oxidation. The most successful oxygen reducing cover is a water cover. This cannot be done with the mine waste facilities at the Project site unless permanent water retaining structures are constructed, which is not deemed a viable long term solution. Relocation to a natural lake or mined out pits was discussed in Section 3.3.

Effective oxygen reducing covers can be constructed using saturated cover materials; however, no suitable fine grained borrow materials are available at the Project site (FEIS Volume 2, Appendix V2-7C). As a result, it was concluded that construction of oxygen reducing covers is not a viable closure strategy.

3.4.3 Infiltration Reducing Cover

By reducing the amount of drainage through the mine waste facility, the volume of ARD is significantly reduced. If this volume of drainage is sufficiently low, the appropriate discharge criteria can be met and thus an infiltration reducing cover can be deemed a viable mitigation strategy.

Infiltration reducing covers in Arctic regions function by shedding water and snow, reducing percolation, or both. Water and snow shedding can be achieved through proper landform design. Reducing percolation can be achieved by constructing the cover with a low-permeability material. There is no suitable natural low-permeability borrow materials at the Project site with which to construct a low infiltration cover (FEIS Volume 2, Appendix V2-7C); therefore, the only viable alternative is to use geosynthetic products such as geomembrane liners. These products are routinely used in the Canadian Arctic for this purpose. Examples include Con Mine, Faro Mine, and Beaverlodge Mine.

Construction of geomembrane covers over the Project mine waste facilities would be an effective means to manage ARD, but it would be very costly to implement. It would therefore have to be carefully evaluated following a rigorous trade-off analysis against other mitigation strategies presented herein.

3.4.4 Freeze Encapsulation Cover

Thermal modeling has demonstrated that the mine waste will naturally freeze back within a short timeframe after placement (FEIS Volume 2, Appendix V2-7E; FEIS Volume 2, Appendix V2-7G). By constructing a freeze encapsulation cover over the PAG material, the material can be kept in a frozen state as a permanent closure strategy. In the frozen state, the rate of oxidation is substantially reduced and the drainage is reduced to zero. This strategy has been successfully applied, or proposed, at many different mines in the Canadian Arctic (Section 4) which is why it has been selected as the preferred mitigation strategy for closure of the Project mine waste facilities.

4 Freeze Encapsulation Mine Waste Cover

4.1 Design Concept

Although there is no suitable natural borrow materials at the Project site with which to construct a freeze encapsulation cover (FEIS Volume 2, Appendix V2-7C), about 58% of the mine waste rock is NPAG and can be used as cover material. The closure strategy therefore entails placing a layer of NPAG material over any PAG material, sufficiently thick that the active layer will be maintained entirely within the NPAG cover material. This will ensure that the underlying PAG material will not produce ARD since the percolation component has been eliminated.

4.2 Thermal Analysis

Comprehensive thermal analysis was carried out to determine what thickness the NPAG cover should be (FEIS Volume 2, Appendix V2-7E; FEIS Volume 2, Appendix V2-7G). Subsequently a cover thickness of at least 5 m was proposed.

The thermal analysis took into consideration climate change in all scenarios, and was based on best practice procedures. All thermal modeling was completed to the year 2100 (FEIS Volume 4, Appendix V4-3C; FEIS Volume 4, Appendix V4-3B). Thermal modeling of coarse WRSAs is a complex process and the analysis outcome is dependent on the modeling assumptions and input variables. Subsequently, the analysis presented (FEIS Volume 2, Appendix V2-7E; FEIS Volume 2, Appendix V2-7G) considered a broad and comprehensive sensitivity analysis to demonstrate uncertainty. The resultant “Base Case” demonstrates that for the duration of the modeling period, the 5 m NPAG cover would achieve the goal of ensuring frozen conditions within the PAG material. However, all thermal analysis results (which includes an allowance for climate change) show a constant and indefinite warming trend, which if extrapolated beyond the year 2100 will inevitably reach a point where frozen conditions in the PAG material cannot be maintained. The reasons for this, and the rationale for limiting thermal analysis to the year 2100 is described further in Section 4.3 below.

Due to the inherent uncertainty associated with the thermal analysis, the “Base Case” was intentionally chosen to be highly conservative. Some of the more “realistic” sensitivity analysis scenarios suggest substantially improved performance of the freeze encapsulation cover. The thermal analysis was reviewed by various technical experts including Dr. Lucas Arenson of BGC Engineering Inc. on behalf of the Kitikmeot Inuit Association (KIA), and Dr. Sharon Smith of Natural Resources Canada. Both of these individuals are preeminent experts in the field of permafrost engineering and thermal analysis, and they concluded that the analysis was appropriate and conservative.

4.3 Climate Change

A rigorous assessment of climate change, in accordance with accepted best practice, was presented (FEIS Volume 4, Appendix V4-3C; FEIS Volume 4, Appendix V4-3B). Although there is no question that climate change is occurring, there is a general understanding regarding the great uncertainty in predicting climate change, particularly regional climate change, into the future. To

that end, it is recognized that predictions beyond the year 2100 are associated with a very significant degree of uncertainty (FEIS Volume 4, Appendix V4-3C; FEIS Volume 4, Appendix V4-3B). The Department of Environment and Climate Change Canada (ECCC) publishes climate change model predictions for all of Canada only to the year 2100 for this very reason. However, the mathematical algorithms allow predictions to be made beyond this timeframe. In doing this, the changes have no upper bound and therefore predict constant climate change trends in perpetuity. For example, mean annual air temperature is predicted to increase up to the year 2100, and if the model is extrapolated beyond that time then climate change is predicted to continue to increase indefinitely. A comprehensive discussion describing the rationale for limiting climate change predictions to the year 2100 was presented in Sabina's March 2016 Responses to Technical Comments, specifically F-INAC-TC-8 and F-INAC-TC-9. This matter was also described in detail by Dr. Maritz Rykaart, PEng. Principal Geotechnical Engineer on behalf of Sabina at the final public hearing (Final Hearing Transcript Volume 5, April 29, 2016, Pages 241-247).

4.4 Closure Strategy Benchmarking

Freeze encapsulation covers are a well-established practice in northern Canada. The covers have been effectively implemented, or are proposed to be implemented, at least at eight other mines in Nunavut and the Northwest Territories, all of which have taken climate change into consideration (Table 1).

Table 1 summarizes measured and modeled waste rock active layer and cover thickness. These results are graphically presented in Figure 1. When directly comparing the waste rock active layer and cover thickness from other mine sites to those estimated for the Project, care must be taken to consider site-specific conditions. Some of these considerations include local climate, waste rock type, material placement history, facility design, stage of operation, and reactivity of the material.

Table 1: Comparative Waste Rock Thickness

Mine	Latitude	MAAT (°C)	Facility	Active Layer Measurement Type	Waste Rock Active Layer Thickness ^[1]	Proposed or Constructed Cover		
						Cover Type	Cover Details	Cover Thickness
Nanisivik Mine, NU	73°02'	-14.8	Area 14 WRSA	Observed	1.2 m ^[2]	Freeze Encapsulation Rock Cover	Two-layer cover: 2.0 m NPAG (shale) overlain by 0.35 m soil (sand and silt) ^[5]	2.30 m
				Modeled (Conduction)	(2.2 m)			N/A
			Observed	1.4 m ^[2]	2.20 m			
				2.0 m ^[2]	2.35 m			
				~1.2 m ^[2]	2.35 m			
			Test Cell Tailings	Modeled (Conduction)	(1.25 m)		Two-layer cover: 1 m NPAG (shale) overlain 0.25 m soil	1.25 m ^[6]
				Observed	~0.95 m			
Surface Cell Tailings	Observed	1.2 m						
Mary River Project, NU	71°20'	-13.3	Porous waste rock	Modelled (Conduction and Air Convective)	50 - 100 m	Freeze Encapsulation Rock Cover	One-layer cover: 2-3 m NPAG waste rock	2.00 - 3.00 m
			Non-porous waste rock	Modelled (Conduction)	3 m			
High Lake, NU	67°22'	-11.8	Waste rock pile	Modelled (Conduction)	-	Freeze Encapsulation Rock Cover	One-layer cover: 1-3 m NPAG waste rock	1.00 - 3.00 m
Meadowbank, NU	65°01'	-11.1	Portage Rock WRSA	Observed	~1.5 m	Freeze Encapsulation Rock Cover	One-layer cover: 4 m NPAG waste rock	4.00 m
				Modelled	-			
			NPAG Waste Rock over tailings	Modelled	-		One-layer cover: 2 m NPAG waste rock	2.00 m ^[6]
Back River Project, NU	65°29'	-10.6	WRSAs	Modelled (Conduction)	3.0 - 6.2 m (4.4 - 9.9 m)	Freeze Encapsulation Rock Cover	One-layer cover: 5 m NPAG waste rock	5.00 m
Meliadine Project, NU	65°01'	-10.4	NPAG Waste Rock over tailings	-	-	Freeze Encapsulation Rock Cover	Two-layer cover: 2.5 m NPAG waste rock underlain by 0.5 m soil	3.00 m ^[6]
Ekati, NWT	64°43'	-10.2	Panda/Koala WRSA	Observed	<2 - 3.8 m	-	-	-
			Panda/Koala WRSA Toe Berm		2 - 3.4 m			
			Fox WRSA (uncovered)		4.8 - 6.0 m			
			Fox WRSA Toe Berm		1.5 - 4.0 m			
			Misery WRSA		2.5 - 14 m ^[3]	Freeze Encapsulation Rock Cover	One-layer cover: 5 m NPAG waste rock	5.00 m
			Pigron WRSA	Modelled (Conduction)	2.4 m (3.6 m)	Freeze Encapsulation Rock Cover, Latent Heat Layer	Two-layer cover: 1 m NPAG waste rock underlain by 3 m of saturated soil (till)	4.00 m
Modelled (Conduction)	3.3 m (5.0 m)	Freeze Encapsulation Rock Cover		-	-			
Diavik, NWT	64°30'	-9.1	Test Pile	Observed (with cover)	2 m	Freeze Encapsulation Rock Cover, Latent Heat Layer	Two-layer cover: 3.0 m NPAG (type 1 rock) underlain by 1.5 m saturated soil (till)	4.50 m
				Observed (no cover)	7 m ^[2]			
			North Country WRSA	Modeled (Conduction)	~ 3 m (3.9 m) ^[4]			
				Modelled (Conduction and Air Convection)	~2 m (2.5 m) ^[4]			
Processed Kimberlite Tailings		-		-	Two-layer cover: 3.0 m NPAG (type 1 rock) underlain by 0.5 m saturated soil (till)	3.50 ^[6]		
Snap Lake, NWT	63°36'	-7.7	North Pile WRSA (active deposition)	Observed	1.6 - 8.6 m	Freeze Encapsulation Rock Cover	One-layer cover: 4 m NPAG	4.00 m

Foot Notes:

¹ Modelled long-term waste rock active layer thickness with consideration of climate change shown in parentheses

² Observed active layer continues to decrease with continued heat loss from the underlying waste rock

³ Deep active layer thought to be associated with proximity to side slopes and accumulation of snow

⁴ Modelled active layer for 5 years after cover placement

⁵ Minor variability in cover layer thickness for facility

⁶ Reduced rock-fill cover thickness for tailings facilities due to tailings properties which alter the thermal regime and reduces active layer thickness

Freeze encapsulation cover thickness is also dependent on cover type and design, which is specific to each waste rock or tailings facility. For example, freeze encapsulation covers consisting of well-drained NPAG waste rock or geochemically suitable quarry rock are expected to exhibit greater active layer thaw when compared to freeze encapsulation covers with a two-layer design (i.e., a coarse rock layer underlain by fine-grained, high moisture content soil forming a latent heat layer).

These two freeze encapsulation cover types inherently have different physical and thermal properties which alter heat transfer and seasonal thaw. Freeze encapsulation covers also include air convection covers (ACC) that are constructed with screened coarse NPAG rock of high air permeability. During the freezing season (winter), thermal gradients result in difference in air density through the cover which allows for greater air circulation and enhanced heat loss. The low heat-transfer properties (low thermal conductivity) of the coarse, well-drained rock also limits the input of heat during the thawing season (summer).

Table 1 shows cover thickness is generally greater at more southerly sites which exhibit warmer mean annual air temperature (MAAT) and longer periods of seasonal thaw. Whereas, northerly sites located at higher latitudes exhibit colder MAAT, shorter periods of seasonal thaw, and require less cover material to maintain the active layer within the cover.

NPAG freeze encapsulation covers for waste rock storage areas range from 2.2 m to 5.0 m in thickness. While for tailings, the freeze encapsulation covers range from 1.2 m to 3.5 m thickness, excluding the 5.0 m cover proposed at the Project site. This is illustrated graphically in Figures 1, 2, and 3.

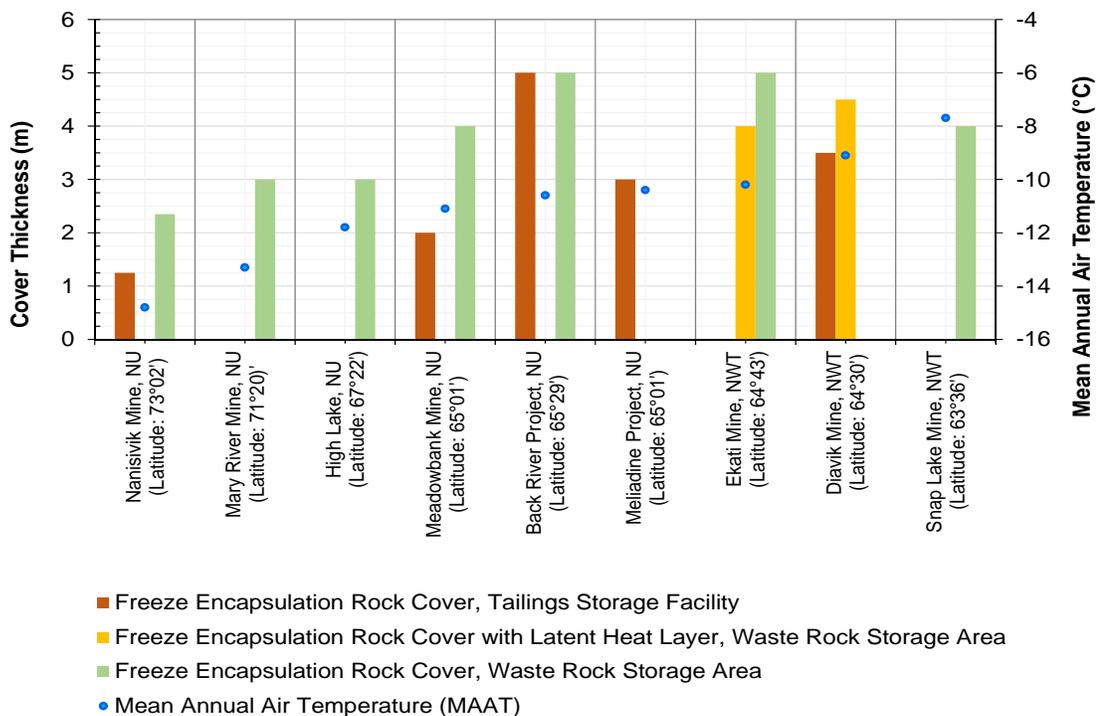


Figure 1: Overall Summary of Freeze Encapsulation Covers in the Canadian Arctic

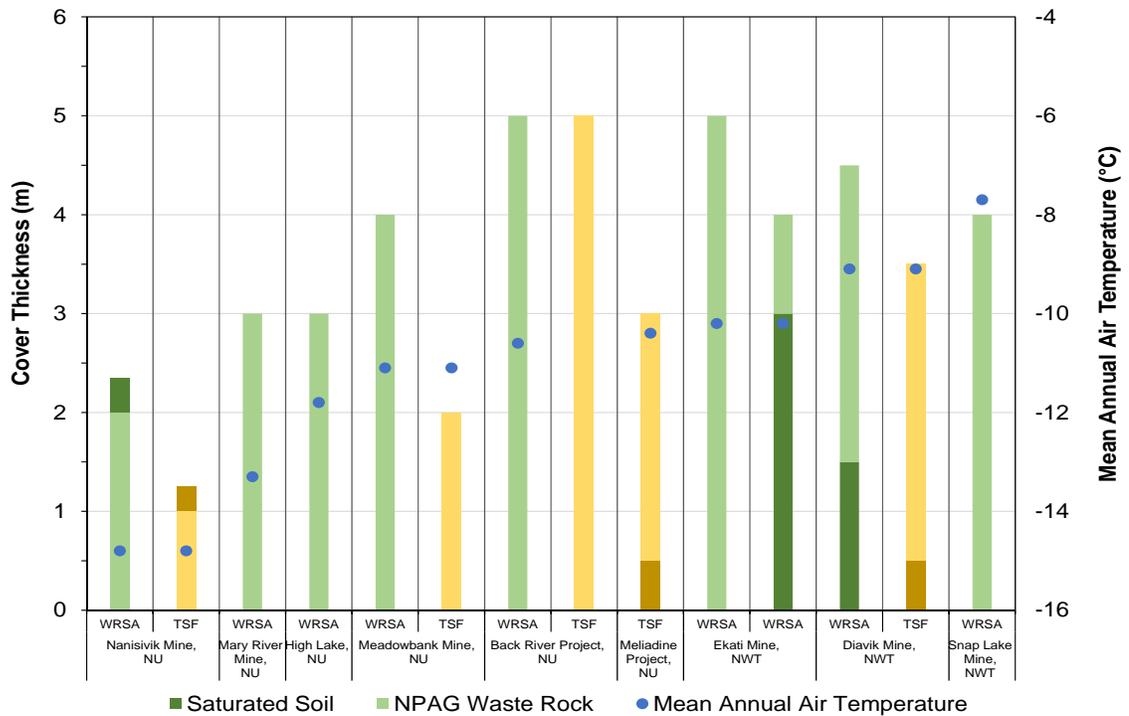


Figure 2: Details of Freeze Encapsulation Covers in the Canadian Arctic

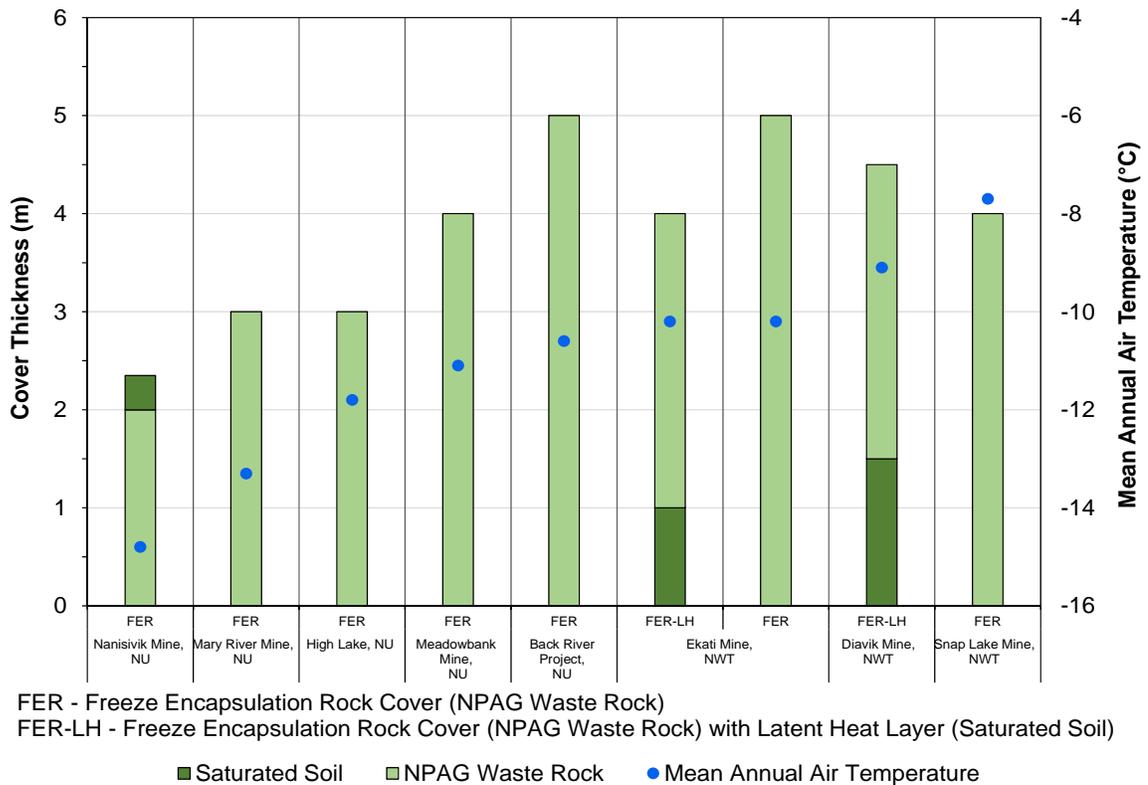


Figure 3: Freeze Encapsulation Covers for WRSAs in the Canadian Arctic

Freeze encapsulation cover thickness is reduced when designed with a latent heat layer. For example, the cover thickness for the Ekati Mine is estimated to be 5 m when constructed completely of NPAG rock and 3.6 m for a freeze encapsulation cover with a latent heat layer (Figure 2). For similar reasons, the required thermal protection cover thickness for tailings is less when compared to waste rock storage areas (Figure 1).

At some sites, the present-day waste rock active layer may exceed the thickness of the thermal protection cover due to ongoing placement of material or the thermal regime which is currently in thermal disequilibrium with surface conditions (Table 1). However, over time and with limited heat generation from the PAG rock, the net heat loss from the waste rock will lead to a decreased active layer thickness as the thermal regime shifts toward colder conditions. The described decreased active layer thickness is consistent with numerical thermal model results for these systems and has been observed at a number of Canadian sites, such as the Nanisivik Mine WRSAs.

Based on the presented benchmarking data, the thickest WRSA freeze encapsulation cover proposed at any Canadian Arctic mine is 5 m. This is proposed at the Ekati Mine and at the Project site. The MAAT at Ekati Mine is however about 4% warmer than the Project site, which means that the proposed minimum 5 m cover at the Project site is more conservative; and therefore, the thickest and most protective freeze encapsulation cover proposed in the Canadian Arctic to date.

At 5 m thick, the TSF cover at the Back River Project is by far the thickest tailings freeze encapsulation cover proposed for any Canadian Arctic mine. The closest comparable cover is the 2 m thick cover at Meadowbank Mine, followed by the 3 m and 3.5 m thick covers at the Meliadine Mine and Diavik Mine, respectively. However, the latter two covers include a 0.5 m thick latent heat layer.

5 Adaptive Management

5.1 Timing

The Project mine plan will result in the first WRSA being completed by Project Year 2. The implication of this would be eight years of performance monitoring data pertaining to the freeze encapsulation cover during Operations that will be available by the time closure activities on the Project site have to be implemented. Monitoring of WRSAs will continue through Closure and into Post-Closure. This cumulative monitoring will span 21 years and is sufficient monitoring time to inform the decisions surrounding whether the freeze encapsulation design needs to be modified, or if an alternate mitigation strategy needs to be adopted. As part of the decision making process, the latest climate change projections will also be considered alongside the monitoring data.

5.2 Monitoring

The primary monitoring method to confirm the performance of the freeze encapsulation cover is ground temperature cables. These cables will be installed through the completed waste rock storage areas (including the TSF WRSA) into the underlying foundation. Ground temperature

beads on the cables will be spaced to allow measurement of the active layer thickness as well as freeze back in the deeper profile. A series of installations will be completed to allow for a comprehensive understanding of different thermal aspects of the WRSAs. Specific shallow thermal seasonal measurements to confirm and calibrate thermal modeling will also be carried out on the mine waste facilities.

Additional monitoring data such as geochemical characterization of the waste material during placement, and ongoing seep surveys over time, will complement the thermal data.

Finally, on-site stations will measure climatic variables, building on the existing site specific climatic database for the Project. These data will be compared to the climate change projections presented as part of the Project, as well as the most recent climate projections available from updated climate change modeling in order to understand how the actual site conditions compare to the information used to inform the Project design.

5.3 Triggers

During Operations, thermal modeling will be periodically recalibrated using the most recent climate observations and climate change projections. Thermal modeling will provide predictions under current climate conditions of freeze back temperatures and rates, active layer thickness, depth of zero annual amplitude, and thermal gradient. It will therefore be possible to track observed freeze back temperatures and rates, active layer thickness, depth of zero annual amplitude, and thermal gradient against modeled values.

If the measured values deviate substantially from predicted values, the source of the variance will be investigated. As part of this investigation, the impact of the variance under future climate change conditions will also be considered. If, based on the analysis under current and future climate conditions, it is concluded that the proposed freeze encapsulation cover closure strategy may no longer be effective, then alternate mitigation strategies will be implemented.

Guidance regarding how effective the mine waste freeze back is; and therefore, the potential success of the freeze encapsulation cover, needs to be provided by an appropriately qualified expert. For this reason, Sabina will, as part of their Annual Geotechnical Inspection, require an independent review of the monitoring data as described in Section 5.2. Based on the third party expert opinion of the qualified Professional Engineer conducting the inspection and subsequent data analysis, supplemented with recalibration thermal analysis if appropriate, Sabina will discuss the need for alternate closure strategies with the appropriate Regulator.

5.4 Mitigation Strategies

Monitoring and modeling will be used to conclude whether the 5 m NPAG cover is sufficient to ensure the underlying PAG rock remains frozen in the Post-Closure phase. If the cover is not sufficient, the following alternative mitigation strategies would be evaluated in the following order of preference:

1. Increase in NPAG cover thickness: Should thermal monitoring demonstrate that an increased cover thickness would yield the required protection under future climate conditions, the NPAG cover thickness would be increased as necessary. Since there is access to additional NPAG waste rock at the Project site, this is a realistic and appropriate mitigation strategy. Additionally, it is possible to further reduce the PAG material footprint by consolidating PAG WRSAs. This would allow for an even greater ability to increase the NPAG cover thickness.
2. Relocation of PAG material to exhausted open pits: As described in Section 3.3, it is possible to relocate much of the PAG material to the Goose Main and Llama open pits during Closure, which would allow the material to be covered with a permanent water cover. This is a proven mitigation strategy previously used at Canadian Arctic mines (see Section 4.3 for examples) and will ensure appropriate ARD management. Should it be concluded that an NPAG waste rock cover of 5 m or greater will not provide the required environmental protection post-closure, a trade-off study will be conducted to determine whether PAG material relocation, construction of a low infiltration cover, water treatment, or a combination of these three mitigation methods would be most suitable for implementation.
3. Design and construction of geomembrane low infiltration cover: Low infiltration geomembrane covers are a proven technology in the Canadian Arctic to manage ARD (see Section 4.4 for examples). If it is concluded that an NPAG waste rock cover of 5 m or greater will not provide the required environmental protection post-closure, a trade-off study will be conducted to determine whether PAG material relocation, construction of a low infiltration cover, water treatment, or a combination of these three mitigation methods would be most suitable for implementation.
4. Water treatment: Water treatment is a tried and tested technology used routinely in Canadian Arctic mines (see Section 4.2 for examples) to manage ARD. If none of the other mitigation strategies can be practically implemented to manage ARD, water treatment will be the final mechanism to be adopted.

6 Conclusions

The Back River Project mine waste rock and tailings contains PAG material that is slow to react. Following a rigorous alternatives assessment, it was concluded that an appropriate environmentally protective strategy for mine waste management would entail construction of a conventional TSF to contain the first two years of tailings production. The remaining tailings will be contained within exhausted open pits with a permanent water cover.

PAG waste rock will be stored on land in four separate WRSAs. Each of these facilities will be clad with at least 5 m of NPAG waste rock or overburden. This cladding serves as a freeze encapsulation cover which will ensure that in the long term the active layer does not penetrate the underlying frozen PAG material. The 5 m cover is based on rigorous thermal modeling taking into consideration best estimates of climate change. Recognizing uncertainty associated with thermal modeling and climate change projections, the thermal analysis included a detailed sensitivity analysis. This analysis demonstrated the considerable conservatism in modeling assumptions, but also recognized that there may be conditions under which a 5 m thick cover may not provide sufficient environmental protection Post-Closure.

Notwithstanding these considerations, the 5 m thick freeze encapsulation covers proposed for the Project are not a new or experimental technology as they are currently being proposed, or are in use, at eight other Canadian Arctic mine sites (Table 1). The waste rock covers proposed for the Back River Project are the thickest and most protective covers proposed to date for any Canadian Arctic mine site. In fact, the Back River Project TSF cover is 43% thicker than the thickest cover currently proposed at other mine sites.

Based on the mine development schedule at the Project site, the first WRSA will be completed in Year 2 of the mine life allowing for performance monitoring of the NPAG cover during the Operations stage, eight years before the final closure plan needs to be implemented. Monitoring of WSAs will continue through Closure and into Post-Closure. During this time, comprehensive monitoring of the cover system will be completed using routine, well-established monitoring tools, procedures, and systems. The freeze back temperature and rate, active layer thickness, and depth of zero annual amplitude within the WRSA and associated NPAG cover will be monitored and continuously compared with a calibrated thermal model. Along with the consideration of the most recent climate projections, this will allow for a good estimate of whether the performance of the NPAG cover system would be attainable Post-Closure.

Should it be determined that the 5 m NPAG cover is not sufficient to ensure Post-Closure environmental protection against ARD, various mitigation strategies are available. This includes increasing the NPAG cover thickness with material that is available, relocating PAG material to available space within the exhausted open pits, covering the PAG material with a low infiltration geomembrane cover, and finally collection, capture, and treatment of impacted drainage water. All of these mitigation strategies can be implemented at the Project site as they are all proven mitigation strategies currently being used at other Canadian Arctic mine sites.

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

ADDENDUM APPENDIX V4-3E: CLIMATE CHANGE EXPERT THIRD PARTY REVIEW (NEW)

February 14, 2017

Project No. 1545534.9000.9002

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PEER REVIEW OF BACK RIVER PROJECT WASTE ROCK AND TAILINGS CLOSURE STRATEGY

Dear Matthew,

Golder Associates Ltd. (Golder) has been retained by Sabina Gold & Silver Corp. (Sabina) to perform an independent third party peer review of the memorandum titled “Back River Project: Considering Climate Change in Tailings Storage Facility and Waste Rock Storage Areas Closure Strategy” (SRK Memo). Overall, the SRK Memo is comprehensive and has sufficient details on how climate change uncertainty can be addressed in the design of the Tailings Storage Facility and Waste Rock Storage Areas. The SRK Memo provides an overview of best practices in cover design, proposes a monitoring plan to reduce the uncertainty associated with projected future climate change, and provides a robust adaptive management plan. The adaptive management plan provides clear recommendations for additional mitigation strategies currently being considered, and the triggers for the implementation of additional mitigation strategies, which are informed by the monitoring and modelling information gathered during the Operations and Closure phases.

Specific comments are provided on each of these areas and additional information on climate change uncertainty analysis is provided for greater context. Golder has been active in the mining community in Canada for over 50 years, with active projects in the Canadian Arctic for more than 25 years. Golder, represented by the authors of this letter, has served as the climate change lead for several mines in Canada and internationally, including the Agnico Eagle Meliadine gold mine in Nunavut. Outside of mining, the authors have acted as the climate change lead for over twelve other Environmental and Social Impact Assessments (ESIAs). Golder also provides a number of climate change adaptation and mitigation services outside of the ESIA framework. Golder provided advisory services to the Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR) as part of the Project Advisory Council for a review of Climate Change Vulnerability assessments as part of Environmental Impact Assessments in the Mining Sector. Golder also provided advisory services to OCCIAR to develop Climate Change Vulnerability case studies for mining operations include a Cost Benefit Analysis that compared “no action” against implementing adaptive management options. In the Arctic, Golder completed the identification of climate risks for large infrastructure and mining operations in Nunavut for the Regional Adaptation Collaborative (RAC). This work assessed vulnerabilities and recommended adaptive measures and best practices. Golder has conducted a number of workshops using a risk based assessment with Government and mining stakeholders. Additional information on the qualification of the authors is included at the end of the memo (Technical Credentials of Reviewers), and curriculum vitae for both authors are provided in Attachment A.

Golder Associates Ltd.

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Overview of the SRK Memo

The SRK Memo begins with a plain language summary providing an overview of how the comments from the NIRB Letter are addressed. The following table outlines the sections of this memo and what information is contained in each.

Table 1: Description of SRK Memo Contents

Section Title	Description
Introduction	This section provides background information on the Back River Project, the previous work already completed for the Project, and the concerns raised by the NIRB in the FEIS Final Hearing Report.
Waste Rock and Tailings Closure Concerns	This section provides a description of tailings, waste rock, and overburden generation at the Project. Acid rock drainage (ARD) is discussed as a key subject that requires a mitigation strategy. The pathways for waste rock exposure are discussed to understand what types of mitigation strategies could be required.
Waste Rock and Tailings Closure Options	This section discussed the possible mitigation strategies, based on the exposure pathways of the previous section. Four possible strategies are considered, with the emphasis placed on the fourth: designing a cover system to manage the acid rock drainage and meet water quality discharge criteria. Three cover designs are compared including a description of approach and any known limitations.
Mine Waste Freeze Encapsulation Cover	This section describes the freeze encapsulation cover in detail, including how thermal analysis and climate change projections are used to inform the chosen design. Descriptions of the thermal analysis carried out and the climate change projections considered are provided. The Project TSF cover design is benchmarked against other freeze encapsulation covers at existing mines in the Canadian Arctic to establish the design as a best practice.
Adaptive Management	This section provides an overview of the adaptive management plan, including timing, monitoring, and a discussion of when mitigation strategies would be required. The timing refers to when the adaptive management plan will be put in place. The monitoring will be used to inform periodic updates of the thermal analysis which, along with climate change projections, will inform the decision on whether additional mitigation strategies are required. Mitigation strategies are proposed in order of preference, and are based on the current understanding of the exposure pathways.
Conclusions	The conclusion provides an overview of the proposed approach for the closure strategy.

The aim of the SRK Memo is to provide additional supporting information regarding the long-term operations and closure of the waste rock and tailings facilities at the Back River Project, including the viability of maintaining freezing conditions beyond closure. The SRK Memo addresses these concerns by:

- demonstrating that best practices in the field of cover design are being followed with comparisons to cover designs for existing mine sites in the Canadian Arctic;
- committing to a monitoring program that will observe that freezing conditions are occurring during the operations and closure;
- outlining the mitigation strategies that could be included as part of an adaptive management plan to overcome the uncertainties of a changing climate in the future;

- reviewing the requirements for additional mitigation strategies under the adaptive management plan to be implemented if freezing conditions are not maintained post closure; and
- discussing the uncertainty regarding climate change.

The following sections outline the listed approaches in further detail.

Considering Best Practices in Field of Cover Design

In the SRK Memo, Sections 3.4.4 and 4.0 discuss the freeze encapsulation cover design. In essence, the mine waste materials are placed in the ground in a region of continuous permafrost, promoting freeze back within a short time after placement. A thick layer of cover material is added so that the active layer for seasonal thaw will be maintained entirely within the cover material, which is essential for maintaining the freezing conditions of the mine waste material. Based on the uncertainty associated with future projected climate change considered by SRK (Section 4.3), the freezing conditions required for the proposed cover design for the waste rock storage areas (WRSAs) and tailings storage facilities (TSFs) could not be guaranteed post-closure. SRK compares the proposed cover designs to the cover designs of other mine sites in the Canadian Arctic. SRK states that the other mine sites considered have included climate change considerations in their designs (Section 4.4); the cover designs from other mine sites were not reviewed as part of this peer review. The benchmarking exercise compares both the measured and modelled waste rock active layer and the cover thickness. Site-specific conditions are considered including differences in local climate and other factors that may influence the freeze encapsulation cover.

When reviewing other mines in the Canadian Arctic, the thickest WRSA freeze encapsulation cover proposed is 5 m. While this is the same as the proposed thickness for the Back River Project, the climate at other mines is warmer, which adds further conservatism to the Back River Project cover thickness. The Back River Project proposed cover thickness of 5 m is approximately 1 m thicker than the largest cover thickness of 3.5 m at other Arctic mines (including the latent heat layer).

The proposed cover design is consistent or better than the best practices exhibited at other mines in the Canadian Arctic in terms of the thickness considered to maintain the seasonal thaw within the cover, leaving the deposited material frozen year round. The SRK Memo addresses uncertainty in future climate projections through design and the adaptive management plan. As part of the cover design, sensitivity studies were conducted to address the uncertainty around the proposed cover thickness, including future climate change considerations. The documentation available from other mines may have been limited, preventing direct comparisons on the inclusion of climate change projections in their cover designs. However, the thermal modelling analysis used to inform the cover design, including the sensitivity studies, are peer-reviewed by experts in the field of permafrost engineering and thermal analysis. Golder agrees that based on the conservative nature of the proposed thickness and the supporting peer-reviewed thermal analysis, the treatment of future climate projections and their uncertainty is at least consistent with other mines in the Canadian Arctic and has followed best practices.

Considering a Monitoring Program to Observe Freezing Conditions

As part of the ongoing adaptive management, performance monitoring (Section 5.2) will be conducted to measure freeze encapsulation of the cover during Operations and through Closure (approximately 21 years). This monitoring, along with the most recent projections of future climate change available, will inform whether the freeze encapsulation cover design requires modification through periodic updates to the thermal analysis modelling discussed in Section 5.3 of the SRK Memo. This monitoring will help to address the uncertainty in the future climate conditions through the collection of thermal data, comparison to a calibrated thermal model, and through the periodic updates to thermal analysis modelling incorporating the most up to date climate change projections available. Golder understands that Sabina has committed to an independent third party monitoring program that

will include ground temperature and freeze back monitoring. Golder agrees with this approach to reduce the uncertainty surrounding future climate change projections by informing the final cover design with the current state of science for climate change, instead of relying on a static analysis.

In addition to the performance monitoring, on-site stations will be installed to measure climatic variables, improving the site specific current climate database for the project. The observations and trends of the observations will be compared to the most recent future climate change projections to understand how the site conditions compare to the conditions used to inform the Project design. Golder agrees with this approach, however, the methodology for this comparison was not provided in the SRK Memo. In order to follow best practices, the comparison should consider a comparison of the climate normal (30 year averages) from both the observations and the climate projections, and the climate projections should be normalized to the site-specific conditions. Periodic comparisons of the observations and projections will help to address the uncertainty in the climate change projections, however, it should be noted that most scenarios of future climate projections do not begin to diverge until approximately mid-century, around the 2050s.

Considering Mitigation Strategies in the Adaptive Management Plan

The focus of the adaptive management plan is to determine whether the freeze encapsulation cover design will be robust enough to maintain freezing conditions post-closure under the range of future climate projections, and on the steps to take if freezing conditions are unlikely to be maintained post-closure. A robust list of mitigation strategies is proposed in Section 5.4 of the SRK Memo based on existing strategies in place at other Canadian Arctic mines. The primary strategy is to increase the cover thickness if field measurements collected and the updated thermal analysis modelling shows that this is required. SRK states that there is likely sufficient cover material on site if required (Sections 4.1 and 5.4). If, based on the updated thermal modelling, sufficient material is not available, the storage areas may be consolidated to reduce the need for cover material. The remaining mitigation strategies involve changing the type of cover considered (water and low infiltration geomembrane) or water treatment that do not rely on maintaining freezing conditions post closure. The water treatment would treat the surface drainage and localized seasonal subsurface flow within the active layer emanating from the mine waste facilities. The SRK Memo states in the executive summary that the proposed mitigation strategies are less sensitive to a changing climate, and that cover designs will be informed by future climate projections.

Considering Requirements for Additional Mitigation Strategies

Based on the adaptive management section (Section 5.0), the Project adequately addresses the viability of maintaining freezing conditions post-closure and the uncertainty associated with climate change projections. The uncertainty is address by having additional mitigation strategies that are less sensitive to changing climate conditions. In addition, as part of demonstrating best practices, the Back River Project provides comparisons to existing Arctic mine sites where the proposed strategies are currently employed (Section 5.4).

As part of the closure plan review process, under the Nunavut Water Board, the appropriate regulating agencies will have a chance to review the final closure strategy, including the comparison of the modelling and monitoring comparison used to inform the requirement for additional mitigation strategies. There will be opportunity at this point to further refine any requirements for mitigation and what mitigation strategies are being considered. Separate to the closure plan review process, Sabina will internally review the modelling and monitoring data on a periodic basis, investigating any substantial deviations between the planned and monitored freeze back conditions. Sabina will consider additional mitigation strategies the analysis informed by current and future climate conditions show the proposed freeze encapsulation strategy would need to be changed. Sabina will rely on the expert opinion of a qualified Professional Engineer to help determine the potential success of the freeze encapsulation cover and the need for any additional mitigation strategies. As the most recent future climate projections will be incorporated

into the analysis provided by Sabina, the expert should be familiar with climate change projections for the Canadian Arctic to help ensure the uncertainty in the climate projections is appropriately addressed.

Considering Uncertainty in Climate Change Projections

The SRK Memo demonstrates how best practices were incorporated when considering climate change in the tailings storage facility and waste rock storage areas closure strategy. The approach in the SRK Memo is to address the uncertainty in climate projections up to 2100 through design and the adaptive management plan. Golder agrees with this approach to addressing climate change uncertainty to the end of the century (2100). Post-2100, the SRK Memo states climate projections are unbounded beyond 2100 and extrapolates the climate projections to show indefinite increases in mean air temperature. This is not supported by the current projections past 2100 provided by peer-reviewed literature, therefore the following section is provided to give more context on the next century climate projections from literature.

Future Climate Conditions Post 2100

Due primarily to computational limitations in early climate modelling and the uncertainty in climate change modelling, most climate model projections extend only to the year 2100. However, the warming effects and radiative forcing resulting from atmospheric greenhouse gases extends long after emissions have ceased and beyond the atmospheric lifetime of the gas (Lenton et al. 2006). Therefore, while a large portion of warming resulting from anthropogenic carbon dioxide (CO₂) will happen on the century timescale, warming can continue beyond 2100. CO₂ is significantly more abundant than other greenhouse gases and aerosols, and has the largest impact, compared to other species, on the radiative forcing used to drive the climate models.

The projected future climate beyond 2100 is described in a qualitative manner using publicly available, peer-reviewed literature, including Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (IPCC 2013; AR5).

The projected ranges of future climate conditions are described using the results accepted by the IPCC for various representative concentration pathways (RCPs). Meinshausen et al. (2011) extends four RCP scenarios (RCP 2.6, 4.5, 6.0 and 8.5) until 2300 in support of AR5 using Earth Models of Intermediate Complexity (EMICs). The results of the EMIC extensions are consistent until 2300 with atmospheric-ocean general circulation models (AOGCM) used in AR5. Zickfield et al. (2013) use the extensions to estimate temperature changes up until the year 3000, assuming that the CO₂ concentration and forcing are held constant at year 2300 levels for all four RCP scenarios. The RCPs are named after the radiative forcing projected to occur by 2100. For example, RCP4.5 represents a scenario where the radiative forcing is stabilized shortly after 2100 at 4.5 W/m². The RCPs are described more fully by van Vuuren et al. (2011) in their paper "The representative concentration pathways: an overview".

As shown on Figure 1, presented in Zickfield et al. (2013), in scenarios RCP4.5 and RCP8.5, rapid warming occurs until the radiative forcing is stabilized (assumed to be 2300), with predicted increases of temperature. After the forcing is stabilized, warming slows but continues at a lesser pace than the current century through the year 3000. Under the RCP2.6 scenario, temperatures peak around 2070 and decreases until 2300 after which it slowly starts to increase again. This significant uncertainty affects the post closure period conditions but the rate of warming is expected to be much less or decrease compared to the current century projections.

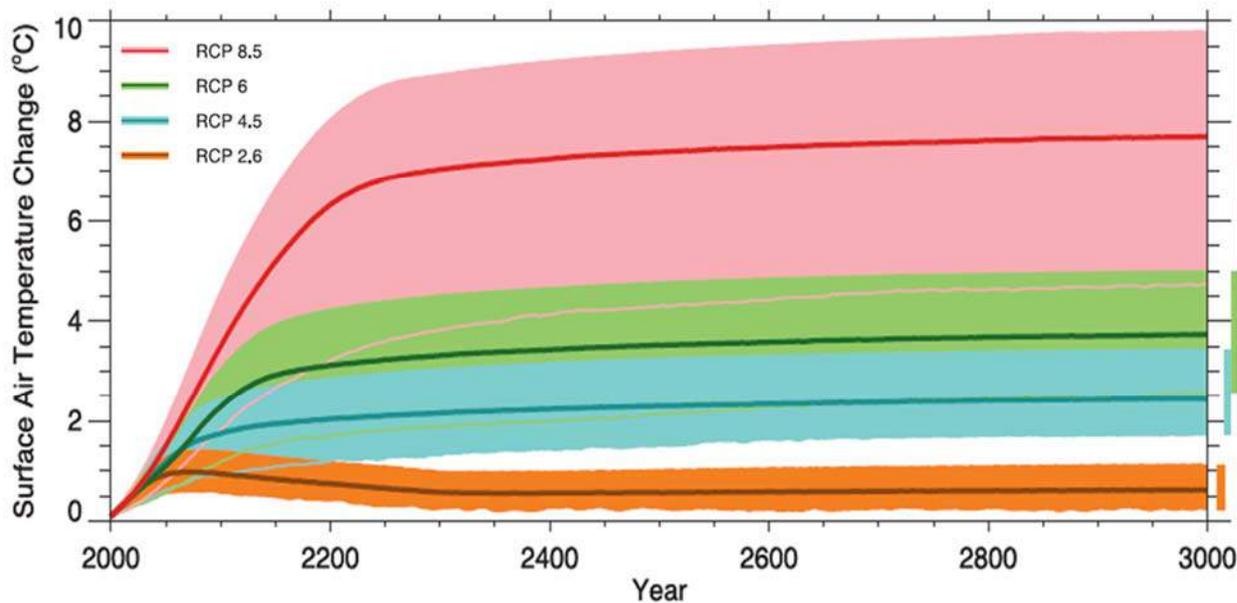


Figure 1: Time evolution of surface air temperature change (from 1985 to 2005 reference period) for the constant composition simulation for all four RCP scenarios (Zickfeld et al. 2013)

It is generally accepted that with increased temperature, mean sea levels and global precipitation will also increase. It is estimated that global precipitation will increase by 1-3% per degree Celsius increase in temperature (IPCC 2013). However, the distribution of precipitation will vary spatially, with increases in some regions and decreases in others.

Given the approach described in the SRK Memo in section 5.3, the cover design and the need for additional mitigation strategies will be reviewed on a periodic basis, informed by the most recent climate change projections available. By the end of operations, 21 additional years of climate change information will be available, likely including a new assessment from the IPCC. With the advancements made in climate change projections over that period, uncertainty in the post-2100 climate will likely be reduced, providing more confidence in the final cover design. With the additional context regarding post 2100 projections, Golder agrees with this approach to reduce the uncertainty associated with climate change in the cover design.

Conclusions

Overall, the SRK Memo is comprehensive and provides clear recommendations and triggers for the implementation of adaptive management plans informed by the additional information that will be gathered during the operations phase. Golder agrees with the approach outlined in the memo. The additional information on climate change uncertainty analysis is provided for greater context of the projected climate change post-2100. If you have any questions or comments, please feel free to contact Sean Capstick (scapstick@golder.com).

Technical Credentials of Reviewers

Sean Capstick, P. Eng.

Principal, Senior Air Quality and Climate Change Specialist

Sean Capstick is a Principal in Golder's Greater Toronto Area Office with over 25 years of environmental consulting and government experience. Sean is directing a number of atmospheric and climate change studies on public/private infrastructure, he has extensive experience in the areas of air quality, greenhouse gas (GHG) inventories and climate change. Sean leads Golder's "Climate Change Technical Community", an internal knowledge sharing initiative to promote the use of the latest climate change science and develop best practices to consider both the potential effects of the project on climate change and the effects of climate change on a project.

Sean has expertise in analysis of climate change projections and assessing the significance of project emissions under the Environmental and Social Impact Assessment Framework and has developed best practices to consider the potential effects of climate change on a project. Has prepared the climate change components for ESIA's under the Performance Standards on Environmental and Social Sustainability (IFC, World Bank Group 2012) and the document "Incorporating Climate Change Considerations in Environmental Assessment: General Guidance for Practitioners (CEAA 2003)" both in Canada and internationally. Sean has experience leading of interdisciplinary technical teams that are assessing climate change impacts and vulnerabilities on existing and planned infrastructure using a risk based approach and Cost Benefit Analysis.

Sean was the Climate Change Lead on Agnico Eagle's Meliadine Project that was successfully approved by the Nunavut Impact Review Board. Sean also was the primary author of two reports that identified the climate risk for large infrastructure and mining operations in Nunavut for the Regional Adaptation Collaborative (RAC). These reports assessed potential vulnerabilities and recommend adaptive measures and best practices.

Sean has presented on the topic of Climate Change Adaption widely and published a number of papers on this subject. Specifically, he has presented at the Nunavut Mining Symposium, the Association for Impact Assessment (IAIA) conferences in Chile and Panama, Adaptation 2016 in Ottawa and the Ontario Association for Impact Assessment. Sean is a member of the organizing committee of the upcoming Artic and Nordic Forum that will be part of the 2017 IAIA conference that will examine Climate Change Impacts in Artic and Nordic Areas.

Janya Kelly, Ph.D.

Air Quality and Climate Change Specialist

Dr. Janya Kelly is an Air Quality and Climate Specialist and has over eight years of experience in air quality and climate change for a variety of industry sectors such as: mining, power generation, aggregate processing, and metal manufacturing. She completed a three-year post-doctorate at Environment Canada studying the future impacts of climate change on air quality in North America. The published results of the post-doctoral work were referenced in the Intergovernmental Panel on Climate Change Fifth Assessment Report. Dr. Kelly is an active member of the Golder's "Climate Change Technical Community", an internal knowledge sharing initiative to promote the use of the latest climate change science and develop best practices to consider both the potential effects of the project on climate change and the effects of climate change on a project.

Dr. Kelly has been the climate change lead on a number of projects, with a primary focus on climate change adaption, and secondary focus on climate change mitigation through greenhouse gas emission reduction. She has experience preparing climate change technical supporting documents for Environmental and Social Impact Assessments (ESIAs) under provincial (Ontario and British Columbia), federal (Canada) and international

(Performance Standards on Environmental and Social Sustainability, International Finance Corporation) requirements. Dr. Kelly has coordinated with interdisciplinary technical teams within these requirements and has prepared and supported the preparation of climate change technical supporting documents in both North and South America, and Europe.

Outside of the ESIA framework, Dr. Kelly has completed analyses of climate change projections, climate change and greenhouse gas assessments to support permitting and compliance projects, as well as the development of greenhouse gas emission inventories. This work includes leading interdisciplinary teams in assessing the climate change vulnerabilities on existing and planned infrastructure and assessing the financial impacts through cost benefit analysis. To successfully complete this work, she has developed a number of tools to help transform the scientific analysis into easily accessible reports written in plain language.

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Janya Kelly, Ph.D.
Air Quality and Climate Change Specialist
Specialist

JK/SC/jr



Sean Capstick, P.Eng.
Principal, Senior Air Quality and Climate Change

Attachments: A: Curriculum Vitae

https://capws.golder.com/sites/p1545534?type=waterlicencebackriverproject/p2000_feis/addendum_thirdpartyreviews/climate/golder_cc_memo_wrtailingsclosure_strategy_final.docx

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ATTACHMENT A

Curriculum Vitae



Education

B.A.Sc. Chemical Engineering, University of Waterloo, 1989

Certifications

Professional Engineer Ontario (P.Eng.)

Languages

English – Fluent

Sean Capstick, P.Eng. is a Principal with over 25 years of environmental compliance experience in Golder’s GTA Operations Atmospheric Services Group that provides a full suite of GHG, Climate Change, Permitting and Environmental Assessment services. Sean provides specialized expertise on strategic and regulatory advice to clients regarding the development of emission inventories recognized as a leading expert in Air Quality services including the emerging GHG / carbon costing framework and Climate Change adaptation services. He is Golder’s Global Climate Change Technical Community Leader.

Sean has worked for both public sector and private sector clients in a variety of industry sectors such as aggregate processing, buildings, cement, chemical processing, electricity generation fertilizer manufacturing, mining, petrochemical, steel manufacturing, landfills, natural resources, oil and gas and infrastructure management. He is sought after by industry, municipalities and legal firms for guidance and practical solutions in regulatory and technical matters related to the environmental permitting process and adaptation to climate change. Sean has expertise in analysis of climate change projections and assessing the significance of project emissions and climate impacts under International, Canadian and Provincial Environmental Assessment Frameworks. He has presented on these topics widely.

Employment History

Golder Associates Ltd. – Mississauga, Ontario
Principal (2006 to Present)

Ministry of the Environment – Toronto, Ontario
Special Project Engineer, Environmental Assessment and Approvals Branch (2001 to 2006)

Golder Associates Ltd. – Mississauga, Ontario
Associate (1998 to 2001)

Ministry of the Environment – Toronto, Hamilton and Guelph, Ontario
Various positions (1989 to 1998)

PROJECT EXPERIENCE – CLIMATE CHANGE AS PART OF ENVIRONMENTAL ASSESSMENTS

Hearing Nunavut Impact Review Board
Meliadine, Nunavut

The project consisted of the Agnico Eagle Meliadine gold mine and access road development in Nunavut. The project involved the completion of an ESIA in accordance with the Nunavut Impact Review Board Standards. Climate Change and Atmospheric Discipline Lead provided senior technical review of the air quality baseline and climate change assessment reports. Climate change data used in Wildlife Cumulative Effect Assessment and Tailing design calculations.



IFC ESIA, Development of a Power Plant
Province of Peravia,
Dominican Republic

The project consisted of the development of a 752 MW (gross) thermal power plant in Punta Catalina in the south-central Dominican Republic. This project is to improve the reliability of the Dominican power supply. Climate Change Lead to identified and evaluated the potential risks associated with climate change that may affect public safety and the environment and identified the need for any supplementary mitigation measures to avoid, minimize and/or control any identified risks.

IFC ESIA, Development of a Gold Mine
Cocula, Guerrero State,
Mexico

The project consisted of the Torex MML El Limon Guajes gold mine development in Mexico. The project involved the completion of baseline studies and an ESIA in accordance with the International Finance Corporation's Performance Standards. Climate Change and Meteorology Discipline Lead and provided senior technical review of the air quality baseline and assessment reports.

IFC ESIA Gap Analysis Development of a Gold Mine
Cocula, Guerrero State,
Mexico

The proposed project consists of a new underground gold, copper and silver mine development in Mexico. Participated in the analysis of potential climate change and atmospheric gaps, and the identification of a planned course of action to address the gaps.

IFC Climate Change Assessment
Cajamarca, Peru

The project consisted of the development of the Minera Yanacocha Conga copper-gold mining project. The project involved the completion of Climate Change Assessment in accordance with the International Finance Corporation's Performance Standards. Climate Change Discipline Lead provided senior technical review of the climate change assessment reports including vulnerability and GHG assessments.

IFC Climate Change Assessment
Autazes, Brazil

The project consisted of the development of the Brazil Potash Corporation of Canada underground potash mine, processing facilities, port and a road connecting the mine to the port in the Amazon. The project involved the completion of Climate Change Assessment in accordance with the International Finance Corporation's Performance Standards. Climate Change Discipline Lead provided senior technical review of the climate change assessment reports including vulnerability and GHG assessments.

Ontario Environmental Assessment of Landfill Expansion
Brighton, Ontario

The Project consisted of an expansion of the existing Brighton Landfill and subsequent ECA application package. Senior review of the Air Quality assessment and responses to MOE comments. Prepared a qualitative assessment of potential effects of climate change to satisfy MOECC comments.

Ontario Environmental Assessment of Landfill Expansion
Niagara Region, Ontario,
Canada

The project consisted of the expansion of the existing Humberstone solid waste landfill site to meet the residual waste disposal needs of south Niagara for a period of 25 years. Senior review of Air Quality environmental impact assessment. Prepared a qualitative assessment of potential effects of climate change to satisfy MOECC comments.

Ontario Environmental Assessment for New Waste Management Facility
Ottawa, Ontario, Canada

The Project consisted of the proposed Capital Region Resource Recovery Centre. Prepared a qualitative assessment of potential effects of climate change to satisfy MOECC comments.



Municipal Class EA of a Road Widening
Region of Waterloo
Canada

The project consisted of a Municipal Class Environmental Assessment for the proposed Erb Street Widening & Corridor Study, Fischer-Hallman Road to Wilmot Line in the Region of Waterloo. Work was sub-contracted through the Walterfedy Partnership Sr review of an air quality and GHG assessment.

Eastern Mainline Pipeline Project
Eastern Ontario, Canada

The project consist of environmental services for the construction and operation of a new approximately 280 km natural gas pipeline, including modifications to 5 compressor stations, from Iroquois to Markham, Ontario. Senior review for the air quality and climate change assessment to meet NEB requirements and responding to information request from stakeholders during the review process.

NEB Section 58, Vaughan Mainline Project
Vaughan, Ontario,
Canada

The project consisted of the construction of approximately 12 km of new 42" natural gas pipeline. Senior review for the air quality and climate change assessment to meet NEB requirements and responding to information request from stakeholders during the review process.

British Columbia Environmental Assessment Office
Howe Sound,
British Columbia

The project consisted of the development of the Woodfiber Liquefied Natural Gas production Facility in Lower Mainland British Columbia. The project involved the completion of baseline studies and an ESIA reviewed by the Environmental Assessment Office. Climate Change and Atmospheric Discipline Lead provided senior technical review of the air quality baseline and climate change assessment reports including vulnerability and GHG assessments.

British Columbia Environmental Assessment Office
Giscome,
British Columbia

The project consisted of the development of the Graymot Lime production Facility in Northern British Columbia. The project involved the completion of baseline studies and an ESIA in accordance with Environmental Assessment Office. Climate Change Discipline Lead provided senior technical review of the climate change assessment reports including vulnerability and GHG assessments.

Joint Ontario and Canadian ESIA Cliffs Natural Resources
Thunder Bay, Ontario

The project consisted of the development the Cliffs Chromite Project that included three separate but linked components, the mine, the Integrated Transportation Corridor and Furnace in Northern Ontario. The project involved the completion of baseline studies and an ESIA in accordance with CEAA and Ontario Requirements. Atmospheric Component Lead; work involved the development of the climate change assessment, emission inventory, dispersion modelling and EA technical support and document writing. Liaison with the client engineering teams to design projects to reduce the potential impact to local and regional air quality.

Joint Ontario and Canadian ESIA Cliffs Argonaut Gold Corporation
Reno, Nevada

The project consisted of the development of the Magino Mine Project in Northern Ontario. The project involved the completion of baseline studies and an ESIA in accordance with CEAA Requirements. Project Director for Air, Noise, Vibration, Light, Climate Change and Human Health Risk Assessment components of the Environmental Assessment. Work involved the liaison with the various other technical disciplines and EA writing team to develop 5 stand-alone Technical Supporting Documents for the EA submission.



**Ontario ESIA Cliffs
Osisko Gold Mine
Project**
Toronto, Ontario

The project consisted of the development of the Hamond Reef Mine Project in Northern Ontario. The project involved the completion of baseline studies and an ESIA in accordance with CEAA and Ontario Requirements. Atmospheric and Climate Change component Lead work involved the development of emission inventory, dispersion modelling and EA technical support document writing.

PROJECT EXPERIENCE – GOVERNMENT/GUIDANCE DEVELOPMENT

**Natural Resources
Canada**
Ottawa/Ontario, Canada

Golder provided advisory services to the Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR) as part of the Project Advisory Council for a review of Climate Change Vulnerability assessments as part of Environmental Impact Assessments in the Mining Sector.

**Natural Resources
Canada**
Ottawa/Ontario, Canada

Golder provided advisory services to the Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR) to develop Climate Change Vulnerability case studies for mining operations include a Cost Benefit Analysis that compared no actions against implementing adaptive management options.

**Government of
Nunavut**
Nunavut, Canada

Identification of climate risk for large infrastructure and mining operations in Nunavut for the Regional Adaptation Collaborative (RAC) assess vulnerabilities and recommend adaptive measures and best practices. Conducted as workshop using a risk based assessment with Government and mining stakeholders.

**Ontario Realty
Corporation**
Ontario, Canada

Conducted a Public Infrastructure Engineering Vulnerability Committee (PIEVC) assessment of public three buildings in Ontario.

Clean Air Partnership.
Ontario, Canada

Developed climate change data sets and participated in a province wide training program to allow municipalities to conduct vulnerability assessments on municipal infrastructure on behalf of the Ontario Regional Adaptation Collaborative (RAC).

**National Resources
Canada**
Ottawa/Ontario, Canada

Prepare a summary of Green Mining Technologies that can reduce mining footprint, and improve waste management, closure and ecological risk assessments based on a survey of mining professionals conducted by the Canadian Institute of Mining, Metallurgy and Petroleum (CIM).

**Centre for Excellence
in Mining Innovation**

Preparation of Guidance Materials that can be used by the Mining Industry to prepare Fugitive Dust Best Management Practice Plans.

**Ontario Ministry of
Natural Resources
(MNR)**
Ontario, Canada

Preparation of a life cycle analysis and greenhouse gas inventory to quantify the GHG emission intensity associated with different scenarios of the Ontario aggregate industry from extraction and transportation. This GHG assessment was part of a larger study concerning the feasibility of alternatives for the Ontario aggregate industry.

**Ontario Ministry of the
Environment**
Toronto/Ontario, Canada

Prepared an overview of GHG emissions from the Large Final Emitters in Ontario, a jurisdictional summary of technology based international regulations and evaluating control options and \$/tonne costs to reduce GHG emissions.

Environment Canada
Gatineau/Quebec,
Canada

Preparing an overview of dust emissions from the Canadian Iron Ore Sector and assessing best practices for dust control from both fugitive and point sources.



Ontario Ministry of the Environment
Toronto/Ontario, Canada

Development of Certificate of Approval sample application packages (ACME Examples) and outreach materials for Air and Noise, Waste Water, Wind Turbines and Waste Approvals.

Ontario Ministry of the Environment
Toronto/Ontario, Canada

Technical Evaluation of Options for Air Pollution Control of Volatile Organic Compounds and Particulate Matter from the Wood Products Manufacturing Sub-sector.

Ontario Ministry of the Environment
Toronto/Ontario, Canada

Development of guidance materials for a new pilot for delivering expedited service for the Ministry's Approvals program.

Ontario Ministry of the Environment
Toronto/Ontario, Canada

Independent third party assessment of Air Quality Reports for compliance with O. Reg. 419/05 submitted under the MOE's STAC program.

PROJECT EXPERIENCE – GHG INVENTORY DEVELOPMENT AND CAP AND TRADE

Canadian Chemical Industry Association
Ontario, Canada

Provided strategic advice in assessing how the chemical sector may be affected by the proposed Ontario Cap and Trade Regulation and identifying key mechanisms to discuss with the Ministry of Environment and Climate Change during the development of the regulation.

Canadian Steel Producers Association
Ontario, Canada

Provided strategic advice in assessing how the steel sector may be affected by the proposed Ontario Cap and Trade Regulation and identifying key mechanisms to discuss with the Ministry of Environment and Climate Change during the development of the regulation.

Confidential Client
Ontario, Canada

Preparation of a study for a quarry including GHG inventory, identification of alternatives for minimizing energy use and GHG emissions and identification of alternatives for offsetting GHG emissions, focusing on a zero carbon operation. The Project include the development of a customized tool for calculation of GHG emissions and removals, allowing the assessment of different GHG scenarios and update the inventory in a cost effective manner.

Confidential Client
Ontario, Canada

Preparation of a study for a forestry operation for the potential to generate afforestation carbon offsets including a high level business case and sensitivity analysis.

Glencore Canada
Sudbury, Ontario, Canada

Preparation of a customized guideline to prepare greenhouse gas inventories for the Sudbury Operations following the specifications of the GHG Protocol and ISO 14064. Development of a carbon costing tool to allow the operations to assess the impact of potential carbon costing scenarios based on the implementation of a Western Climate Initiative type of GHG reduction program and conducts various scenario assessments for production increases and GHG reduction programs.

Ontario Ministry of the Environment
Toronto, Ontario, Canada

Prepared an overview of GHG emissions from the Large Final Emitters in Ontario, a jurisdictional summary of technology based international regulations and evaluating control options and \$/tonne costs to reduce GHG emissions.



Canadian Fertilizer Institute
Canada

Golder was retained to provide strategic advice and prepare emission rate calculation and sector wide summaries to support discussions with the Federal Government in setting GHG limits and controlling regulations for Canadian Ammonia and Potash Fertilizer facilities.

Confidential
Ontario, Canada

Project Director of technical analysis and life cycle analysis data using GHG Genius to support the company positions to lobby and negotiate with the federal and provincial government for the support of incentive programs to assist renewable fuels manufacturers and distributors.

Ivaco Rolling Mills
Ontario, Canada

Project Director for a multi-year Air Quality compliance services project (2012 to present) including GHG inventories and reporting, support during GHG emission, assessment of the financial implications of Cap and Trade in Ontario and various technical assistance related to new Climate legislation.

PROJECT EXPERIENCE – ENVIRONMENTAL PERMITS

Environmental Permitting
Canada Wide

Responsible for the completion of hundreds of Environmental Permit applications for the aerospace, aggregate processing, automotive manufacturing and assembly, commercial printing, construction materials, electricity generating, iron and steel plywood, mining, remediation transportation, wood products and waste industries. Successfully, negotiated terms and conditions for the approvals and assisted clients with on-going compliance with these conditions.

PROFESSIONAL AFFILIATIONS

- International Association for Impact Assessment
- Association of Professional Engineers of Ontario
- Air and Waste Management Association
- Ontario Mining Association - Environmental Committee

SELECTED PAPERS/PRESENTATIONS

OAIA 16

Presented at Environmental Assessment: Time to Hit the Reset Button, Toronto, Canada
October 25, 26, 2016

Capstick S., Zizzo L., Robicheau S. ***Incorporating Climate Change into EA's a Facilitated Discussion***

IAIA Special Symposium

Mega-Infrastructure Symposium, Panama City, Panama
December 1 – 3 2015

Capstick S., Kelly J. ***Climate Change Adaptation and Mining: Best Practices***

OAIA 15

Presented at, Environmental Assessment: a Critical Tool for Tackling Climate Change, Toronto, Canada
October 25, 26, 2015

Capstick S., Cheyenne M. ***Climate Change Adaptation and Mining: Case Studies from Ontario and the World***



Power of Water

Niagara Falls, Canada May10, 2015

IAIA 15

Presented at: Impact Assessment in the Digital Era, Florence, Italy. April 20-23, 2015

IAIA 14

Presented at: Impact Assessment for Social and Economic Development, Vina del Mar, Chile. April 8-11, 2014.

Capstick S., Kelly J., Barrett, A. ***How is Climate Change Changing Hydropower?***

Capstick, S., Arnold, S., Barrett, A., Santander, A., and Perez, J. ***Climate Change Adaptation in the Mining Sector.***

Capstick, S., Kelly, J., Barrett, A., and Penailillo, R. ***Incorporating Climate Change Impacts into Environmental Assessments.***



Education

Ph.D. Earth and Space Science and Engineering, York University, Toronto, 2007

B.Sc. (Honours) Physics, Dalhousie University, Halifax, 2002

Languages

English – Fluent

Golder Associates Ltd. – Mississauga

Biography - CC

Dr. Janya Kelly is an Air Quality and Climate Specialist and has over eight years of experience in air quality and climate change in a variety of industry sectors such as: mining, power generation, aggregate processing, and metal manufacturing. She has completed a three year post-doctorate at Environment Canada studying the future impacts of climate change on air quality in North America. The published results of the post-doctoral work were referenced in the Intergovernmental Panel on Climate Change Fifth Assessment Report.

Dr. Kelly has been the climate change lead on a number of projects, with a primary focus on climate change and adaptation, and secondary focus on climate change mitigation through greenhouse gas emission reduction. She has completed climate change assessments in support of Environmental and Social Impact Assessments for projects in North and South America, including coastal regions. Dr. Kelly has completed analysis of climate change projections, climate change and greenhouse gas assessments to support permitting and compliance projects, as well as the development of greenhouse gas emission inventories.

Employment History

Golder Associates Ltd. – Mississauga, ON

Air Quality Specialist (2010 to Present)

Janya Kelly is a member of the Air and Noise Group (Environmental Services A) within Golder. Janya joined Golder in 2010 after completing her post-doctoral work studying the projected impacts of climate change on regional air quality.

Janya specializes in climate change, air quality modelling and data representation.

Environment Canada – Toronto, ON

Visiting Fellow in a Government Laboratory (2007 to 2010)

Coupled the chemical transport model, A Unified Regional Air-quality Modelling System (AURAMS), with the Canadian Regional Climate Model (CRCM) to examine the impact of climate change on future (2050) air quality.

Calculated scaling factors that contributed to the projection of future emissions (2050) from current emissions. Improved ground based concentrations of ozone and particulate matter in comparison to observations by implementing a new vertical diffusion calculation from literature.

Prepared a review of scientific literature on climate change and air quality for Canadian Smog Science Assessment.



PROJECT EXPERIENCE – CLIMATE CHANGE ADAPTATION

**Confidential Clients -
Environmental
Assessments**
Various, International

Developed climate change data sets for numerous mining and resource developments for use in Environmental Impact Assessments in North and South America, including coastal regions. Data sets are prepared following the guidance of Incorporating Climate Change Considerations in Environmental Assessment: General Guidance for Practitioners (CEAA 2003) and Performance Standards on Environmental and Social Sustainability (IFC, World Bank Group 2012). Climate change data is used by other technical disciplines to assess the effects of climate on the project.

**Natural Resources
Canada**
Ottawa, Ontario, Canada

Golder provided advisory services to the Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR) to develop Climate Change Vulnerability case studies for mining operations include a Cost Benefit Analysis that compared no actions against implementing adaptive management options.

**Natural Resources
Canada**
Ottawa, Ontario, Canada

Golder provided advisory services to the Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR) as part of the Project Advisory Council for a review of Climate Change Vulnerability assessments as part of Environmental Impact Assessments in the Mining Sector

**Glencore Canada
Corporation (formerly
Xstrata Nickel)**
Sudbury, Ontario,
Canada

On-going climate change support services dealing with both adaptation and mitigation. Provided analysis and advice on the impacts of the incoming cap-and-trade regulation for Ontario, as well as developing a scenario analysis tool to examine the potential financial impact according to the selected operation scenario. Provided support work for a cost benefit analysis of proposed climate change adaptation based on known climate vulnerable infrastructure at the selected facility. Also provided climate change data sets to support assessment of water management infrastructure. Coordinated annual workshop to communicate results to environmental management team at the involved facilities.

Xstrata Nickel
Sudbury, Ontario,
Canada

Prepared a climate change vulnerability assessment to link into Xstrata's established risk management framework. Followed PIEVC Engineering Protocol for Climate Change Infrastructure Vulnerability Assessment.

**Government of
Nunavut**
Nunavut, Canada

Identification of climate risk for large infrastructure and mining operations in Nunavut for the Regional Adaptation Collaborative (RAC), assessed vulnerabilities and recommended adaptive measures and best practices. Conducted as workshop using a risk based assessment with government and mining stakeholders.

Infrastructure Ontario
Ontario, Canada

Conducting a Public Infrastructure Engineering Vulnerability Committee (PIEVC) assessment of three public buildings in Ontario.

Clean Air Partnership
Ontario, Canada

Developing climate change data sets for use in a training program to allow municipalities to conduct vulnerability assessments on municipal infrastructure.



PROJECT EXPERIENCE – CLIMATE CHANGE MITIGATION / GREENHOUSE GAS EMISSIONS

Glencore Canada Corporation
Sudbury, Ontario, Canada

Developed Excel-based carbon costing tools based on the California, Quebec and Ontario cap-and-trade regulations, in order to understand and estimate the potential financial impact of the Ontario regulatory framework for greenhouse gas emitting facilities. This tool was also used to provide strategic advice on negotiations during the development of the regulation and in determining the financial exposure of the company due to the regulation. Multiple workshop presentations were prepared to educate Glencore on the regulation and to train Glencore on using the carbon costing tool. Work is on-going to provide support during the registration process and the advocacy for the continued development of the regulation.

Canadian Vehicle Manufacturer's Association
Ontario, Canada

Developed a carbon costing tool based on the proposed Ontario regulatory framework for the incoming cap-and-trade regulation to understand and estimate the potential financial impact to the automotive sector. This tool was also used to provide strategic advice on negotiations during the development of the incoming regulation.

Canadian Steel Producers Association
Ontario, Canada

Developed a carbon costing tool based on the proposed Ontario regulatory framework for the incoming cap-and-trade regulation to understand and estimate the potential financial impact to the steel sector. This tool was also used to provide strategic advice on negotiations during the development of the incoming regulation.

Ministry of the Environment and Climate Change
Ontario, Canada

Provided analysis on the greenhouse gas benefits of non-disposal management of organic waste in Ontario

Various Clients
Ontario, Canada

Provided assistance and consulting services related to Ontario's Climate Change Mitigation and Low-Carbon Economy Act, 2016, including the Cap and Trade Program. This work includes education and training workshops, carbon costing tools and compliance obligations under the Cap and Trade Program.

Provided assistance and consulting services related to annual reporting requirements under the Greenhouse Gas (GHG) Emissions Reporting Program and Ontario's GHG Emissions Reporting Regulation O. Reg. 452/09

Confidential Clients
Various, International

Managed the development of greenhouse gas emission data sets for numerous mining and resource developments for use in Environmental Impact Assessments. Data sets are prepared following the guidance of Incorporating Climate Change Considerations in Environmental Assessment: General Guidance for Practitioners (CEAA 2003) and Performance Standards on Environmental and Social Sustainability (IFC, World Bank Group 2012), as well as following national and sub-national requirements.



PROFESSIONAL AFFILIATIONS

Air and Waste Management Association

PUBLICATIONS

Conference Proceedings

Capstick, Sean and Janya Kelly. 2015. *Climate Change Adaptation and Mining: Best Practices*. IAIA Special Symposium: Mega-Infrastructure Symposium, December. Panama City, Panama.

Capstick, Sean, Janya Kelly and Allison Barrett. 2015. *How is Climate Changing Changing Hydropower*. Power of Water, May. Niagara Falls, Canada.

Capstick, Sean, Janya Kelly, Allison Barrett and Rinaldo Penailillo. 2014. *Incorporating Climate Change Impacts into Environmental Assessments*. IAIA 2014: Impact Assessment for Social and Economic Development, April. Vina del Mar, Chile.

Journal Articles

Kelly, J., P.A. Makar and D.A. Plummer. Projections of mid-century summer air-quality for North America: effects of changes in climate and precursor emissions. *Atmospheric Chemistry and Physics*, 12 (2012), 5367-5390.

Kelly, J., D.V. Michelangeli, P.A. Makar, D.R. Hastie, M. Mozurkewich and J. Auld. Aerosol Speciation and Mass Prediction from Toluene Oxidation under High NOx Conditions. *Atmospheric Environment*, 44 (2010), 361-369.

Stroud, C.A., A. Makar, D.V. Michelangeli, M. Mozurkewich, D.R. Hastie, A. Barbu and J. Humble. Simulating Organic Aerosol Formation during the Photo-oxidation of Toluene/NOx Mixtures: Comparing the Equilibrium and Kinetic Assumption. *Environmental Science and Technology*, 38 (2004), 1471-1479.

Lohmann, U., J. Humble, R. Leaitch, G. Isaac and I. Gulpepe. Simulations of ice clouds during FIRE.ACE using the CCCMA single column model. *Journal of Geophysical Research*, 106 (2001), 15 123-13 138.