



Assessing Climate Change Risk on Abandoned or Orphaned Mine Sites in Ontario, Yukon and Northwest Territories

Plan Assessment Adaptation Measures Report



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Climate Risk Institute (CRI)

The Climate Risk Institute is a not-for-profit, academic-based entity that provides climate change impacts and adaptation decision and planning support.

Disclaimer

This document outlines a series of potential adaptation measure to address the risks associated with climate change based on a review of reclamation / remediation / rehabilitation plans and other documents. The proposed measures are generally a higher-level, broad list of adaptation measures that should be further developed and evaluated in terms of capacity required for implementation. As part of implementation, managers and decision-makers will develop additional, more specific detail around each of the potential adaptation measures. This list does not represent an exhaustive or recommended course of action but are for illustrative purposes. Further detailed analyses (e.g. climate change risk assessment) at each site are necessary to fully address potential climate risks.

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Introduction

For orphaned and abandoned mines, climate change has the potential to compound existing risks to ecosystems and communities and, in general, raise levels of risk for governing jurisdictions. It is possible that in many cases, levels of current and planned rehabilitation may be insufficient to account for future climate and extreme weather. While some assert that these facilities have been “over engineered” from the beginning, many mines in Ontario, Northwest Territories, and Yukon originally operated when there was little or no awareness that climate change was a relevant consideration and when environmental regulations provided little oversight on measures to mitigate risks to the environment. The result is a legacy of orphaned and abandoned mines where climate change may be creating hazards that had not been previously considered during the planning and operational phases of mines.

Plan Assessment/Review Methodology

Using a policy review framework developed by OCCIAR, a suite of criteria (Table 1), was modified to evaluate reclamation/remediation/rehabilitation plans and other documents for a) reference to a changing climate, b) the need for increased monitoring, c) specific vulnerabilities to specific weather events, d) thresholds of extreme weather, and, e) adaptive management. All sections of the plans and documents, where climate change could be reflected, and what types of adaptive measure could be employed were captured.

Table 1: Criteria and indicators used to evaluate plans

	Criteria	Notes and Indicators
Enabler	Presence of climate-change related terminology	Yes = A; B = indirect / not explicit; No = C Reference to climate change terminology would include projections, climate models, etc. (this would be A). B would include reference long term trends, but not explicit reference climate change. 'C' would be precipitation, temperature.
	Presence of risk-management related terminology	Yes = A; B = indirect / not explicit; No = C Reference to risk management could risk, vulnerability (...). Future risk discussion including environment/climate (A); historical evaluation (B); no risk management (C).
	Creation of an adaptive political environment	Identification of political action that could be taken to promote climate change adaptation OR features that build political support for climate change adaptation (e.g. statements that have an adaptation function and closely mirror other political goals; <i>attention to climate change from an industry association</i>)
	Creation of an adaptive economic environment	Direct or indirect (statement of intent) support to climate change adaptation. This could include: direct funding or investment to climate change research, guidance and adaptation measures (E.g. funding for ongoing training of stakeholders in environmental management under a changing climate); OR requires practitioners to commit funding to climate change adaptation related activities.

	Creation of an adaptive legal environment	Suggests a minimum standard or practice that must be met to avoid climate related liability.
	Creation of an adaptive social environment	Encourages outreach or engagement of the public to promote climate change adaptation in the community or region (E.g. standards that encourage public engagement throughout planning and review phases) <i>OR considers how remediation/reclamation impacts nearby community resilience.</i>
	Creation of an adaptive operational environment	Provides tools and support to incorporate climate change adaptation into decision-making; OR requires stakeholders to take operational adaptive actions (E.g. requirement to undertake climate change risk assessments)
	Encourages or mandates adaptive behaviour change	Encourages or mandates specific action
	Demonstrates flexibility with regard to changing climate trends	Promotes standards that adjust (are adjusted) to accommodate changing environmental conditions or climate patterns (e.g. statements/procedures that focus on adaptive management; OR that have a built in review process).
	<i>Identifies need for data or data gaps to support development of rehabilitation plan</i>	<i>Refers to references gaps in required data, or recommendations for the collection of additional data (monitoring).</i>
	<i>Identifies need for increased monitoring</i>	<i>Refers to recommendations for increased monitoring.</i>
	Makes taking adaptation action easier/less expensive/more efficient	Provide information resources, tools or economic assistance to support appropriate and efficient adaptation action
Barrier	Blocks or hinders adaptive behavior or actions	Elements that hinder climate change adaptation (e.g. restricts access to technologies, equipment or information required to act; limits the ability to act; encourages short-term planning for long-lived operations or infrastructure).
	Promotes mal-adaptation (actions or activities that increase risk or vulnerability)	Promotes actions that may increase climate change risks (e.g. promotes standards/procedures based on historical weather trends; or returning systems to a pre-approved state after a climate event that causes damage)
	Discourages adaptation	Actively discourage adaptation action, for example, references to uncertainty in climate models. Includes 'soft' barriers through language, ideology, communication.

An evaluation system (Table 2), was used to generate an overall picture of the plans and how they influenced adaptation. The scoring highlighted sections of the plans that had an immediate, direct or explicit impact on adaptation (either as an enabler or barrier) and those that indirectly created opportunities or barriers. For example, using an adaptive management approach does not directly support adaptation, but does create an environment where climate impacts and adaptation can be addressed.

Table 2: Scoring of enablers and barriers

Rating		Description
A = Active Support	A	Directly or strongly supportive of climate change consideration in planning OR climate change adaptation action
B = Passive Support	B	Indirect or weak support of climate change consideration in planning OR insinuation that climate change is a challenge
C = No Effect	C	This no effect on how climate change impacts are considered OR is not thematically relevant to the driver/barrier criteria in question.
D = Passive Barrier	D	Indirect or weak barrier of climate change consideration or adaptation. Ex. Encouragement to use historical climate data in decision-making
F = Active Barrier	F	Strong or direct barrier to climate change adaptation action

Reclamation/remediation/rehabilitation plans and other documents were provided by the Government of Ontario, through internet research of websites (e.g. Mackenzie Valley Land and Water Board website), and research conducted by Northern Climate Exchange.

A list of key word were developed to search plans for climate change relevant information:

- climate
- climate change
- climatic change
- adaptive management
- future
- projections
- global warming
- temperature
- rain and rainfall
- precipitation
- seasonal
- extreme
- weather
- risk
- assessment
- vulnerability
- monitor
- revegetation
- Infrastructure
- Dust

The steps of the process are highlighted in the figure below (Figure 1) and all result were tabulated in a plan assessment spreadsheet.

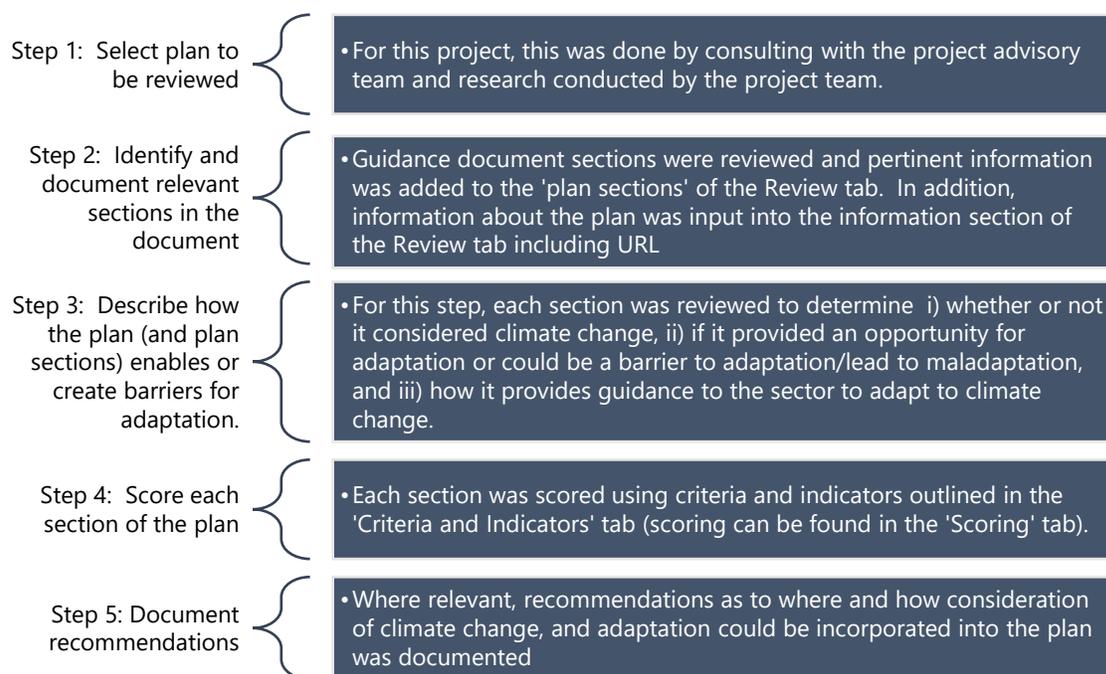


Figure 1: Steps of the plan assessment for climate change.

Assessment Results

This review evaluated reclamation / remediation / rehabilitation plans and other documents for a) reference to a changing climate, b) the need for increased monitoring, c) specific vulnerabilities to specific weather events, d) thresholds of extreme weather, and, e) adaptive management (Appendix 1). All sections of the plans where climate change could be reflected, and what types of adaptive measure could be employed were captured. Refer to policy review frameworks for results of each evaluation.

This section outlines a series of potential adaptation measure to address the risks associated with climate change based on a review of reclamation / remediation / rehabilitation plans and other documents. The proposed measures are generally a higher-level, broad list of adaptation measures that should be further developed and evaluated in terms of capacity required for implementation. As part of implementation, managers and decision-makers will develop additional, more specific detail around each of the potential adaptation measures. This list does not represent an exhaustive or recommended course of action but are for illustrative purposes. Further detailed analyses (e.g. climate change risk assessment) at each site are necessary to fully address potential climate risks.

Kam Kotia Mine (Ontario)

Final Design Document for the Kam Kotia Rehabilitation Program

Part 1, 2 and 3

D. Comrie Consulting, 1987

The purpose of the report was to develop final recommendations and design for rehabilitation of the Kam Kotia Mine site and associated effected area.

Potential Adaptation Measures

- Assess abandoned or orphaned mine sites using climate change vulnerability and/or risk assessment tool (e.g., PIEVC Protocol) to identify highest priority risks and develop adaptations to reduce those risks and to determine if existing control measures (e.g. confined tailings) are or will be impacted by climate change (e.g. extreme precipitation event leading to erosion of tailings).
- Strengthen existing remediation measures to reduce the risks associated with climate change.
- Develop robust rehabilitation monitoring programs that includes indicators of climate change to ensure rehabilitation has been/is effective. It can also help identify if climate change is impacting the site. An adaptive management approach should be considered to allow for changes to monitoring program to capture additional data to increase effectiveness of the program. For example, timing and length of water quality monitoring program may need to be reassessed to ensure it captures changes in water quality due to impacts of climate change on the mine site.
- Reconsider design parameters when designing or upgrading infrastructure. Designing infrastructure (e.g. dams) to meet design storms of the past (i.e. Timmins Storm) may not be sufficient to withstand impacts of future climate change. Changing precipitation patterns, variability and intensity may change what is currently thought of as a 1:100 year storm.
- Mine closure and rehabilitation plans should take an adaptive management approach to allow the consideration of new climate science and the identification of changes due to changes in weather and climate.
- Evaluate new and existing revegetation efforts against climate change to help identify the most effective program. Climate change in the form of changing precipitation patterns and variability may pose challenges for existing revegetation efforts.

Kam Kotia E.L.O. Environmental Summary Report

Klohn Crippen – 1997

The Environmental Summary Report presents a review of surface and groundwater quality data collected between 1992 and 1996 at the former Kam Kotia mine site near Timmins. T

Potential Adaptation Measures

- Include consideration of climate change in the development of rehabilitation plans.

- Undertake an assessment to identify how climate change may impact mine drainage and evaluate existing drainage plans/infrastructure to ensure it is robust enough to withstand the impacts of climate change. Develop adaptation options to strengthen existing plans.
- Consider how climate change may change snowmelt and rain storm events, including how it may impact flow rates, peak conditions, seasonal loading rates, and baseflow conditions. Ensure monitoring programs are robust to capture changes due to climate change. Develop adaptation options to reduce risks of negative impacts.
- Undertake assessments to understand how changes in climate and weather may affect metal loading.

Kam Kotia Tailings Reclamation Project – Final Report Volume 1, Phase 1 and 2 Kilborn Limited, 1983

These reports provided preliminary plans/concept for the decommissioning of the Kam-Kotia site.

Potential Adaptation Measures

- Include projections of climate change in descriptions of climate.
- Including projections of climate change in estimates (e.g. erosional loss estimates and sediment yields for a period of 100 years). Warmer spring temperatures accelerating snow melt and how that may impact erosion of tailings may pose challenges for tailings areas. Evaluate existing control measure to ensure they are robust enough to withstand climate change. Develop adaptation measures where they fall short in an effort to reduce the negative impacts.
- Assess how current and future climate change may impact existing vegetative covers used for rehabilitation. Changes in precipitation and temperature may pose challenges (or opportunities) for existing and future rehabilitation efforts.

Kam Kotia Rehabilitation Project Phase 1

Senes Consultants Ltd, Lakefield Research Ltd; ESG International; Denison Environmental Services, 2000

The scope and purpose of the Phase I Study was to review the extensive available information for the property, conduct site visits, and review the state-of-the-art technology for acid drainage control, and apply this information to develop practical options for the rehabilitation of the mine property.

Potential Adaptation Measures

- Assess abandoned or orphaned mine sites using climate change vulnerability and/or risk assessment tool (e.g. PIEVC) to identify how climate change, including extreme events, may impact mine site. Assessment would include identification of the highest priority risks and the development of adaptation options to reduce those risks and evaluate if existing control measures and rehabilitation efforts are or will be impacted by climate change.
- Assess whether larger flows as a result of changing precipitation regimes could cause flooding and additional erosion that may contaminate surrounding area.
- Include projected climate change parameters when assessing risk of failure.

- When characterizing technologies or methodologies considered to reduce the negative impacts of a mine, include consideration of how projected climate change may impact the various options.
- Water balance calculation should include current and future climate change.
- Geotechnical studies should include the consideration of climate change.
- Control options/designs for mine site to mitigate damage from acid mine drainage should include consideration of current and future climate change, and how changes in precipitation and temperature may impact the effectiveness of the control measures.
- Mine site rehabilitation options and strategies, guidelines and standards should include consideration of current and future climate change, and how it might impact the mine site and the effectiveness of rehabilitation efforts.
- Current Acts, standards and regulations should require consideration of climate change and rehabilitation that avoids mal-adaptation by considering if climate change will impact the success of the rehabilitation plan developed in accordance to the Act.
- Analyses of risk should include assessment of current and future climate change risk.
- Determine if current design storm is outdated. Planning under design storm parameters may lead to maladaptation.
- Consider climate change when assessing surface hydrology.

Central Patricia Mine (Ontario)

Central Patricia Mine - Tailings Delineation and Remedial Options - Final Draft
McIntosh Perry Consulting Engineers Ltd., October 2018

The purpose of this report was to identify data gaps in existing studies, assessments, and reporting related to the site, delineate the limits of known tailings areas, identify any new areas of impounded tailings, chemical characterization of all on-site tailings, chemical characterization of shallow (overburden) and deep (bedrock) groundwater, and identify site-specific rehabilitation/remediation options to protect human and environmental health.

Potential Adaptation Measures

- Include historical and future climate data when characterizing a site to identify how weather and climate may change into the future and impact the site.
- Determine how climate change (e.g. changes in precipitation, wind) could increase erosion and the mobility of tailings and mobility of contaminants into groundwater sources.
- Conduct a vulnerability and risk assessment considering projected climate change, including risks to humans and groundwater.
- Develop guidance around how to understand/consider how climate change may impact abandoned mines.
- The "Modified Generic Risk Assessment Approved Model", should include consideration of current and future climate change.
- Pilot projects should be required to consider climate change (e.g. consider the future impact of climate change on the choice of plant species for revegetation).
- Drainage plans should consider changes in precipitation patterns (e.g. intensity and frequency)/

- Inspection schedule should be determined and should also incorporate criteria to account for or identify impacts of climate change.
- Include consideration of climate change impacts and adaptation in all community engagement sessions.

Long Lake Gold Mine (Ontario)

Detailed Design Report - Detailed Design and Construction Management for Remediation of the Long Lake Gold Mine Tailings
SNC Lavalin, May 2017

The purpose of this report was to carry out detailed design and construction management for the remediation of the Long Lake Gold Mine at Sudbury, Ontario.

Potential Adaptation Measures

- Include consideration of current and future climate change in all assessment programs (e.g. groundwater assessment program)
- Undertake an assessment to identify how climate change may impact the transport of contaminants (e.g. during more frequent, intense precipitation events).
- Report included descriptions of the general hydrology of the area (i.e. climate normal, regional meteorological records, monthly precipitation, temperature, etc.). Description should include projections of future climate indicating how it may change into the future and how the impact of changing climate (e.g. temperature and precipitation) may impact the mine site.
- Hydrological assessments should include projections of future climate change and the impacts of climate change on permanent (and temporary) construction.
- Re-evaluate design criteria against climate change to identify how climate change may change the definition of a 1:1000 year storm and how that will impact design structures.
- Long-term monitoring programs should include consideration of climate change by identifying and including indicators of climate change to ensure rehabilitation has been/is effective. Monitoring can also help identify if climate change is impacting the site. An adaptive management approach should be considered to allow for changes to monitoring program to capture additional data to increase effectiveness of the program.

Remediation Options Report - Long Lake Guild Mine Tailings
CH2MHILL, April 2014

Following completion of site characterization, CH2M HILL evaluated remediation options to reduce the resulting arsenic concentration within Long Lake.

Potential Adaptation Measures

- Engineering assessments (e.g. stability analysis of tailings containment), class EA process, investigations, studies, methodologies, plans, etc., should require consideration of future projections of climate change.
- Establish monitoring programs to monitor effectiveness of rehabilitation efforts and identify when efforts are being impacted by climate change. Include how the monitoring program will consider climate change.
- Regulations can help advance consideration of climate change adaptation but including requirement to assess impacts and associated risks of climate change on a design and closure plan.
- Permit applications should require explanation how plan will consider impacts of climate change.
- Evaluation criteria should include impacts of climate change.

Long Lake Gold Mine Remediation Wetland Restoration

SNC Lavalin, November 2015

Potential Adaptation Measures

- Consideration of climate change should be a required component of any restoration plan. Ecological Restoration methodology is an excellent way to include and achieve that requirement.

Goudreau Pits (Ontario)

Existing Conditions and Rehabilitation Options for the Iron Range Property near

Goudreau, ON

EcoMetrix Inc., December 2016

Potential Adaptation Measures

- Guiding regulations (e.g. Mine Reclamation Code of Ontario (Mining Act, 1. Reg 240/00)), should include requirement to consider climate change in remediation planning.
- Hazards assessment provides an opportunity to include climate change projections to determine whether risk will become unacceptable into the future.
- Establish baseline conditions to provide a starting point to identify if/when changes occurs as a result of changing climate parameters. An adaptive management approach should be used to allow for adjustments to be made when deemed necessary.
- Require site description to include information on projected climate.
- Results of analyses should be re-evaluated against projections of future climate change. Future analyses should include projections of climate change.
- Monitoring programs should include consideration of climate change (e.g. climate change indicators and criteria), and use an adaptive management approach to make changes to program as the need arises.
- Consider possible impacts due to changes in climate and weather for long-term revegetation and general appearance of area.

South Bay Mine (Ontario)

Design Report – Detailed Design and Construction Management for the Reclamation of the South Bay Mine

CH2MHILL Canada Ltd, January 2018

The purpose of this report was to present a detailed design for the preferred remedial option for the South Bay Mine tailings management area, to mitigate metal leaching and acid mine drainage in surrounding lakes.

Potential Adaptation Measures

- Designs based on outdated design storm criteria may lead to maladaptation. Calculations of rainfall intensity should include projections of future climate change.
- Models and analyses should include a range of possible values for future climate.
- Consider installation of a weather station to collect weather data. Useful to correlate issues in the field with weather data collected at the site versus weather data from a separate location. Could also capture data in the event of an extreme weather event.
- Consider how climate change may impact groundwater seepage management options.
- Assessments tailings retention structures should include an assessment how the structure will withstand the impacts of climate change. Consider conducting a climate change risk assessment on tailings retentions structure.
- Regular checks and maintenance of structures can extend the shelf-life, especially in the event of extreme weather or other changes in climate. Establish and conduct regular maintenance checks of remediation structures.
- Consult climate models to determine how the current 1 in 1000 year event will change into the future. In addition, guidelines and standards should require and provide guidance on how to consider climate change.
- Evaluate reclamation scenarios against projections of climate change to ensure reclamation efforts are able to withstand the impacts from storm events.
- Using an adaptive management approach for monitoring programs would allow for adjustments to be made depending on the success of the treatment option. Including climate change indicators and criteria in monitoring of tailings management areas will help determine whether the management options are effective against climate impacts.
- Impacts of climate change from changes in precipitation could lead to problems into the future. Assessment of rehabilitation options should consider how options will be impacted by climate change.
- Water balance calculations should include projections of future climate change.
- Future water balance should be calculated for the catchment area, and consider how this change may impact the area.
- Re-evaluate design flood event against projections of future climate change.
- Engineering protocols (e.g. threshold channel design) should include projections of future climate change.

Colomac Mine (NWT)

Colomac Site Remediation Plan - water license MV2000L2-0018

INAC, March 2004

The intent of the Colomac Remediation Project is to minimize health and safety and environmental risks associated with the Colomac site and implement a remediation plan that meets the needs and concerns of INAC, its Tlicho partners and all Northerners.

Potential Adaptation Measures

- Assess vulnerability of tailings containment areas considering projected climate change.
- Although the plan does not explicitly state climate change, the adaptive nature of the conceptual monitoring plans allows for changes to be made to ensure the success of the project. Evaluate monitoring programs to ensure they monitor for impacts related to changes in climate.
- New water licenses should require consideration of climate change.
- Partnership with Tlicho people provides a good opportunity to raise the issue of climate change during the implementation of the remediation plan. Community members and Elders may have a close connection to the land and may have extensive knowledge to share about changes to the area as a result of changing climate. Propose a series of workshops to exchange information about the site, remediation plans, climate change and impacts. If agreeable with the community, hire a community member to collect traditional and local knowledge about changes in climate and weather, and associated impacts to the mine site. Incorporate this knowledge into developing adaptation options to address existing and new risks posed by climate change.
- Guidance material used to develop remediation plans should include consideration of and instruction on how to include climate change in remediation planning and implementation of plans. This could include consulting climate change experts when developing remediation plans, provide guidance on where to obtain climate projections and how to use them, and guidance on how to conduct vulnerability and risk assessments.
- Climate change will impact containment areas, especially those contained by ice. Warming temperatures could cause structures/construction material to thaw, potentially leading to failure and/or releasing contaminants into the surrounding areas. Consult climate change and engineering experts, and conduct climate change vulnerability/risk assessment (such as PIEVC protocol) on containment and engineering structures to identify potential vulnerabilities and risks, and develop and implement adaptation measures to reduce existing and new risks.
- Consult experts/academia to understand how climate change may impact ice/permafrost for containment structures and mine site in general.
- Along with conducting climate change vulnerability / risk assessment (e.g. PIEVC) on engineering structures to identify and address existing and new risks posed by climate change, qualified personnel should have an understanding and awareness of the potential impacts and incorporate into annual inspections. In addition, utilizing and adaptive management approach - adjustments should be made to remediation options when new information is made available (either through research or inspection reports, for example).
- Conduct vulnerability/risk assessment to determine if windblown dust will become more problematic with climate change.

- Conduct climate change risk assessment to determine if open pits will be impacted future changes in climate (e.g. will heavy precipitation events compromise the stability of the open pit walls?).
- Assess waste-rock piles to determine if they will be impacted by climate change such as changes in precipitation regimes (e.g. heavy precipitation), and/or increased frequency of freeze-thaw events leading to pile instability.
- Changing precipitation regime as a result of climate change may pose additional challenges on mine site infrastructure such as roads (culverts) and storage yards. Increased intensity of precipitation events could lead to increased erosion and instability of road embankments (especially
- If staying onsite, include airstrip in a climate change risk assessment to identify if currently vulnerable and where future risk exists and prioritize where adaptation should be undertaken.
- Include spilled hydrocarbon site and hazardous waste storage locations in climate change risk assessment.
- Consideration of climate change should be incorporated in all remediation efforts. This could include evaluating existing and future remediation efforts under changing climate.
- Include climate change data in water balance equations to determine how it will change into the future, impacting the mine site.
- Include climate change data in model input to determine how it will change into the future, impacting the mine site.
- Include water quality in climate change risk assessment to determine how it may change with changing climate, and develop adaptation options to reduce the associated risks. In addition, incorporate climate change projections into future contaminant estimates.
- Description of climate only considers historical climate. Descriptions should require consideration of future climate change.
- Evaluate remediation methods against climate change to determine if the methods will be impacted by changing climate, both negatively reducing the effectiveness of the method and positively, enhancing the success of the method.
- Increased frequency and intensity of rain events and periods of drought may result in fluctuating water levels in Tailing Lake. Evaluate remediation measures against projections of climate change to ensure the measure will be successful into the future. Adopting an adaptive management approach will help ensure the effort is successful by allowing changes or adjustments to the remediation measure when new information is obtained.
- Evaluate contingency plans against climate change (e.g. extreme rainfall events) to determine if contingency plan will perform as desired, or whether plan needs additional measures to ensure performance under adverse conditions.
- Remediation methods should be evaluated against projections of climate change.
- Consider climate change when designing new infrastructure, especially if it relies on permafrost. While adaptation such as ground freezing methods and other permafrost protection methods may be sufficient in the short-term, consideration for long-term projects such as tailings dams may be maladaptive.
- Guidance used in remediation of abandoned sites should be reviewed to determine how and if climate change is considered. All guidance documents should be updated to include consideration of climate change and guidance on how to consider climate change in remediation efforts.
- Adopting an adaptive management approach in the remediation process, including monitoring in order to evaluate effectiveness, allows for adjustments if method is not effective or new challenges such as climate change impacts reduces the effectiveness of the method.

- Remediation methods should not be maladaptive (e.g. emitting carbon). Evaluate remediation methods in terms of how they will be impacted by climate change, but also whether or not they are maladaptive.
- Assessments should include consideration of climate change by including projections of climate change and how the changes may impact remediation plans.
- Include monitoring results in vulnerability/risk assessment to identify current and new risks under a changing climate.

Discovery Mine (NWT)

Discovery Mine 2004 Remediation Plan - Final Report
INAC, December 2004

Discovery Mine (NWT) Year-10 Long-Term Monitoring Program

Potential Adaptation Measures

- Legislation (Acts) and policy documents should be reviewed and updated to include consideration of climate change including guidance on how to account for climate change in remediation plans.
- Remediation plans should make explicit mention of climate change, climate change impacts, and the need to ensure remediation activities are robust enough to withstand future climate change and associated impacts that may not be a problem currently.
- INAC objectives, Treasury Board guidance, federal legal requirements, etc. should all include consideration of climate change and where applicable guidance to help incorporate climate change into remediation planning and activities.
- Engagement provides an opportunity to work with First Nations to gather, in partnership and with permission, traditional knowledge about changes experienced in the area related to climate change. This knowledge can inform risk assessments to develop adaptation for existing remediation activities and/or develop new remediation activities that will provide additional risk protection from climate change.
- General principles on the approach to preparing the remediation plan are supportive of adaptation and provide opportunities to include consideration of climate change and associated impacts. For example, build consideration of climate change into risk assessment processes or add a climate change risk assessment to remediation planning. Update guidelines to include consideration of climate change and guidance on how to achieve that consideration. Adopt an adaptive management approach to allow for adjustments to the plan when new information becomes available.
- Technical team should have a good understanding of climate change and climate change impacts and adaptation and team should include a climate change expert.
- Community involvement (including First Nations) provide an opportunity to hear about changes being experienced because of climate change. Local and traditional observations can be used to inform the incorporation of climate change into remediation work. In addition, site visits provide an opportunity to look for indications of changes from climate change (e.g. indications of

permafrost melt in the north, flooding, etc.). Observations can be used to further identify how the site may be impacted by climate change.

- Evaluate previously completed remediation work against projections of climate change to ensure remedial efforts are robust enough to withstand future climate change. Evaluation could be undertaken as a climate change vulnerability assessment (e.g. PIEVC type assessment). Remediation efforts deemed not sufficient could be adapted to ensure continued resilience with climate change.
- Review already known climate-related impacts (e.g. permafrost degradation) and future climate change impacts to determine if existing remediation is sufficient to withstand future climate.
- Understand how winter road access may be limited in the future as a result of climate change.
- Incorporate climate change throughout the process, e.g. specific reference to climate change in objectives, use of climate change projections to identify remediation issues, etc.).
- Make specific mention of current and future climate change in mine-site remediation objectives.
- Monitoring plan should include assessment of potential climate change impacts to remediation efforts. Identification of potential impacts allows for monitoring to capture potential changes that may reduce the effectiveness of remediation.
- Individual component-specific remediation criteria provides an opportunity to explicitly acknowledge that impacts of climate change may challenge remedial activities put in place and an opportunity to highlight how climate change may impact the site and remedial activities.
- Monitoring plan should include assessment of potential climate change impacts to vegetation used in remediation. Identification of potential impacts allows for monitoring to capture potential changes that may reduce the effectiveness of the vegetative cover.
- Development of remediation actions could have had a more specific consideration of climate change using climate projections to understand impacts of climate change on remediation activities.

Tundra Mine (NWT)

Phase 2 - Remedial Action Plan

Golder Associates, October 2008

To address remaining environmental issues of concern from Phase 1 Remedial Plan and activities previously carried out.

Potential Adaptation Measures

- Understand how changes in climate may impact winter road access to the site. Consult experts / academics and conduct a climate change vulnerability to identify risks and develop adaptation strategies to mitigate those risks.
- Water balance calculations should include consideration of climate change to determine how climate change may impact water levels in the future.
- Understanding of biophysical environment should include an understanding of future climate change to ensure remedial actions stand up to the impacts of climate change into the future.
- Descriptions of climate should include projections of future climate change.
- Risk assessments should be required to incorporate climate change (e.g. climate change risk assessment) to help determine if risk rankings may change into the future.

- Climate change impacts may reduce the effectiveness of the remedial action. Objectives of remediation plans should include specific consideration of climate change. Remediation plans should adopt an adaptive management approach allowing monitoring and evaluation to ensure they perform as expected and providing the flexibility to make changes or adjustments if new information is obtained or if action is not performing well.
- Evaluations should consider projections of climate change to ensure remedial actions with withstand the impacts of climate change.
- When developing scenarios for monitoring plans, projections of climate change should be included to ensure the monitoring captures information that would enable adjustments of the remedial action if necessary.

Ketza Mine (Yukon)

Northern Affairs Programme Canamax - Ketza River Project Mine Closure Plan (1990)
Government Consulting and Audit Agency

Potential Adaptation Measures

- Design the capacity of tailings pond to meeting increased precipitation.
- Design spillway for increased flows.
- Consider changes in permafrost, moisture, and temperature on revegetation efforts; select Yukon appropriate species.
- Increased precipitation intensity and frequency may heighten erosion potential on the dam crest.
- Cover/seal must account for increased runoff.
- Dewatering plan must account for higher volumes of water. Must account for increased rainfall intensity and frequency in slope stability design.
- Increased precipitation may require longer operation of water treatment, or an upgrade in water treatment facility.

Ketza 2011 Proposal Appendix L - Reclamation Plan, EBA
EBA. 2011

Potential Adaptation Measures

- Waste rock dumps/slopes must be designed for fully saturated conditions if hydrogeological conditions change with increased rainfall intensity and frequency.
- Design cover for increased runoff volumes.
- Design slopes for increased rainfall intensity and frequency, saturated conditions.
- Dam failure: changes in permafrost must be considered for the dams.
- The amount of water requiring pumping and treatment may be affected by climate change.
- Evaluate geotextile cover against future projections of climate change. Increased runoff may impact effectiveness of geotextile cover.
- Course armoured channel should be designed for higher peak flows and intensity.

- Diversions must be designed for peak predicted flows.
- Account for increased rainfall intensity and frequency in slope stability designs.
- Changes to climate and extreme events may impact site monitoring.

Mt Nansen Mine (Yukon)

Mt Nansen Conceptual Closure Plan, Tailings Conceptual Closure
EBA

Potential Adaptation Measures

- Design cover for increased runoff volumes
- Consider changes in permafrost, moisture, and temp for revegetation.
- Wick drains must be designed for changed groundwater conditions.
- Design trench/diversion for increased rainfall, and changes in permafrost.

Keno Mine (Yukon)

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Potential Adaptation Measures

- Understand how changing permafrost conditions may affect structural integrity of adits and shafts.
- Understand how changing hydrogeological conditions and ground temperatures may further exacerbate the ice plug problem at the site, affecting ice and water management plans.
- Increased runoff will require higher volume of water to manage with respect to discharge water quality, and bulkheads/hydraulic plugs need to be designed for this.
- Design caps to withstand increased runoff.
- Consider higher volumes of water ponding in the open pit.
- Consider increased rainfall intensity and frequency in slope stability design; while there may be no foreseeable geotechnical instability under current climactic conditions, this may change."
- Consider increased rainfall intensity and frequency in slope stability design.
- Design diversions for peak flow, and changes in permafrost as a result of climate change.
- Consider increased runoff for soil cover design.
- Design roads for future climatic conditions, most notably increased rainfall events, to prevent washouts.
- Understand for changes in permafrost and rainfall to prevent dam failure.
- Design slopes for saturated conditions, increased precipitation frequency and intensity.
- Design water channels for peak flood flows, and changes in permafrost.

- Design WTP for peak flood flows anticipated during active remediation phase. Operation of WTP may require more months of the year/larger plant capacity given increased precipitation volume.
- Consider impacts of temperature changes on biological treatments.
- Determine whether power requirements for operation of WTP may change with increased water volumes requiring treatment.
- Historical culverts and channels may need to be upgraded for peak flood flow.
- Grading of stable slopes should account for saturated soil conditions and increased rainfall.

Conclusion

Review and evaluation of the reclamation / remediation / rehabilitation plans and other documents identified many opportunities for the consideration of climate change impacts and adaptation. The proposed measures should be further developed and evaluated in terms of capacity required for implementation. As part of the implementation, managers and decision-makers will develop additional, more specific detail around each of the potential adaptation measures.

This list does not represent an exhaustive or recommended course of action. Further detailed analyses (e.g. climate change risk assessment) at each site are necessary to fully address potential climate risks.

Appendix 1

List of documents reviewed for each mine site.

Jurisdiction	Mine site	Documents
Ontario	Central Patricia	1. Central Patricia Mine - Tailings Delineation and Remedial Options - Final Draft
	Kam Kotia Mine	2. Final Design Document for the Kam Kotia Rehabilitation Program, D. Comrie Consulting 3. Final Design Document for the Kam Kotia Rehabilitation Program Reports - Part 2, D. Comrie Consulting 4. Final Design Document for the Kam Kotia Rehabilitation Program - Part 3, D. Comrie Consulting 5. Surface Hazard Location at the Kam Kotia Mine, Kian A. Jensen Exploration and Consulting Services and William E. MacRae Geological Services 6. Crown Pillar Study Kam Kotia Mine, Trow Consulting Engineers Ltd. 7. Kam Kotia Tailings Reclamation Project - Final Report, Vol 1 Phase 1, Kilborn Limited 8. Kam Kotia Tailings Reclamation Project - Final Report, Vol 1 Phase 2, Kilborn Limited 9. Kam Kotia Tailings Reclamation Project - Final Report, Environmental Summary Report, Klohn Crippen 10. Kam Kotia Rehabilitation Project Phase 1, Senes Consultants Ltd, Lakefield Research Ltd; ESG International; Denison Environmental Services
	Long Lake Gold Mine	11. Detailed Design Report - Detailed Design and Construction Management for Remediation of the Long Lake Gold Mine Tailings 12. Appendix I - Final Cover Selection 13. Remediation Options Report - Long Lake Guild Mine Tailings 14. Long Lake Gold Mine Remediation Wetland Restoration
	Goudreau Pits	15. Existing conditions and rehabilitation options for the iron range property near Goudreau, ON 16. Summary Report Goudreau Property
	South Bay Mine	17. Design Report – Detailed Design and Construction Management for the Reclamation of the South Bay Mine
Northwest Territories	Colomac Mine	18. Colomac Site Remediation Plan -water license MV2000L2-0018, INAC 19. Colomac Mine Remediation Project - "Post-Reclamation Monitoring and Residual Hydrocarbon Remediation Management Plan"
	Discovery Mine	20. 2Discovery Mine 2004 Remediation Plan - Final Report
	Tundra Mine	21. Tundra Mine - Phase 2 - Remedial Action Plan 22. Tundra Mine - Erosion, Sediment and Drainage Control Plan

		23. Tundra Mine - Tundra Mine Remediation Project - Final Plan
Yukon	Ketza Mine	24. Northern Affairs Programme Canamax - Ketza River Project Mine Closure Plan (1990) *working from the cost memo 25. Ketza 2011 Proposal Appendix L - Reclamation Plan, EBA
	Mt Nansen Mine	26. Mt Nansen Conceptual Closure Plan, Tailings Conceptual Closure Plan
	Keno Mine	27. UKHM Reclamation Project, YESAB Project Proposal Submission