Cost Benefit Analysis of Climate Change Impacts and Adaptation Measures for Canadian Mines

Final Report

Prepared for Natural Resources Canada

2015

OCCIAR
Ontario Centre for Climate Impacts and Adaptation Resources

Golder Associates

Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR)

OCCIAR at MIRARCO (Laurentian University) is a university-based resource hub for researchers and stakeholders and provides information on climate change impacts and adaptation. The Centre communicates the latest research on climate change impacts and adaptation, liaises with partners across Canada to encourage adaptation to climate change and aids in the development and application of tools to assist with climate change adaptation. The Centre is also a hub for climate change impacts and adaptation activities, events and resources.
www.climateontario.ca

Golder Associates Ltd.

Golder Associates delivers solutions that help clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in the specialist areas of earth, environment and energy.
www.golder.ca

Authors:

Caroline Rodgers
Project Manager
OCCIAR
crodgers@mirarco.org

Al Douglas
Director
OCCIAR
adouglas@mirarco.org

OCCIAR Ontario Centre for Climate Impacts and Adaptation Resources

Golder Associates

Please cite this document as:

Rodgers, C. and A. Douglas. (2015). *Cost Benefit Analysis of Climate Change Impacts and Adaptation Measures for Canadian Mines: Final Report*. Report submitted to the Climate Change Impacts and Adaptation Division, Natural Resources Canada, 36p.

This project was made possible with the support from Natural Resources Canada through the Adaptation Platform

Natural Resources Canada Ressources naturelles Canada Canada

TABLE OF CONTENTS

Acknowledgments 3
Glossary 4
Executive Summary 5
1.0 Introduction 6
1.1 Background 6
1.2 Goal of the project 9
2.0 Assumptions 10
3.0 Approach 13
4.0 Findings 16
4.1 Vulnerability 16
4.2 High costs expected 16
4.3 Benefits of the risk bin approach in conjunction with the Climate Change Cost Benefit Analysis Tool 17
4.4 Resolution of cost and threshold data in CBA analysis 18
4.5 Adaptation Selection 18
4.6 Economic suitability of adaptation options 19
5.0 Lessons Learned and Recommendations 21
5.1 General lessons and recommendations 21
5.2 Lessons and recommendations for governments 24
5.3 Recommendations for communication of project results 24
6.0 Conclusion 26
Appendix A: References 27
APPENDIX B: Developing Climate Change Economic Case Analysis: A Guide to using the Climate Change Cost-Benefit Analysis Tool 30
APPENDIX C: Climate Change Cost- Benefit Analysis Tool 31
APPENDIX D: Economic Analysis of Climate Change Impacts and Adaptation Measures: Glencore's Sudbury Integrated Nickel Operations 32
APPENDIX E: Cost Benefit Analysis for Climate Change Impacts and Adaptation Measures for Canadian Mines: Literature Review 33

Acknowledgments

OCCIAR would like to acknowledge the vital contribution of the Golder team in developing the Climate Change Cost Benefit Analysis Tool and conducting the analysis.

Sean Capstick, Principal
Michael Fabro, Environmental Engineer
Janya Kelly, Air Quality Specialist
Kathleen Monahan, Air Quality Specialist
Cheyenne Martin

OCCIAR and Golder would like to acknowledge the hard work and significant contribution of our expert Project Advisory Committee (PAC) in the development of the products associated with this project. The PAC comprises a group of key government, academic and industry stakeholders that specialize in climate change, the environmental assessment process and the mining sector. The expertise provided by the group contributed to the development of the Climate Change Cost Benefit Analysis Tool that was used to analyze climate change impacts and adaptation measures at the partner mines.

Project Advisory Committee Members

Chris Beaumont-Smith, Manitoba Ministry of Innovation, Energy and Mines
Ben Brodie, Saskatchewan Water Security Agency
Maxine Cunningham, International Institute of Sustainable Development
Pamela Kertland, Natural Resources Canada
Cal Liske, Manitoba Ministry of Innovation, Energy and Mines
Randall Shymko, Manitoba Conservation and Water Stewardship
Jennifer Pouliotte, British Columbia Ministry of the Environment
Dr. David Pearson, Laurentian University

Glossary

Coping Costs: refers to costs related to existing risk management efforts (e.g., costs related to dewatering during rain events).

Direct costs: refers to costs directly triggered by climate (e.g., capital costs related to infrastructural damage caused by a flooding event)

Event Costs: refers to all costs that are directly or indirectly related to the occurrence of an environmental trigger (see Appendix B and D for examples of direct and indirect event costs considered in the Glencore assessment).

Indirect costs: refers to costs that are indirectly related to climate events (e.g., costs related to reputational damage after an overtopping incident).

Executive Summary

In the mining industry, economic assessments, such as Cost-Benefit Analysis (CBA) or Cost-Effectiveness Analysis (CEA), are employed to systematically determine the best use of scarce resources (Boyd et al., 2013). In the context of climate change, economic analysis can be used to weigh costs associated with climate risks, against risk management measures, to identify preferred investment and timing with regard to adaptation implementation. Moreover, the analysis enables a comparison between the costs of existing coping measures and those of longer term, deliberately planned actions to adapt to the defined risks, leading to a stronger business case for adaptation action.

This research aims to support adaptation decision-making in the Canadian mining sector by assessing the economic impact of climate change on mine operations. It focuses on evaluating the costs and benefits associated with climate change impacts and adaptation measures for mining operations in two locales in Canada. The study's specific objectives are:

- To provide examples of the costs of climate change impacts on critical aspects of mining operations;
- To develop a methodology that can be used by others in the mining sector to quantify the costs of climate risks on their operations and the potential cost savings/avoided costs associated with adaptation measures; and
- To develop a tool that will facilitate economic assessment of climate change impacts and adaptation measures for Canadian mine sites.

The Cost-Benefit Analysis (CBA) conducted at the two mine sites generated several key findings with respect to the assessment process and the costs of climate change for Canadian mines. These findings were paired with lessons learned for future application and recommendations to facilitate future economic analysis of climate change impacts and adaptation measures within the Canadian mining sector.

The cost-benefit analyses were conducted for two mining operations in Canada. At the time of release of this report, we do not yet have permission to release one of the case studies, thus this report has been edited to remove all reference to the outstanding case. A complete report, including the findings of both case studies, will be released when OCCIAR has authorization to present the full results.

Cost Benefit Analysis of Climate Change Impacts and Adaptation Measures for Canadian Mines

Final Report

1.0 Introduction

1.1 Background

Climate Change

Climate changes, including increases in annual average temperature, changes to precipitation regimes, and increases in the frequency and intensity of extreme rain, heat and wind, have been observed in many regions across Canada (Lemmen et al., 2008, IPCC, 2014). Over the past sixty years, average air temperature has increased by 1.5 degrees Celsius, with more rapid increases observed in Northern regions of the country (Warren and Lemmen, 2014). In the same time period, Canada's average annual precipitation has increased by approximately 16%, with significant increases in spring and fall precipitation levels and a decrease in winter snowfall (Bush et al., 2014).

Global climate models indicate that many of these trends will continue as the climate continues to change in Canada (IPCC, 2014). By 2050, average annual air temperature during the summer months is expected to increase by 1.5 -2.5 degrees Celsius under an A2 emissions scenario, while winter temperatures could rise by 3-7 degrees Celsius (Bush et al., 2014). During the same time period, average, annual precipitation is also expected to increase across Canada, although modeled projections demonstrate significant variability with regard to the magnitude of expected change (Bush et al., 2014). By mid-century, the intensity and frequency of extreme heat events is also expected to increase, such that a 1-in-20 year heat event would become a 1-in-5 year event (Kharin et al., 2007). In the same timeframe, return periods for extreme precipitation are expected to shorten; e.g. a 1-in-20 year event is expected to become a 1-in-10 year event (Kharin et al., 2007).

A broad array of literature has characterized the environmental, social and economic impacts of these changes on Canadian municipalities, industry, businesses, and the general population (Table 1).

Table 1: Examples of Environmental, Social and Economic Risks Associated with Climate Change Impacts

Impact	Environmental	Social	Economic
Increase in annual average temperature	Changes in wildlife phenology (life cycle timing), gradual sea level rise	Increase in health risks related to disease and pests (e.g. Lyme disease)	Changes in agricultural output, changes in freshwater quality
Increase in annual average precipitation	Changes in freshwater quantity	Reduced need for irrigation in some regions, increased availability of freshwater in some region	Higher flood insurance premiums, reduced irrigation costs in some regions
Increase in intensity and frequency of extreme heat events	Increased risk of forest fire, increasing drought frequency	Increased health risks related to extreme heat or air quality (e.g. heat stroke, asthma)	Damage to critical infrastructure (e.g. asphalt based roads electricity transmission lines), strain on electricity systems during event
Increase in intensity and frequency of extreme rainfall events	Changes in water quality and quantity, increased erosion, contamination of groundwater table	Changes in food availability, increasing power and communications outages, transportation restriction due to damage (e.g. road washout)	Increase in insurance claims and subsequently, premiums, possible disruption to supply chains, changes in agricultural output
Increase in intensity and frequency of extreme wind events	Damage to forests, increase in soil erosion,	Changes in food availability, increasing power and communications outages	Increase in insurance claims and subsequently, premiums, possible disruption to supply chains, possible disruption of electricity and communications causing lost production/loss of business
Weather variability	Loss of biodiversity, changes in wildlife phenology (life cycle timing)	Impact on winter recreation activities, changes in food availability	Damage to infrastructure (e.g. roadways due to freeze-thaw events),

(Sources: Lemmen et al., 2008; Warren and Lemmen, 2014; Melillo et al., 2014)

Environmental, Vulnerability and Risk Assessments are currently employed by both the private and public sectors to identify and assess the specific risks these impacts pose for their operations. The results of these assessments provide insights into environmental and social climate risks facing Canadians, but often they do not include costs of the impacts, or benefits of adaptive responses. Thus a more specific understanding of economic risk helps to quantify costs of impacts and provide further impetus for appropriate adaptive responses.

Economic Analysis

Economic assessment such as Cost-Benefit Analysis identifies financial consequences of inaction in the face of climate risk (Boyd et al., 2012; GIZ, 2013). In addition, economic assessment can help to identify optimal adaptive measures, helping practitioners to reduce and manage future risk (Boyd et al., 2012).

With respect to climate change, the use of economic assessment in decision-making has some important benefits:
Evaluation of climate risks: Economic assessment enables decision-makers to evaluate costs stemming from impacts under a variety of climate change scenarios (Boyd et al., 2012). Using the results of these assessments, decision-makers can also prioritize adaptation investment in areas most vulnerable to the impacts.

Selection and prioritization of adaptation options: Economic assessment as a component of the decision-making process can help companies select and prioritize adaptation options based on the balance of costs and benefits (Boyd et al., 2012). When combined with localized climate projections, economic assessment may also inform decisions on the timing of adaptation investments.

Due Diligence: As climate change impacts affect a greater number of Canadian businesses and industries, there is a growing demand for climate risk disclosure by stakeholders in the public and private sectors. In the Canadian mining industry, increased interest by shareholders (Fonds de solidarité; SHARE, 2013), industry organizations1 and regulatory agencies,2 in the identification and disclosure of climate change related risks has been observed. This trend could reinforce the case for adaptive action to allay stakeholder concerns (ICF Marbek, 2012). The use of economic analysis in decision-making can provide evidence of due diligence with regard to the identification and management of climate risks and satisfy the demands of shareholders and regulators.

Mining

The mining industry is important to the Canadian economy. In 2012, the industry contributed $52.6 Billion to the Canadian GDP, accounting for 20.4% of goods exports for the year (Mining Association of Canada). With over 200 active mines throughout the country, the mining industry employs approximately 400,000 people and is ranked fifth in the world for global production of aluminum, cobalt, tungsten, titanium, cadmium, platinum, diamonds, sulphur, potash and nickel (Mining Association of Canada). Given its economic importance, assessing and managing climate risks would help to safeguard assets and operations and promote long-term sustainability and profitability of the industry.

Growing evidence of the risks of climate change for the Canadian mining industry (Lemmen et al., 2008) have made adaptive action at the site and sector levels an essential component of business continuity and profitability. Damage related to climate change impacts such as permafrost thaw, ice jams, flooding,

[1] Such as the Mining Association of Canada (Stratos, 2013).
[2] Such as the Canadian Environmental Assessment Agency or Canadian Securities Administrators (CSA, 2010).

erosion and forest fires can affect mine productivity, result in economic loss and, in some cases, damage the surrounding environment and communities. Adaptation measures can help mine operators to manage these impacts and avoid or reduce costly future damage.

Government, industry and some mine operators have taken steps to encourage and facilitate the implementation of effective adaptation within the mining sector. These include: the development (or amendment) of key policies to encourage consideration of climate change in industry decision-making and promote adaptation action[3]; changing industry standards[4]; and investment by mine operators to obtain accurate climate science or facilitate the development of needed climate resources (Fraser Basin Council and MIRARCO, 2014).

Awareness of climate change impacts is on the rise in the mining sector, but "integration of these impacts into business planning is generally lacking" (Lemmen et al., 2014). This integration is critical to the promotion of adaptation action in the mining sector, given the scale of investment required to implement many adaptation options (e.g. replacement/retrofit of key infrastructure) and the long time horizons involved in decision-making (e.g. infrastructure lifecycles of approximately 50 years).

1.2 Goal of the project

Cost and benefit analyses are intimately tied to business decision-making, with mining as no exception. However, there are few examples of explicit application to climate change impacts and adaptation within the mining sector. As climate change impacts increasingly affect aspects of mining operations in Canada, knowledge of expected costs and an economic evaluation of potential adaptation measures could help mines to prepare for expected weather changes and reduce associated risk.

In this report we provide examples of the costs associated with climate change impacts and adaptation measures at Canadian mine sites and demonstrate ways in which the results can inform decision-making.

Specifically, we:

- Report on available methods and guidance for climate change economic analysis in natural resource sectors;

[3] For example, the Ontario Provincial Policy Statement, 2014 (Government of Ontario, 2014).

[4] For example, the most recent Canadian Dam Safety Guidelines recommend that stakeholders explicitly consider the risks of climate change in decision-making and design structures that will withstand future climate stresses (CDA, 2007).

- Develop and apply an economic analysis tool to assess climate change impacts and adaptation measures at a mining operation in Canada; and
- Identify other actions that might be taken, by the sector, government, or others in order to advance the role of economic analysis in supporting climate adaptation decision-making in Canada's mining sector.

2.0 Assumptions

The cost benefit analysis was bounded by assumptions pertaining to the approach, cost inputs and the mining operations. In addition to the assumptions discussed here, several case-specific assumptions are described within the case study (Appendix D).

Cost Benefit Analysis Approach: A Cost Benefit Analysis approach was employed to quantify and compare the costs and benefits associated with both climate change impacts and identified adaptation options. This approach does not evaluate the effectiveness of adaptation measures, and assumes that options chosen for assessment will address the expected climate change impacts effectively.

Climate Data: Results from a multi-model ensemble of climate models under a variety of emissions scenarios was used to assess the future risk of environmental triggers.

Inflation and Discount Rates: The analysis utilized an inflation rate consistent with the Bank of Canada's long-term inflation control target (2.00%). A confidential company specific discount rate used in the case study reflected the risk tolerance, internal budget and forecasting priorities, and average weighted cost of capital[5] of the mining partner.

Risk bin approach: The analysis employed a "risk bin" approach to determine the risk of environmental triggers occurring under baseline and future climate conditions. Professional judgment was used to place environmental triggers into risk ranges (or 'bins'), based on a variety of available information including historic climate data, infrastructural and operational thresholds, site-specific hydrologic models and vulnerability assessment results. The direct input of historical climate data and climate projections into the economic analysis model as a representation of future weather at the mine site (a process that has significant computational, temporal, knowledge and informational requirements) is possible but was deemed to be overly complex for the current level of assessment. The risk bin data was then incorporated into a stochastic model to determine whether risk associated with the occurrence of each trigger changed under future climate conditions. The approach was adopted to provide robust

[5] Weighted Average Cost of Capital (WACC) measures the average cost of capital to a firm or corporation. It is calculated as the average of debt and equity, weighted to represent the proportion that each contributes to the capital structure of the organization (Giddy, NYU)

modeled assessment in the absence of high-resolution climate data and climate modeling expertise. The approach mirrors the risk assessment approach utilized by the Public Infrastructure Engineering Vulnerability Committee (PIEVC) assessments of climate change impacts on civil infrastructure.

No Market Imperfections: The project was narrowly focused on the cost of climate change impacts and adaptation at individual mine sites, and did not consider market imperfections such as barriers to market entry, costs associated with obtaining credit, or costs related to hiring employees (Kiel Institute).

Comparing Different Types of Costs: The analysis relied upon the calculation of all costs related to the selected climate change impacts and adaptation measures. The costs were subsequently modeled to estimate the likely economic risk for each mine. The @Risk model was selected to conduct the simulations because of its transparency and compatibility with widely used programs[6]. Like other models, the @Risk model assumes that all costs are treated equally. However, in the mining industry, as well as other natural resources sectors, there are two types of costs that should be considered in a CBA. Capital costs, such as investment in new equipment or infrastructure retrofit, are fixed costs, and are dependent on market values. In contrast, costs associated with a mine's social license to operate are more complex and dynamic. They are linked to public acceptance of a mining company's presence and practices. In the event that an environmental impact causes damage at a mine site and the surrounding area (e.g. overtopping of dams due to flooding), the decline of public acceptance for the mining operations could result in long-term, unpredictable losses. Combining capital costs and costs associated with social license to operate in one analysis is challenging.

To address this issue without access to a more sophisticated model, several assumptions were made with regard to costs associated with social license to operate (such as environmental permit violation fees and subsequent declines in market capitalization). It was difficult to estimate the size of environmental permit violation fees in the model, as the size of the fee is based on a variety of factors including the type of environmental damage and the number of offences committed by the company, among others. The model therefore assumed that the maximum fee of $1million CAD would be applied at the first infraction. In the event that an environmental permit violation fine was triggered, a further set of probabilities was used to determine if a one-time 1% loss in market capitalization would occur (Table 2). Note that in these calculations, the risk of market capitalization is specific to each environmental trigger. For example, an environmental permit violation fine triggered in relation to E2 would not be counted when calculating the probability of a loss in market capitalization related to the occurrence of E3.

---

[6] The @Risk model is a simple stochastic tool designed to be an add-on to excel spreadsheets. The compatibility between the model and Excel adds a level of transparency to the process, allowing the user to see the calculations without needing additional programs.

Table 2: Probability of market capitalization loss following an ECA fine

Description of Environmental Permit Violation Fine Occurrence	Probability
Probability that share price drops 1% after ***first*** environmental offence (ECA fine) in 5 year period	**15%**
Probability that share price drops 1% after ***second*** environmental offence (ECA fine) in 5 year period	**40%**
Probability that share price drops 1% after ***third*** environmental offence (ECA fine) in 5 year period	**75%**

3.0 Approach

The study was guided by two over-arching questions:

- What are the costs and benefits related to climate change impacts and adaptation for Canadian mining companies?
- How can climate change economic analysis be used to promote adaptation in the Canadian mining sector?

Probabilistic analysis was employed to estimate the likelihood that environmental triggers would occur, and those events or conditions would trigger costs for the site. More detailed descriptions of the methodology and analysis can be found in *Developing Climate Change Economic Case Analysis: A Guide to using the Climate Change Cost-Benefit Analysis Tool* (Appendix B) as well as in the case study (Appendix D).

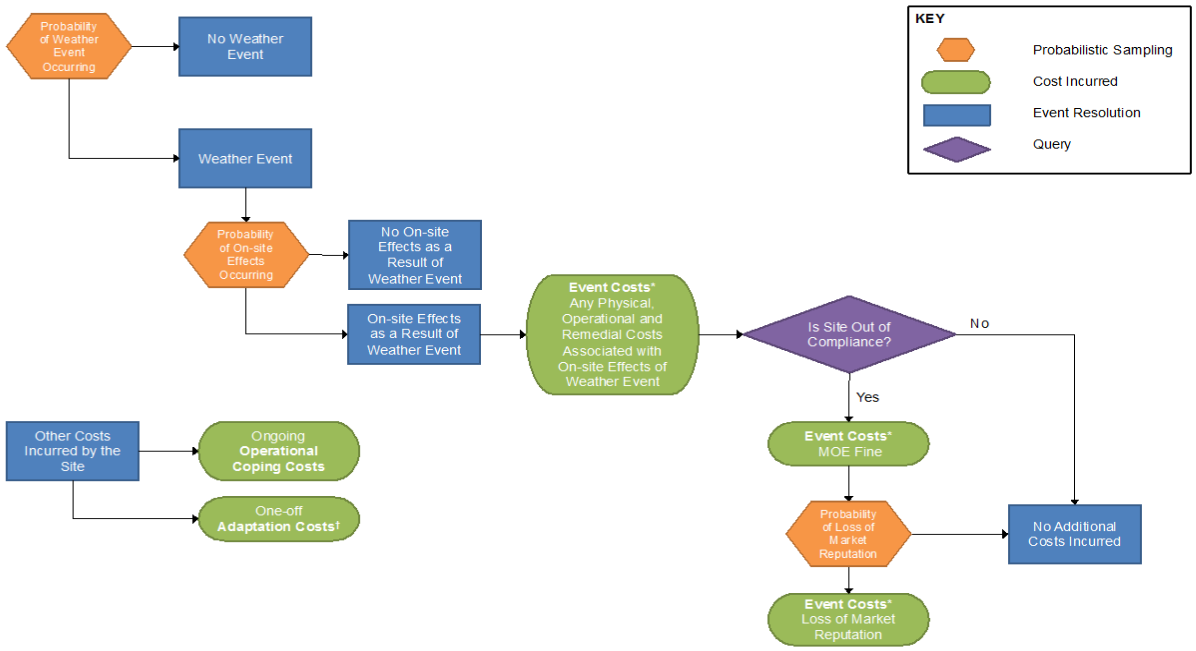
Review of existing scholarship and guidance: Research and guides on conducting economic analysis for climate change impacts and adaptation were compiled and reviewed (Appendix E) to identify gaps in knowledge and existing methodologies. This review provided the basis for development of the Climate Change Cost Benefit Analysis Tool, and lent context to case study development.

Identify mining partners: Based on initial consultation with research advisors, and through existing relationships, Glencore's Sudbury Integrated Nickel Operations volunteered to be one of the case studies. Support from the company as well as the availability of high-resolution historical climate data, site-specific models and detailed cost information, made Sudbury Integrated Nickel Operations an ideal partner for the case study.

Development of the Climate Change Cost Benefit Analysis Tool: A spreadsheet-based tool, the Climate Change Cost Benefit Analysis Tool was developed to organize data pertinent to the analysis including climate data, economic factors (such as inflation and discount rates), costs, and operational and infrastructural thresholds (Appendix C). After establishing probabilistic relationships between mine operations and climate, the tool was used to calculate economic risk associated with each environmental trigger. An accompanying guidebook was developed to provide directions on use of the tool; the goal of which was to support use in other mine settings (Appendix B).

Development of the case study: The cost-benefit analysis of climate change impacts and adaptation measures at the mine site progressed through a series of steps (Figure 1), which are explored in detail in the guidebook and the case study (Appendix B & D). Select staff and management were consulted to establish analysis scope and focus, including theme (e.g. water management, transportation etc.) and climate hazard (e.g. precipitation, wind etc.). Environmental triggers (specific climate hazards, impacts or conditions that may trigger costs for the site) were defined and linked to likely consequences for the chosen theme area. Professional judgment from company staff and consulting personnel helped to determine risk ranges (or 'risk bins') for each environmental trigger using available climate and threshold information.

Figure 1: Analysis and cost calculation for climate change impacts and adaptation measures



Additional information on the types of costs used in the assessments can be found in the Guidebook (Appendix B). To protect proprietary company information, costs were represented by ranges throughout the case studies (Table 4).

Table 4: Cost ranges employed in case studies

Cost range	Amount in dollars ($ CAD)
Low	< $100,000
Medium	$100,000 - $ 999,999
High	>$1,000,000

Costs associated with each environmental trigger were then modeled to compare the economic risk for the company under current and future climate conditions. The economic risk for each trigger was re-assessed to account for the costs and benefits associated with adaptation measures. This risk could then be compared to risk under the business-as-usual scenario, to assess the benefits of adapting to future climate changes.

Identification of challenges, best practices and lessons learned: The economic analysis conducted for each the case study generated several key results, including:

- A calculation of the level of economic risk posed by each environmental trigger (i.e. How costly could it be for the company if the trigger occurred?);
- An indication of how risk may change under future climate conditions;
- An understanding of the effect adaptation measures may have on existing or expected economic risk, by increasing the resilience of infrastructure/operations to withstand future climate conditions; and
- An estimation of when (and how often) environmental triggers are expected to occur under baseline and future climate conditions.

The results compare current costs to those that are likely to occur under future climate conditions, and under business-as-usual (coping) or adaptation scenarios. A detailed description of the results appears in the case study.

Key facets of the project and lessons for subsequent application were noted and appear in Section 6 of this report.

4.0 Findings

The analysis revealed findings regarding the resolution of cost and threshold data within the analysis; choice of adaptation measures for analysis; and economic suitability of adaptation measures.

4.1 Vulnerability

During initial consultation the mine partners were asked to select an aspect of their operations on which the analysis would focus. Choices included transportation, water management systems, tailings design and management, and energy. Glencore's Sudbury Integrated Nickel Operations selected their water management system as the focal point, based on the potential risk of extreme rainfall and flooding events. A previous formal climate change vulnerability assessment (2011) identified the water management systems as a high risk.

Climate change projections indicate that for many parts of Canada, extreme rainfall and weather variability will likely become more frequent and intense (Bush et al., 2014), leading to increased pressure on mine water management systems. Assessments like this one will use such climate change information to tabulate possible damage and related costs for mining companies, thus building the business case for adaptation.

4.2 High costs expected

Results revealed that the cost estimates related to climate impacts were significant. On average, costs associated with the occurrence of environmental triggers were high (Table 5). This pattern is important because the probability of environmental triggers occurring is expected to increase under continued climate change (with the exception of seasonal flooding), indicating higher economic risk for many Canadian mine sites in the future. Without investing in adaptation, mining companies increase the potential for damage to mine infrastructure and operations, as well as the environmental health and safety of surrounding communities.

Table 5: Cost ranges associated with environmental triggers for Glencore

Environmental Trigger	Risk Bin	Event Costs (CAD)	Coping Costs (CAD)
E1. High water levels	2	> $1,000,000	< $100,000
E2. Low water levels	6	>$1,000,000	< $100,000
E3.Significant rainfall event	1	>$1,000,000	None
E4. Low-risk flooding	2	< $100,000	None

E5. High-risk flooding	1	$1,000,000>	None*

4.3 Benefits of the risk bin approach in conjunction with the Climate Change Cost Benefit Analysis Tool

Development of the Climate Change Cost Benefit Analysis Tool was guided by initial questions regarding the depth and specificity that should be achieved in the analysis. The use of high-resolution climate projections, detailed, local historic climate data and site-specific modeling of the water management system was integrated into a stochastic weather generator to develop scenarios of possible future climate conditions at a mine site. This data can then be used in conjunction with infrastructure and operational threshold data to calculate costs associated with the occurrence of environmental triggers. However, this level of input detail can be difficult to achieve, requiring time, resources, expertise and tools that may not be available to mining practitioners.

With the goal of developing a transferrable tool and easily replicable process for other companies in the sector, the Climate Change Cost Benefit Analysis Tool was designed to accommodate varying levels of data resolution. The risk bin approach used climate and weather data as inputs and professional judgment to establish risk ranges for each trigger. Subsequent modeling of environmental triggers under future climate conditions could then inform changes in the level of risk associated with the occurrence of each environmental trigger. This approach reduced the informational requirements for conducting cost-benefit analysis for climate change impacts and adaptation resources, removing the need for downscaled climate projections.

In addition to reducing the level of detail required to conduct cost-benefit analysis of climate change impacts and adaptation measures, the risk bin approach enabled the modeling of consequences under future climate conditions. Broadly speaking, conducting a CBA for climate change impacts requires the calculation of costs associated with impacts stemming from future weather events. This can be challenging because costs are associated with the consequences of a climate hazard or impact rather than with the hazard itself. For example, compiling and calculating costs related to a flooding event yields due to the large number of variables involved in such a calculation including the size of the flood, aspects of the mining operation affected and infrastructure thresholds. In contrast, calculating costs associated with the overtopping of a dam or breach of a retaining structure is concrete, often including cost information gleaned from prior incidences or knowledge of resource costs.

Using the risk bin approach, risk ranges were calculated for environmental triggers based on the probability that the trigger would occur, as well as the probability that the occurrence would then result in a consequence/damage. Infrastructure and operational thresholds as well as professional judgment were used to specifically define environmental triggers and associated consequences likely to occur. The environmental triggers could then be modeled to determine the level of risk associated with each trigger under future climate conditions. Costs associated with trigger consequences were calculated and could be evaluated against costs associated with coping or adaptation measures.

This approach yielded a description of the mine's risk of incurring costs related to environmental trigger consequences, under current and future climate conditions. In this way, the challenges related to modeling consequences and using that data to determine precise costs related to potential future climate events were resolved.

4.4 Resolution of cost and threshold data in CBA analysis

Under the risk bin approach, the level of detail in cost or threshold data can significantly influence evaluations of:

- The type of climate hazards or impacts that trigger costs for the mine site (environmental trigger definitions);
- When and how often environmental triggers may occur under future climate conditions; and
- The costs associated with the occurrence of an environmental trigger and associated adaptation measures, thereby affecting the precision (and value) of the results.

The cost and threshold data supplied by Glencore was derived from various assessments and modeling exercises completed by Golder. This previous work generated highly detailed infrastructural and operational threshold information and provided context that allowed Glencore to narrowly define environmental risks and generate detailed cost expressions for use in modeling exercises. These elements contributed to a higher level of accuracy in modeling future climate conditions and cost-impacts for the mine site.

In cases where cost and threshold information is less detailed in nature, analysis can be informed by historic costs and professional judgment. This approach may result in broader definitions of environmental triggers, which will affect the risk bin categorization for the site. However, analysis under these conditions can still provide practitioners with a basic understanding of the level of economic risk their site may face under future climate conditions.

The Climate Change Cost Benefit Analysis Tool, using the risk bin technique, can facilitate analysis using either high-or low- resolution cost and threshold data. However, practitioners should be cognizant of the limitations of the results, in order to optimize the value of the information.

4.5 Adaptation Selection

The Climate Change Cost Benefit Analysis Tool allows users to compare the costs and benefits associated with multiple adaptation options. This allows comparison of several adaptation options that correspond to one environmental trigger, to identify the most appropriate and cost-effective option; or it can be used to compare the costs and benefits of adaptation options that address different environmental triggers, in order to prioritize investment and support implementation planning.

In the Glencore case study, the company identified only one adaptation option per environmental trigger for analysis. The measures were pre-selected based on their ability to reduce risk associated with the occurrence of the environmental trigger. In this context, the analysis provided valuable cost comparison between existing coping measures and proposed adaptation options. The results of these comparisons were used to determine whether to invest in adaptation, based on the cost and effectiveness of existing coping measures as well as the estimated future risk associated with the environmental triggers.

Assessing adaptation options in this manner creates a situation whereby adaptation is either accepted or rejected based on a comparison of the coping and adaptation options. The exclusion of alternative adaptation options in the analysis limits a company's ability to identify investment or implementation strategies that might better address the environmental risk. When several adaptation options are considered in CBA, practitioners may select the optimal option based on a broader suite of result criteria including the consideration of their current financial outlook and optimal investment levels. In some cases, that may mean that the company could start with low-cost, no-regret measures and proceed toward more significant adaptation action until risk levels are tolerable. This approach promotes and complements adaptive management techniques that may currently be used in decision-making. When one adaptation is considered in CBA, the results can only reveal whether or not the specific measure should be adopted under the specific conditions considered in the analysis.

4.6 Economic suitability of adaptation options

Comparison of the costs and benefits associated with existing coping measures and adaptation options (under current and future climate conditions) in the Glencore analysis revealed that in the majority of cases, investment in adaptation was economically advantageous. Adaptation action was preferred over existing coping measures for 3 of the 5 environmental triggers over a 39-year period assuming future climate conditions (Table 6).

Adaptation was not preferred in cases where coping costs were very low and the risk of the environmental trigger occurring was also low; or in cases where the environmental trigger was very likely to occur (e.g., seasonal flooding), adaptation costs were high and coping costs were low. The analysis highlights cost savings (vs. coping costs) or costs avoided (where coping costs are not recommended) for specific adaptation actions.

Table 6: Glencore- Economic suitability of coping measures vs. adaptation action over a 39-yr period

39 Year Period		Coping Preferred	Adaptation Preferred
		Payback Not Achieved	Payback Achieved
E1	Current Climate	83.1%	16.9%
	Future Climate	79.2%	20.8%
E2	Current Climate	0.2%	99.8%
	Future Climate	0%	100%
E3	Current Climate	73.8%	26.2%
	Future Climate	4.3%	95.7%
E4	Current Climate	100%	0%
	Future Climate	100%	0%
E5	Current Climate	88.6%	11.4%
	Future Climate	30.8%	69.2%

5.0 Lessons Learned and Recommendations

5.1 General lessons and recommendations

A CBA Climate Change Cost Benefit Analysis Tool is most valuable if it is tailored to fit the nuances of the industry or sector using it. For example, many natural resource sectors, including the mining industry, are heavily influenced by a social license to operate (SLO), the agreement of local populations with the presence and practices of the mine. This element is formally included in mine planning and design processes (e.g. public consultation and impact benefit agreements between First Nations populations and a mine) and can informally influence decision-making at a mine through the threat of lost market capitalization (i.e. in the event of an oil spill, stock prices decline, prompting a parallel decline in market capitalization) (Flammer, 2011).

The costs associated with SLO are different than other capital or operational costs in that they are unpredictable, untethered to market or asset value, and can be long-term disruptions. The value of the Climate Change Cost Benefit Analysis Tool will increase if it can better account for these differences when analyzing the costs and benefits associated with climate hazards and impacts that can potentially result in SLO costs. In this assessment:

- SLO costs were considered in both case studies,
- Research was completed to estimate future SLO costs including fines related to environmental permit violations and loss of market capitalization
- Assumptions about SLO costs were clearly stated to ensure transparency

Recommendation: Future assessments would benefit from the use of a highly intricate model to better capture future SLO costs related to environmental triggers, for comparison and calculation with capital and operational costs. At present, this type of model is not available. Further research will be required to develop one.

A second lesson pertains to the management of uncertainty within a CBA of climate change impacts and adaptation measures. Cost benefit analyses contain uncertainty that stems from potential future scenarios that consider choices for future action, investment, costs, policies, etc. Applying CBA to climate change impacts and adaptation measures creates additional uncertainty by trying to calculate anticipated costs based on uncertain future conditions. Determining the magnitude and timing of discrete, extreme weather events remains difficult, with more complex models carrying greater uncertainty (Ackerman, 2008; GIZ, 2013). In addition, the capacity to adapt to climate change is a dynamic function that increases and decreases as internal (mine) and external factors evolve. Furthermore, the presence of capacity does not imply its utilization. Thus accounting for, and balancing, the various components of the assessment that contain uncertainty can help develop context for decision making.

In this assessment various inputs and techniques were employed to manage uncertainty in the assessment, including:

- Risk bin approach (probability *ranges* for the occurrence of environmental triggers and their consequences enables the use of high and lower resolution climate data in CBA);
- High resolution climate data;
- Detailed cost and threshold data;
- Clear statement of assumptions.

Recommendation: CBA results can be considered a snapshot of expected economic risk under set variables. Regular review of CBA inputs, assumptions and results is recommended to reduce uncertainty and increase accuracy and value of results.

A third lesson pertains to the use of analysis results in decision-making. Cost-benefit analysis of climate change impacts and adaptation measures for a mine site produces several types of results including:

- Probability relating to environmental trigger occurrence (e.g. Significant 1:100 year 24-hr rainfall event);
- Probability relating to consequence occurrence (e.g. Breach of retaining structures);
- Direct and indirect costs related to the environmental trigger;
- Coping costs and benefits; and
- Adaptation costs and benefits.

These results were used to compare the relationship between coping and adapting costs in the context of varying climate risks. Probability of the occurrence of environmental triggers and consequences were combined with related costs to form "climate risk costs". These costs could then be compared to coping and adaptation costs to determine when adaptation was an economically suitable option (Figure 3). Examples of cost comparisons are provided below:

1) Climate Change Cost Benefit Analysis Tool results:

- Low coping costs,
- High adaptation costs, and
- Low climate risk costs

In this scenario, the mine site can choose to take **No Action**, given the relatively low level of risk involved. It is recommended in these scenarios that mine sites maintain regular monitoring so as to maximize their preparedness levels.

2) Climate Change Cost Benefit Analysis Tool results:

- Medium coping costs,
- Medium – High adaptation costs, and

- Medium climate risk costs,

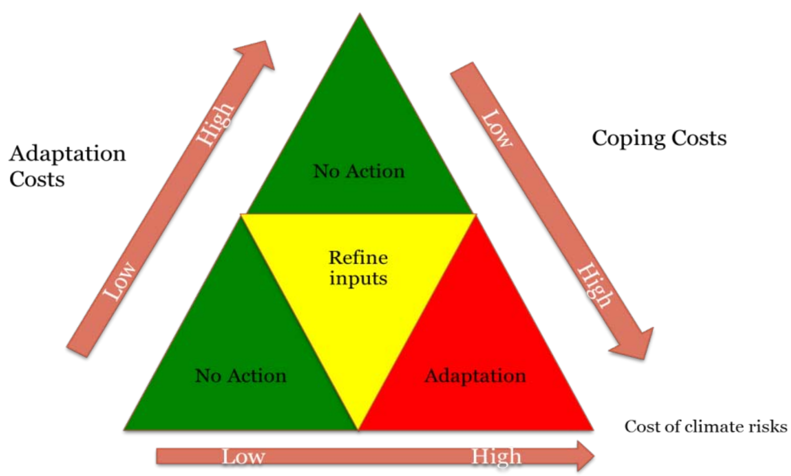
In this scenario, the mine site can choose to refine their cost, benefit and climate data inputs to narrow the scope of the analysis to better capture climate risks to the operation. Additional studies may be required to adjust proposed adaptation measures or to better understand operational vulnerability.

3) Climate Change Cost Benefit Analysis Tool results:

- High coping costs,
- Low adaptation costs, and
- High climate risk costs

In this scenario, the mine site can choose to adapt, as the costs they face in implementing and maintaining adaptation measures will be offset by the benefit they will realize from avoided climate risk and coping costs. Additional engineering analyses may be undertaken to provide decision-makers with a more detailed understanding of the impact the adaptation measure will have on mine operations.

Figure 3: Interpretation of Climate Change Cost Benefit Analysis Tool results



Recommendation: Assessing and managing costs/benefits for climate change impacts and adaptation is best presented using concepts of risk assessments, while results are best interpreted recognizing trade-offs between coping and adapting in the context of varying climate risk.

Finally, cost-benefit analysis provides decision-makers with financial information that supports sound investment decisions. In the context of climate change decision-making, cost-benefit analyses provide a business case for adaptation. This type of financial validation, notably in natural resource sectors, may encourage the management of climate risks as a business decision.

The research also demonstrated that although CBAs generate economic information, they could inform other decision-making techniques such as risk or vulnerability assessments. The quantification of climate change impact costs can help hone levels of vulnerability and risk. These decision-making tools complement each other and provide decision-makers with a clear understanding of their priorities with regard to adaptation action.

Recommendation: Although CBA results can inform decisions about adaptation investment and implementation, they are most valuable when used in conjunction with complementary decision-making tools and techniques such as vulnerability and risk assessments.

5.2 Lessons and recommendations for governments

The CBA analysis for Glencore highlighted the benefits of using high-resolution climate data in calculations of future economic risk related to climate change. Although the risk bin approach is designed to compensate for uncertainty in model results, using regional-scale climate model output can account for local landscape features that influence local climate, thus improving the accuracy of the assessment results. Many Canadian mines are located in regions (remote or otherwise) where high-resolution climate data and projections may not be available. Development of these resources/data is helpful for not only CBA for the mining sector, but for other climate change-related assessments.

Recommendations:

- Conduct a survey to determine climate data needs for the mining sector.
- Seek private-public alliances to establish additional weather monitoring stations, especially in remote locations. Data sharing outcomes are also beneficial.

Increasingly, shareholders, industry groups and regulators are requesting or requiring detailed information on the ways in which changing weather and climate will impact mining operations. Economic analysis can 1) quantify the risks in monetary terms and 2) demonstrate due diligence with regard to taking measures to manage those risks through suitable, cost-effective adaptation. Transparently disclosing climate change risk can be detrimental to the company's reputation and share price, but if acted upon through adaptation, can provide proof of action (due diligence) to assess and manage those risks.

Recommendation: Climate change adaptation will become more common in regulatory reporting if policies are updated and expanded to support the inclusion of climate risks in company risk assessments.

5.3 Recommendations for communication of project results

Interest shown by the companies to participate in the process was encouraging. The case studies provided examples of the costs and benefits associated with climate change impacts and adaptation, which are of benefit for the entire industry. Use of the Climate Change Cost Benefit Analysis Tool yields mine site-specific cost information that supports decisions to protect assets, safeguard employees and protect the environment.

Communicating the products to key interest groups including the mining industry and other natural resource sectors will hopefully inspire further edits to the Tool, subsequent applications and additional case studies.

Recommendations for communication of analysis work:

- The Climate Change Cost Benefit Analysis Tool, guidebook and case studies will be posted to relevant information hubs and websites including Climate Change Adaptation Community of Practice, Ontario Climate Consortium, Mining Association of Canada and regional Mining Associations.
- Presentation of these products and methodology at mining industry groups may serve to increase interest and uptake within the sector.
- Webinar presentations (following the presentations to mining industry groups) can promote interactive communication about the practical use of the tool
- A forensic analysis of recent mining failure can be used to demonstrate how economic analysis could be used to prioritize climate risks; identify and build a business case for potential climate adaptations; and prioritize adaptation investment and implementation.

6.0 Conclusion

An increase in observable climate change and impacts, combined with a growing body of scientific evidence, has supported increased awareness of the issue and the need for adaptation in the Canadian mining sector (Lemmen et al., 2008; Ford et al., 2011). In this context, cost-benefit analysis is useful for decision-makers, providing the opportunity to build a business case for adaptation action, calculate expected costs related to climate change impacts, and prioritize investment and implementation of adaptation options. Although results of this analysis are case-specific and based on the review of a small sample of climate hazards on a single theme, observations, lessons and recommendations can have implications for economic assessment throughout the Canadian mining sector.

The analysis demonstrated that information requirements for the assessment were significant. Although CBA can be conducted with lower resolution climate, cost and threshold data using the risk bin approach, the clarity and accuracy of the results are tied to the level of detail provided in these areas.

The assessment demonstrated that in the majority of cases (3 out of 5 environmental triggers), adaptation options were preferred over standard and current coping measures. Although specific to this case study and environmental risks, the results serve to demonstrate that adaptation measures can be economically beneficial, achieving payback on the investment and reducing future costs related to climate risks.

As the concept of a CBA for climate change impacts and adaptation grows in Canada and around the world, we expect that further interest and application will occur. This research shows how the general aspects of CBAs can be adapted to fit the context of mining. This adaptable process, including the lessons and recommendations, shows significant potential for further development and application in mining and other sectors.

Appendix A: References

Baker, M. 2005. Equity in Transport Planning. Accessed online at: http://www.michael-baker.com/dissertation/chapter_9.html

Boyd, R., A. Gados and T. Maynes. 2012. Economic Guidance for the Appraisal and Prioritization of Adaptation Actions. Natural Resources Canada.

Bush, E.J., Loder, J.W., James, T.S., Mortsch, L.D. and Cohen, S.J. (2014): An Overview of Canada's Changing Climate; in Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation, (ed.) F.J. Warren and D.S. Lemmen; Government of Canada, Ottawa, ON

Canadian Dam Association (CDA). 2007. Dam Safety Guidelines. Accessed online at: http://www.imis100ca1.ca/cda/Main/Publications/Dam_Safety/CDA/Publications_Pages/Dam_Safety.aspx?hkey=52124537-9256-4c4b-93b2-bd971ed7f425

Canadian Securities Administrators (CSA). 2010. CSA Staff Notice 51-333: Environmental Reporting Guidance. Accessed online at: https://www.osc.gov.on.ca/documents/en/Securities-Category5/csa_20101027_51-333_environmental-reporting.pdf

Christensen, J., B. Hewitson, A. Busuioc, A. Chen, G. Xuejie, I. Held, R. Jones, R. Koli, W. Kwon, R. Laprise, V. Rueda, L. Mearns, C. Menendez, J. Raisanen, A. Rinke, A. Sarr and P. Whetton. 2007. Regional Climate Projection in Climate Change 2007: The Physical Science Basis; Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. (ed.) S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. Averyt, M. Tignor and H. Miller. Cambridge University Press.

Deutche Gesellschaft fur Internationale Zusammernarbeit (GIZ). 2013. Economic Approaches for Assessing Climate Change Adaptation Optuions Under Uncertainty: Excel tools for Cost-Benefit and Multi-Criteria Analysis.

Federal-Provincial-Territorial Committee (FPTC) on Climate Change and Environmental Assessment. 2003. Incorporating Climate Change Considerations in Environmental Assessment: General Guidance for Practitioners. Canadian Environmental Assessment Agency. Canada

Flammer, Caroline. 2011. Corporate social responsibility and shareholder value: the environmental consciousness of investors. MIT Sloan School of Management.

Fonds de solidarité. Optimizing Responsible Investment. Accessed online at: http://www.fondsftq.com/2013report/ethics-and-governance/2.html#sthash.CeJNI45Y.dpbs

Fraser Basin Council and MIRARCO. 2014. Climate Change Planning at Glencore in Sudbury, Ontario: A Climate Adaptation Case Study in Canada's Mining Sector. Fraser Basin Council. Accessed online at: http://www.retooling.ca/_Library/Mining_Essentials/mining_case_study_glencore.pdf

Government of Ontario. 2014. Provincial Policy Statement. Ministry of Municipal Affairs and Housing. Accessed online at: http://www.mah.gov.on.ca/AssetFactory.aspx?did=10463

ICF Marbek. 2012. Adaptation Platform Mining Working Group: State of Play Report. Submitted to Natural Resources Canada. Accessed online at: http://www.retooling.ca/_Library/docs/mining_state_of_play_2012.pdf

International Panel on Climate Change (IPCC). 2007(a). Climate Change 2007 : Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, (Eds). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 976pp

International Panel on Climate Change (IPCC). 2007(b). Climate Change 2007 : The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon, s., D. Quin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignow and H.L. Miller (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996pp

International Panel on Climate Change (IPCC). 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp.

International Panel on Climate Change (IPCC). 2013. Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Kharin, S., V, Kharin, F. Zwiers, X. Zhang and G. Hegerl. 2007. Changes in Temperature and Precipitation Extremes in the IPCC Ensemble of Global Coupled Model Simulations. Journal of Climate. v.30, p 1419-1444.

Kiel Institute. 2014. Macroeconomic Policy Under Market Imperfections. Accessed online at: https://www.ifw-kiel.de/academy/monetary-policy-under-market-imperfections

Lal, P.N., T. Mitchell, P. Aldunce, H. Auld, R. Mechler, A. Miyan, L.E. Romano, and S. Zakaria 2012. National systems for managing the risks from climate extremes and disasters. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 339-392.

Lederwasch, A. & P. Mukheibir. 2012. Independent review of the Coalpac Environmental Assessment. Institute for Sustainable Futures; University of Technology Sydney

Lemmen, D.S., Warren, F.J., Lacroix, J., and Bush, E., editors (2008): From Impacts to Adaptation: Canada in a Changing Climate 2007; Government of Canada, Ottawa, ON, 448 p.

Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2.

Mining Association of Canada. 2014. Online at: http://mining.ca

Nelson, Julia, and Ryan Schuchard. 2011. Adapting to Climate Change: A Guide for the Mining Industry. Accessed January 6 2014 at: http://www.bsr.org/reports/BSR_Climate_Adaptation_Issue_Brief_Mining.pdf

Olenski, S. 2014. Nearly Four Years After Deepwater Horizon has BP's Brand Image Recovered? Forbes. Accessed online at: http://www.forbes.com/sites/steveolenski/2014/01/24/nearly-four-years-after-deepwater-horizon-has-bps-brand-image-recovered/

Pearce, T., Ford, J.D., Prno, J., Duerden, F., Berrang-Ford, L.,Smith, T., Pitman, J., Reid, A., Beaumier, M and Marshall, D. 2009. Climate change and Canadian mining: Opportunities for Adaptation. David Suzuki Foundation. Accessed online at: http://www.davidsuzuki.org/publications/downloads/2009/Climate_Change_And_Canadian_Mining.pdf

Pearce, T.D., Ford, J.D., Prno, J., Duerden, F., Pittman, J., Beaumier, M., Berrang-Ford, L., & B. Smit. 2011. Climate change and mining in Canada. Mitigation and Adaptation Strategies for Global Change 16:347-368.

Stratos. 2013. Emerging Transparency Standards, Expectations and Practices for Mining Companies. Produced for the Mining Association of Canada. Accessed online at: http://mining.ca/sites/default/files/documents/EmergingTransparencyStandardsExpectationsandPracticesforMining.pdf

The Guardian. July 22nd, 2010. BP Oil Spill Timeline. Accessed online at: http://www.theguardian.com/environment/2010/jun/29/bp-oil-spill-timeline-deepwater-horizon

Warren, F. and Lemmen, D. 2014. Synthesis; in Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation. Government of Canada, Ottawa. Pgs. 1-18.

Yohe, G.W., R.D. Lasco, Q.K. Ahmad, N.W. Arnell, S.J. Cohen, C. Hope, A.C. Janetos and R.T. Perez. 2007. Perspectives on climate change and sustainability. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 811-841.

APPENDIX B: Developing Climate Change Economic Case Analysis: A Guide to using the Climate Change Cost-Benefit Analysis Tool

APPENDIX C: Climate Change Cost- Benefit Analysis Tool

APPENDIX D: Economic Analysis of Climate Change Impacts and Adaptation Measures: Glencore's Sudbury Integrated Nickel Operations

APPENDIX E: Cost Benefit Analysis for Climate Change Impacts and Adaptation Measures for Canadian Mines: Literature Review

This page intentionally left blank.

THE ONTARIO CENTRE FOR CLIMATE IMPACTS AND ADAPTATION RESOURCES (OCCIAR)

935 RAMSEY LAKE ROAD

SUDBURY, ONTARIO

CANADA

P3C 2C6

WWW.CLIMATEONTARIO.CA