APPENDIX V
CLIMATE CHANGE REPORT

IAMGOLD amec

CÔTÉ GOLD PROJECT
CLIMATE CHANGE REPORT

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GLOSSARY AND ABBREVIATIONS

AMEC	AMEC Environment & Infrastructure
CCCSN	Environment Canada's Canadian Climate Change Scenario Network
cm	Centimetres
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
^oC	Degrees Celsius
EA	Environmental assessment
EC	Environment Canada
GCMs	Global Climate Models
GHGs	Greenhouse gases
ha	Hectare
IDF	Intensity-duration-frequency
IPCC	Intergovernmental Panel on Climate Change
km	Kilometre
km/h	Kilometres per hour
kV	Kilovolt
L	Litres
LRIA	Lakes and Rivers Improvement Act
m	Metre
m^3	Cubic metres
mm	Millimetre
Mm^3	Million cubic metres
MNR	Ministry of Natural Resources
MOE	Ministry of the Environment
Mt	Million tonnes
PMP	Probable Maximum Precipitation
Tpd	Tonnes per day
T_{max}	Maximum temperature
T_{min}	Minimum temperature
TMF	Tailings management facility
WCRP	World Climate Research Programme
WCSC	Wildlife Conservation Society Canada

EXECUTIVE SUMMARY

The objective of this climate change review is to firstly assess the potential interactions between potential climate change and the Project from two viewpoints: i) influences the Project may have on climate change and ii) influences climate change may have on the Project. Secondly, to determine and recommend, where appropriate and practical, mitigation and adaptation planning strategies to reduce and manage potential impacts related to the Project that may pose a risk to the public or to the environment.

This report also documents the regulatory framework, quantification methods, data and assumptions that were used to estimate the GHG emissions for the Project. Based on the estimated greenhouse gas (GHG) emissions the following comparisons can be made:

- the total emissions from the Project will be above the GHG reporting requirements under the Federal and Provincial reporting programs at some point during the Project lifetime. It should be noted that input data used to estimate the emissions is conservatively based on current operating assumptions and may overestimate the actual emissions in any given year. Regulatory reporting requirements will therefore be assessed on a year by year basis once actual consumption data is available; and
- the total emissions from the Project represent 285 kilotonne CO_2e (carbon dioxide equivalent), which is approximately 0.17% of Ontario's GHG inventory for 2011 or 0.04% of the Canadian GHG inventory for that same year.

Since the predicted GHG emissions from this Project are insignificant in comparison to Canadian and global emissions, the Project will have virtually no impact on current estimates of future global climate change.

A climate analysis was also conducted in this report in order to i) establish a set of climate parameters describing the climatic and meteorological phenomena relevant to the study area, and to ii) establish a general expectation of occurrence of each climate parameter both historically and in the future. Various climate parameters were assessed based on perceived relevant climate events and change factors (based on climatic and meteorological phenomena deemed relevant to the Project). Each climate parameter was assessed in detail to provide historical and future climate parameter probability scores. Seven parameters (high temperature, heat waves, freeze thaw cycles, 1-day and 5-day rain, winter rain, freezing rain, drought/dry periods) have been identified with increasing probability moving into the future, and three winter related parameters (low temperatures, cold waves, snow accumulation) have been identified with decreased probability, primarily related to the anticipation of rising temperatures. Of particular interest are increases in the rain related parameters which could have a direct impact on performance of the subject infrastructure.

It is anticipated that climate change will alter the demands placed on, and the availability of linked groundwater and surface-water resources in Canada, although the ultimate effects of climate change on the distribution of water in Canada are highly uncertain. However, it is anticipated that climate change will result in a longer snow-free season which will in turn produce a combination of greater seasonal evaporation and potentially increased infiltration because of a shorter period of frozen ground. Further, changes in the seasonal patterns of snowfall and rain, especially less frequent summer showers and longer inter-event dry periods, coupled with increased evaporation due to higher temperatures, may reduce the infiltration of surface water into groundwater systems in the summer. The overall result is a situation which may be problematic for ecosystems dependent on the baseflow discharge of groundwater and may result more generally in lower water tables, causing lower surface water levels toward the end of the summer.

A risk assessment was conducted to determine the likely effects of individual climate events on Project components and infrastructure. Vulnerability exists when the total load effects on a functional element exceeds the total capacity to withstand them, while meeting the desired performance criteria. Where the total loads or effects do not exceed the total capacity, adaptive capacity exists. This screening-level assessment was completed as a means of determining if more detailed assessments were warranted. It was determined that climate change has the potential to affect the majority of Project elements across all three phases, namely; construction, operations and closure. However, it can be surmised that the more prominent effects may be seen into the 2030's and beyond through the late stages of Project operations and then during closure. Of particular interest is precipitation for which individual storms are projected to increase in intensity and total volume of rain. The design of structures that will remain past 2030 will consider climate change predictions. It is therefore not considered a concern.

In general, given the Project timeline, it can be concluded that options to negate or mitigate perceived vulnerability have been integrated into the design of the infrastructure and/or operations where necessary. It is also generally considered that sufficient data is presently available to support integration of potential climate change influences into the design process.

The risk assessment also determined the likely effects of climate events on Project administration (personnel, operations), electrical power supply, transportation and communications. The primary performance responses considered in regard to Project administration (personnel, operations) were related to their ability to complete normal and emergency operations and maintenance activities specific to the Project. Rain, freezing rain, snow accumulation and high winds could contribute to impaired movement of crews and associated resources and equipment. High temperature and heat waves could also impact crews' abilities to maintain normal operations and maintenance schedules. Potential impacts to the base electrical transmission system were generally related to those that could affect damages to the transmission system such as freezing rain and high winds. In light of these findings, IAMGOLD is currently considering backup power generation capacity in the Project design to accommodate off-line power generation for a period appropriate to maintain Project operation. Climate parameters that could potentially impact or disrupt transportation systems (specifically related to impacts to the ability of supplies to be delivered to the Project) included freezing rain and precipitation. Of particular importance was the delivery of fuel for the backup power generation at the Project. IAMGOLD is considering stocking essential material for Project operations at levels that are appropriate to maintain Project operation during periods when re-stocking from outside sources cannot be completed. Communication systems necessary to maintain operation of the Project were not considered to be at serious risk from any of the climate phenomena evaluated for this risk assessment.

It should also be noted that this climate analysis is not meant to be exhaustive. The climate information presented in the following sections is not based on new science or analyses generated through this Project, but rather a review of readily available information from other sources. It is clear that climate science is advancing rapidly and this review should not be construed as a comprehensive characterization of the historic climate or future projections for the Project area. As well, uncertainty in climate projections is clearly demonstrated in the varied results from the present array of global climate models. The information developed and used for this Project is adequate to meet the stated objectives of the study, however other potential users of the information should consider it in the appropriate context.

1.0 INTRODUCTION

1.1 Overview

Our changing climate is considered one of the globe's most significant environmental, social and economic threats. In Canada, changes observed in the climate over the past number of decades have influenced an increase in economic losses from extreme weather events, premature weathering of infrastructure, stresses on water supplies, worsening air quality and related health and economic impacts, affecting the quality of life Canadians and the economy. It has been projected that Ontario may in the future experience changes in the frequency and/or severity of extreme weather as well as changes to average climate over several decades or more as a result of our changing climate. These changes are expected to continue to affect natural, social and built infrastructure, potentially having significant socio-economic consequences.

The effects of climate change presents a two-fold challenge: mitigation strategies that limit further climate change by reducing the production of greenhouse gases (GHG); and adaptation planning that prepares for the altered temperature and precipitation regimes that global warming will bring.

The objective of this climate change review is to firstly assess the potential interactions between potential climate change and the Project from two viewpoints, namely:

- GHG considerations: where a project may contribute to GHG emissions; and,
- impact / influence considerations: where climate change may affect a project.

Further, this review will determine and recommend, as appropriate and practical, mitigation and adaptation planning strategies to reduce and manage potential impacts related to the Project that may pose a risk to the public or to the environment.

1.2 Climate Change Review Guidelines

The review of potential climate change influences has been prepared according to the guidance presented in the "*Incorporating Climate Change Considerations in Environmental Assessment: General Guidance for Practitioners"*, prepared by the Federal-Provincial-Territorial Committee on Climate Change and Environmental Assessment (FPTC, 2003).

1.2.1 Project Influences on Climate Change

A summary of the review tasks focused on the assessment of Project influences on climate change is outlined as follows: GHG emissions from combustion sources will be estimated based on information on equipment and truck fleet provided by IAMGOLD and compared to appropriate emission inventories and other major industrial sources. Strategies will then be developed for the site to minimize GHG emissions. This aspect of the climate change review is detailed in Section 3 of this report.

1.2.2 Climate Change Influences on the Project

A summary of the review tasks focused on the assessment of climate change influences on the Project is outlined as follows:

- define the future periods for the assessment;
- identify the infrastructure and other components of the Project to be included in the vulnerability assessment;
- determine the design basis / threshold against which vulnerability will be assessed;
- develop a list of measureable climate variables relevant to the geographic location;
- develop a preliminary assessment of the list of climate variables against each of the target infrastructure and other Project components to develop a short-list of variables for a more detailed definition for the defined future periods;
- assess each Project component / climate variable interaction with a view to probability of occurrence (with regard to the climate variable) and severity of occurrence of the interaction; and,
- develop mitigation and/or adaptation planning strategies for significant vulnerabilities.

This aspect of the climate change review is detailed in Section 4 of this report.

1.2.3 Review Time Frames

1.2.3.1 Historical

The time frame used for this assessment for representation of historical information is the period 1971 - 2000. This 30-year period matches the most recent climate normal period available from Environment Canada. Further, this period is also used for data representation from the Atmospheric Hazards website (ontario.hazards.ca; Klaassen, 2005). This time frame is also consistent with baseline climate data periods used for most projections (the other is 1961 - 1990). Where independent data analyses were completed for this assessment, the 1971 - 2000 time frame was used unless otherwise indicated.

1.2.3.2 Future

Three future periods have been identified for this assessment, namely 2020, 2050 and 2080. These future years generally reflect the tri-decade periods 2005 - 2034 (representing 2020), 2035 to 2064 (representing 2050) and 2065 to 2094 (representing 2080). In some cases the periods 2011 - 2040 and 2041 - 2070 have also been used to represent the 2020 and 2050 period properties, respectively, depending on data availability.

2.0 PROJECT INFLUENCES ON CLIMATE CHANGE

The projected annual emissions of GHGs have been assessed in the Greenhouse Gas Report (see Appendix F of the EA Report). This report documents the regulatory framework, Project boundaries, quantification methods, data and assumptions that were used to estimate the GHG emissions for the Project. Based on the estimated GHG emissions the following comparisons can be made.

- the total emissions from the Project will be above the GHG reporting requirements under the federal and provincial reporting programs at some point during the Project lifetime. It should be noted that input data used to estimate the emissions is conservatively based on current operating assumptions and may overestimate the actual emissions in any given year. Regulatory reporting requirements will therefore be assessed on a year by year basis once actual consumption data is available; and
- the total emissions from the Project represent 285 kilotonne CO_2e (carbon dioxide equivalent), which is approximately 0.17% of Ontario's GHG inventory for 2011 or 0.04% of the Canadian GHG inventory for that same year.

Since the predicted GHG emissions from this Project are insignificant in comparison to Canadian and global emissions, the Project will have virtually no impact on current estimates of future global climate change.

3.0 CLIMATE CHANGE INFLUENCES ON THE PROJECT

3.1 Overview

Vulnerability exists when the total load effects on a functional element exceeds the total capacity to withstand them, while meeting the desired performance criteria. Where the total loads or effects do not exceed the total capacity, adaptive capacity exists.

A matrix of the Project components and infrastructure that are likely to be sensitive to changes in climate is presented in Section 5. A qualitative assessment was completed, based on professional judgment and experience, which focused on the review of relevant climate parameters and the completion of a risk assessment which together identified potential impacts of the changing climate on individual elements of the Project. This screening-level assessment was completed as a means of determining if more detailed assessments were warranted.

3.2 Climate Analysis

3.2.1 Overview

The objectives of this study component were to:

- establish a set of climate parameters describing the climatic and meteorological phenomena relevant to the study area; and,
- establish a general expectation of occurrence of each climate parameter both historically and in the future.

As noted previously, the term ‘historical’ relates to climate from the current time frame and recent past, while “future” relates to the three future time frames identified for this study, namely 2020, 2050 and 2080.

It should also be noted that this climate analysis is not meant to be exhaustive. The climate information presented in the following sections is not based on new science or analyses generated through this Project but a review of readily available information from other sources. It is clear that climate science is advancing rapidly and this review should not be construed as a comprehensive characterization of the historic climate or future projections for the Project area. As well, uncertainty in climate projections is clearly demonstrated in the varied results from the present array of Global Climate Models (GCM’s). The information developed and used for this Project is adequate to meet the stated objectives of the study, however other potential users of the information should consider it in the proper context.

3.2.2 Climate Data Sources

3.2.2.1 Historical

The basic analysis of historical data for the study area was based on data from a variety of sources including:

- Environment Canada's Climate Normals (Appendix D; available at http://climate.weatheroffice.gc.ca/climate_normals/index_e.html);
- Environment Canada's Climate Data Online (available at http://climate.weatheroffice.gc.ca/climateData/canada_e.html); and
- Environment Canada's Canadian Daily Climate Data (CDCD v1.02; available at ftp://arcdm20.tor.ec.gc.ca/pub/dist/CDCD/).

There is no long-term weather station in the immediate vicinity of the Project site as illustrated in Figure 4-1. However, a number of Environment Canada (EC) weather stations are located in the same region as the Project site (see Figure 4-1 and Table 4-1).

Table 3-1: Regional Weather Stations

Location	EC ID	Distance From Site	Period of Record
Chapleau	6061358	110 km (NW)	1965 - 1976
	6061359		1886 - 1996
	6061361		1994 - present
Timmins	6078280	120 km (NE)	1922 - 1957
	6078282		2008 – 2012
	6078285		1955 – 2012
	6078286		2012 - present
	6078290		1951 - 1969
Sudbury	6068145	130 km (SE)	2011 - present
	6068148		1887 - 1977
	6068150		1954 – 2012
	6068153		2013
	6068155		1977 - 1979
	6068158		1986 - 1996
Kirkland Lake	6074209	150 km (E)	1950 - 1996
	6074211		2001 – 2013
Earlton	6072223	160 km (E)	2011 - present
	6072224		2000 - 2011
	6072225		1953 - 2005
Massey	6065005	160 km (S)	1963 - 1964
	6065006		1983 - present
Sault Ste Marie	6057589	235 km (SW)	1949 - 1959
	6057590		1973 - 2002
	6057591		2012 - present
	6057592		1961 - present

The Environment Canada Weather Office Forecast Regions are closely aligned with cities, communities and municipal boundaries. Further, local factors such as terrain, climatology, land cover and population patterns are also used to define these regions.[1] In this context, the Gogama - Foleyet Region, within which the Project site is located, is linked with the Chapleau - Missinaibi Lake Region.[2]

The Chapleau weather station was, therefore, used from the above noted data sources, where available. Where data for the Chapleau weather station was not available in the databases above, data from a nearby station or information in the literature based on a regional context was used. Any other data sources, when used, are documented in the specific climate parameter sections that follow.

3.2.2.2 Future

Future climate projections were analyzed using climate model outputs from:

- Environment Canada's Canadian Climate Change Scenario Network (CCCSN; available at http://cccsn.ca/?page=main);
- Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report (IPCC, 2007);
- World Climate Research Programme's (WCRP) Coupled Model Inter-comparison Project Phase 3 (CMIP3) multi-model dataset (WCRP, 2009); and
- Other readily available literature as documented in the specific climate parameter sections that follow.

Climate projections for a number of climate parameters were obtained from the bias-corrected and spatially downscaled WCRP CMIP3 Climate Projections archive (WCRP, 2009) described by Maurer (2007). The WCRP archive was developed jointly by the U.S. Bureau of Reclamation, Santa Clara College and the Lawrence Livermore National Laboratory. The WCRP-CMIP3 archive has been developed using peer reviewed methods (Wood et al. 2002; Wood et al. 2004; Maurer, 2007) and is currently being used by the U.S. Bureau of Reclamation and many other entities, such as the IPCC's Working Group 1 for climate change impact analyses.

The 112 projections in the WCRP CMIP3 archive originates from runs of 16 GCMs using the B1, A1B and A2 scenarios of future GHG emissions, as shown in Table 4-2. For each of the 112 scenarios, and for each month of the year, a precipitation ratio and a temperature offset were calculated between the overlap period and each of the future projection periods. These adjustment factors were then used to adjust the daily historical maximum temperature, minimum temperature and precipitation values for Chapleau from 1966 – 2011 (not including the period of April 1976 through June 1978) by applying the appropriate month's adjustment ratio or offset for each day of the month. Both maximum and minimum temperatures were adjusted by the same offset.

[1] http://www.ec.gc.ca/meteo-weather/default.asp?lang=En&n=10220A6B-1
[2] http://www.ec.gc.ca/meteo-weather/default.asp?lang=En&n=2A8C1486-1

The precipitation and temperature values for grid cells were weighted according to their distance from the Project (-81.9353W, 47.5506N). Typically, four grid cells are weighted to characterize a point. In this case, due to the proximity of a cell to the Project, only that single grid cell was used. The grid cell located at 47.5625N, -81.9375W was used to calculate both the monthly total precipitation and the average daily temperature for each month of the year for the overlap period and future periods, 2020 (2005 - 2034), 2050 (2035 - 2064) and 2080 (2065 - 2094).

Table 3-2: Downscaled CMIP3 Projections

	SRES Scenario			Total
	a1b	**a2**	**b1**	
GCM	**Number of Runs**			
bccr_bcm2_0	1	1	1	3
cccma_cgcm3_1	5	5	5	15
cnrm_cm3	1	1	1	3
csiro_mk3_0	1	1	1	3
gfdl_cm2_0	1	1	1	3
gfdl_cm2_1	1	1	1	3
giss_model_e_r	2	1	1	4
ilnmcm3_0	1	1	1	3
ipsl_cm4	1	1	1	3
miroc3_2_medres	3	3	3	9
miub_echo_g	3	3	3	9
mpi_echam5	3	3	3	9
mri_cgcm2_3_2a	5	5	5	15
ncar_ccsm3_0	6	4	7	17
ncar_pcm1	4	4	2	10
ukmo_hadcm3	1	1	1	3
Total	39	36	37	112

SRES – Special Report on Emissions Scenarios (IPCC, 2000).
See Table 3 in Appendix C of WCRP (2009) for definition of GCM's in the archive.

Source: LLNL (2011).The results of the adjusted daily data were then processed to find the number of:

- days when the maximum temperature (T_{max}) exceeded 30°C;
- days when T_{max} exceeded 35°C;
- days when the minimum temperature (T_{min}) was less than -20°C;
- days when T_{min} was less than -25°C;
- heat waves (3 or more consecutive days with a T_{max} greater than or equal to 32°C)[3],
- cold waves (3 or more consecutive days with T_{max} less than -10°C)[4];

[3] As defined by Environment Canada (http://www.canadiangeographic.ca/glossary/definition.asp?word=heatwave&id=60)
[4] Environment Canada defines a "Cold Wave" in south central and southwestern Ontario, when minimum temperatures are expected to fall to -20°C or less with maximum temperatures not expected to rise above -10°C

- days with a freeze thaw cycle (# of days when T_{min} was less than 0°C and T_{max} was greater than 0°C); and,
- drought periods (10 or more consecutive days with less than 0.2 mm of precipitation)[5].

For Heat Waves and Cold Waves, 3 - 5 days in a row were considered 1 period, while 6 days in a row was taken to count as 2 periods (of 3 days each). Six to eight days in a row would also count as 2 periods changing into 3 periods in a row on the 9th consecutive day of heat or cold and increasing in the same manner.

The historical period (with no adjustment) was also processed to give a baseline to provide a comparison with the future projection periods.

3.2.3 Study Area Climate Normals

The Project is located in the Boreal Shield Ecozone of Ontario, which is itself characterized by long, cold winters and short, warm summers. Regional EC climate stations indicate climate normals in the range of 800 – 900 mm of total annual precipitation, average temperatures in the range 1.3°C to 3.7°C with minimums occurring in January and maximums in June/July. Winds are generally from the south or southwest during the summer months and from the north and northwest during the winter months. The statistical summaries below, based on the Chapleau weather station climate normals (1971 - 2000) provide a general overview of the Project area climate:

- precipitation[6],
  - average precipitation: 796.6 mm (276.9 mm snowfall / 531.8 mm rainfall),
  - extreme daily rainfall: 82.6 mm (June 1991),
  - extreme daily snowfall: 39.0 cm (March 1900),
  - extreme snow depth: 132 cm (March 1997),
  - rainfall events (with totals >25 mm in one day) generally occur between May and October and average about 3 events per year;
- temperature[7],
  - daily average minimum temperature: -4.2°C,
  - daily average maximum temperature: 7.6°C,
  - extreme minimum temperature: -50.0°C (January 1984),

over a 3 day period. This has been interpreted as 3 or more consecutive days with T_{max} less than -10°C to simplify the analysis using the available data

[5] The term drought has always been difficult to define. Its meanings often differ between individuals, depending on how the water shortages impact on their lives. For the purposes of this study the definition of 10 consecutive days with rain < 0.2mm has been adopted consistent with the drought analysis data presented at the Ontario Hazards website at http://ontario.hazards.ca/maps/background/Drought-e.html

[6] Source: Environment Canada Climate Normals 1971-2000 for the Chapleau weather station, Environment Canada, 2011e

  - extreme maximum temperature: 36.5°C (June 1995);
- frost[7],
  - earliest last spring frost: late May to mid June[8],
  - earliest first autumn frost: early to late September[8],
  - Approximate frost free season: about 80-130 days[8,9].

A complete listing of the climate normals for a number of climate stations (Chapleau, Sudbury and Timmins) located in the region is provided in Appendix D of the EA Report.

3.2.4 Climate Variables for Assessment

A preliminary 'long' list of climate parameters was developed based on perceived relevant climate events and change factors as indicated below:

- high and low temperatures
- heat and cold waves
- freeze thaw cycles
- heavy rain
- daily total rainfall
- winter rain
- freezing rain
- snow accumulation
- blowing snow/blizzards
- lightning
- hurricane/tropical storms
- high winds
- drought/dry periods
- ice storms

The list was then refined to a 'short list' based on climatic and meteorological phenomena deemed relevant to the Project in consultation with the Project Team:

- high and low temperatures
- heat and cold waves
- freeze thaw cycles
- 1-day and 5-day rain
- winter rain
- freezing rain
- drought/dry periods
- snow accumulation
- high winds

The groundwater level across the site is a consideration in the design and operation of the Project. In this context, the potential for climate change to influence groundwater levels was also reviewed.

Justification for selection of a climate parameter was based on the parameter's potential to affect vulnerability to the infrastructure and its components as a result of either an extreme or

[7] Source: http://www.almanac.com/content/frost-chart-canada
[9] Source: http://sis.agr.gc.ca/cansis/publications/maps/cli/250k/agr/cli_250k_agr_41p.pdf

persistent occurrence. Each climate parameter in the short list was assessed in detail to provide historical and future climate parameter probability scores.

3.2.5 Assessment of Climate Variables

3.2.5.1 High Temperatures

Definition

The maximum temperature currently recorded for Chapleau is 36.5°C, which occurred in June of 1995 (TWN, 2013). As a reflection of this recorded high temperature, threshold temperatures of 30°C and 35°C have been selected as representative of the measure of high temperatures for this study. This definition is consistent with other climate change vulnerability assessments (e.g., TRCA, 2010; AMEC, 2012).

Historical Climate

Climate data for Chapleau, obtained from Environment Canada Data Online (Environment Canada, 2013a) for the periods from 1930[8] to 2012, indicate an average of four days per year with temperatures greater than 30°C and an average of 0.2 days per year had temperatures greater than 35°C (see Table 4-3).

Table 3-3: Summary of High Temperature Days

Description	Days/Year			
	Historic[1]	2020[2]	2050[2]	2080[2]
> 30°C	4.0	6.6	11.4	18.6
> 35°C	0.2	0.3	0.5	1.5

Sources: Environment Canada (2013a); WCRP (2009).

Trends

In a study by Zhang et al. (2000), trends in temperature over Canada were analyzed during the 20th century. Specific temperature elements included in the analysis were the minimum, maximum, and mean temperature. For southern Canada, trends were computed for the period 1900 - 1998 and for the rest of Canada for the period 1950 - 1998.

Over southern Canada, the mean annual temperature was found to have increased between 0.5°C and 1.5°C (between 1900 and 1998), with the greatest warming found in the Prairie Provinces. It was found that the change was due largely to warmer overnight temperatures, meaning that the region was becoming less cold but not hotter. The trend in increasing overnight temperatures was statistically significant over all of southern Canada. Even though a positive trend in daytime maximum temperatures was found for southern Ontario, it was not

[8] Data is also available for the Chapleau station between 1886 and 1929, however, the data are sporadic with significant contiguous months of missing data. The period from 1930 to 2012 is considered a sufficient time span to estimate historic occurrence and only minimal data gaps were identified.

statistically significant. Easterling et al. (2000) discuss a similar finding in studies on the trends of temperatures in the United States over the period 1910 - 1998.

Research by the Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR, 2010) focused on data from the Chapleau weather station, illustrated in Figure 4-2, demonstrates varied upward trends in Average Seasonal Maximum temperatures, as well.

Climate Projections

Zwiers and Kharin (1998) performed CO_2 doubling experiments with a GCM in equilibrium mode. A GCM in equilibrium mode simply means that the atmosphere-ocean interface is in equilibrium and is not truly coupled as more recent models are. This study looked at 20-year return values of selected parameters and found that the 20-year return value for maximum temperature increased by approximately 6°C over southern Ontario.

Environment Canada has its own coupled GCM known as the CGCM2 (Canadian Coupled Global Climate Model). The horizontal resolution of the model is approximately 300 km by 400 km. The model has been run for a variety of scenarios over Canada to simulate past and present conditions under increased CO_2 concentrations. Winter temperatures in the vicinity of the Site are predicted to rise 2°C by 2040 and by as much as 5°C by 2100 over the base period of 1971 - 2000. Similar temperature changes are expected to occur during the summer months.

Ouranos (2010) completed a study of the effects of climate change across Ontario using the latest Canadian Regional Climate Model (CRCM; version 4.2.3) output data at 45 km resolution, regarding the geographical distributions and trends of major climate change indicators (e.g. daily mean temperature, annual precipitation and mean snow depth). The analysis was based on the SRES-A2 future emissions scenario (IPCC, 2000). Although the A2 emissions scenario is considered a relatively pessimistic scenario, it still trends lower than what is presently expected in the near term. The results from this study indicate that Mean Daily Maximum Temperatures are anticipated to increase 3 - 4°C and 4 - 5°C, for the periods 2050 and 2080, respectively, when compared with values from the period 1980.

The CCCSN Localizer reporting tool[9] was used to generate future projections of temperature for the Chapleau weather station for a variety of SRES scenarios, as summarised in Table 4-4, for the summer season. There is a clear upward trend for Chapleau across the three scenarios, although these results do not suggest the increases will be as significant as those indicated by the Ouranos (2010) or Environment Canada CGCM2 results.

A specific analysis of occurrence of High Temperature days was completed for this study using the WCRP CMIP3 database for 2020, 2050 and 2080. The results of this analysis are summarized in Table 4-3. It is clear that the trend in High Temperature is upward with numbers of days above 30°C and 35°C, on average, increasing into the future with a marginal increase

[9] Available at http://www.cccsn.ec.gc.ca/index.php?page=main

from historic conditions to the 2020 time frame, but a significant, comparable, increase between the 2020 to 2050, and 2050 to 2080 time frames.

Table 3-4: CCCSN Localizer Report Projections for Summer Temperatures

Period	Mean Summer Daily Temperature (^{o}C) by SRES Scenario (Chapleau Weather Station)		
	SR-A2 / High	SR-A1B / Medium	SR-B1 / Low
1971 - 2000	17.2		
2020's	18.3 ± 0.4	18.4 ± 0.5	18.3 ± 0.5
2050's	19.8 ± 0.8	19.9 ± 0.9	19.1 ± 0.7
2080's	21.6 ± 1.3	20.8 ± 1.2	19.8 ± 0.8

3.2.5.2 Low Temperatures

Definition

The minimum temperature currently recorded for Chapleau is -50.0°C, which occurred in January of 1984 (TWN, 2013). As a reflection of this recorded low temperature, a threshold temperature of -40°C was considered a representative, and the measure of low temperature for this study has been identified as the number of days where the minimum daily temperature was less than -40°C.

Historical Climate

Climate data for Chapleau, obtained from Environment Canada Data Online (Environment Canada, 2013b) for the periods from 1930 to 2012, indicate an average of 1.0 day per year with temperatures less than -40°C, and an average of 0 days per year with temperatures that were less than -50°C (see Table 4-5).

Trends

Osborn (2011) analysed temperature trends in Canada during the last sixty years, concluding that changes are not consistent across Canada. Only during autumn in the extreme south of Ontario and Quebec has there not been any rise or drop in the average temperature since 1948. For most seasons and regions however, the trend since 1948 has been to a warmer climate with increases in average temperatures from 1948 to 2007 of 0.9°C, 1.3°C, 0.8°C and 0.2°C for winter, spring, summer and autumn, respectively, for most of Ontario Quebec, Labrador and north-eastern Manitoba.

Figure 4-3 depicts the upward trend for winter temperature, illustrating that winter temperatures have been at or above normal since 1996/1997. The red dashed linear trend line indicates that winter temperatures have warmed over the last 64 years by about 2.8°C. The *Winter Summary 2010/2011 Climate Trends and Variations Bulletin,* (Environment Canada, 2011) also indicates that of the ten warmest winters recorded, four have occurred within the last decade, and 11 of the last 20 years are listed among the 20 warmest.

Table 3-5: Summary of Low Temperature Days

Description	Days/Year			
	Historic[1]	2020[2]	2050[2]	2080[2]
< -50°C	0	0	0	0
< -40°C	1.0	0.5	0.2	0.1
< -30°C	17.1	13.5	10.6	7.7
< -25°C	33.6	28.7	24.1	19.5
< -20°C	53.9	48.3	42.8	37.1

Sources: Environment Canada (2013a); WCRP (2009).

Climate Projections

Minimum temperatures averaged increases of about 2.7ºC across Ontario for projections over the period 2071 - 2100. Higher minimum temperatures would appear mainly in southern Ontario, while the highest would appear along the shores of the Great Lakes (CSEE, 2010).

Research by the Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR, 2010) focused on data from the Chapleau weather station, illustrated in Figure 4-4, demonstrates varied upward trends in Average Seasonal Minimum temperatures, as well. The trends identified in the seasonal minimum temperatures are consistent with those noted in Figure 4-2 associated with seasonal maximum temperatures.

A specific analysis of Low Temperature was completed for this study using the WCRP CMIP3 database. The results of this analysis are summarized in Table 4-5. It is clear that the trend in Low Temperature is upward with numbers of days below -20°C, -30°C and -40°C, on average, decreasing significantly into the future. However, the general warming trend aside, the Site will still periodically experience very cold temperatures during the winter.

3.2.5.3 Heat Waves

Definition

A heat wave, as defined by Environment Canada, is considered to have occurred when there are three or more consecutive days when the maximum temperature is 32°C or higher. This Environment Canada definition was also used for this study.

Table 3-6: Summary of Heat Waves

Description	Heat Waves/Year			
	Historic[1]	2020[2]	2050[2]	2080[2]
Occurrences of three or more consecutive days when the maximum temperature > 32°C	0.1	0.4	0.5	0.5

Sources: Environment Canada (2013a); WCRP (2009).

Historical Climate

Daily temperature for Chapleau, obtained from Environment Canada's Climate Data Online (Environment Canada, 2013a), was analysed for the occurrence of heat waves from 1930 to 2012. It was determined that in the 83-year period, eleven heat waves had been recorded in Chapleau, an average of 0.1 heat waves per year (11/83).

Trends

The historic assessment of heat waves noted above was used to review trends in heat wave occurrence as outlined in Table 4-7. The results of the data analysis suggest an increase in the frequency of heat waves over the past 30 years.

A assessment of the historic occurrence of days with a maximum temperature of greater than 32°C was also completed. There is a clear upward trend in the annual number of extreme hot days as illustrated in Figure 4-5. The data suggests that with an increasing number of extreme hot days there is a potential for increasing numbers of heat waves (as defined for this study).

Table 3-7 Historic Occurrence of Heat Waves - Chapleau Weather Station

Period	# of Years	# of Days	Average # of Days / Year
1940 - 1970	30	2	0.1
1950 - 1980	30	3	0.1
1960 - 1990	30	3	0.1
1970 - 2000	30	2	0.1
1980 - 2010	30	4	0.1
1990 - 2010	20	3	0.2
2000 - 2010	10	3	0.3

Climate Projections

A specific analysis of Heat Waves was completed using the WCRP CMIP3 database. The results of this analysis are summarized in Table 4-6.

The trend for heat waves in the near term (i.e., 2020) suggests a significant jump from the historic average occurrence. However, as noted in Table 4-7, average annual occurrence of heat waves in recent years (2000 to 2010) is about 0.3 heat waves per year (or about once every three years). The future projection of about 0.4 to 0.5 heat waves per year (or about once every two years) does not represent a significant concern.

3.2.5.4 Cold Waves

Definition

For this study, and to better relate with the definition of a heat wave, a cold wave was considered to be three or more consecutive days with a minimum temperature of -20°C, or colder, and a maximum temperature of -10°C.

Table 3-8: Summary of Cold Waves

Description	Cold Waves/Year			
	Historic[1]	2020[2]	2050[2]	2080[2]
Occurrences of three or more consecutive days with a minimum temperature of -20°C, or colder, and a maximum temperature of -10°C	5.6	4.3	3.2	2.2

Sources: Environment Canada (2013a); WCRP (2009).

Historical Climate

Daily temperature data for Chapleau, obtained from Environment Canada's Climate Data Online (Environment Canada, 2013a), was analysed for the occurrence of cold waves. On average, 5.6 cold waves per year were recorded over the period 1930 to 2012.

Trends

The historic assessment of cold waves noted above was used to review trends in cold wave occurrence as outlined in Table 4-9. This view of cold wave occurrence indicates come consistency in occurrence over the period.

An assessment of the occurrence of days, with a minimum temperature of less than -20°C, was also completed. There is a clear downward trend in the annual number of cold days as illustrated in Figure 4-6. The data suggests that with decreasing number of cold days there is a potential for increasing numbers of cold waves (as defined for this study).

Table 3-9: Historic Occurrence of Cold Waves - Chapleau Weather Station

Period	# of Years	# of Cold Waves	Average # of Cold Waves / Year
1930 - 1960	30	158	5.3
1940 - 1970	30	171	5.7
1950 - 1980	30	169	5.6

1960 - 1990	30	162	5.4
1970 - 2000	30	167	5.6
1980 - 2010	30	168	5.6
1990 - 2010	20	109	5.5
2000 - 2010	10	59	5.9

Climate Projections

A specific analysis of Cold Waves was completed using the WCRP CMIP3 database. The results of this analysis are summarized in Table 4-8. The analysis indicated a downward trend in expectation of cold wave occurrence from the historic range of 5.6 to a projected occurrence in 2808 of 2.2 cold waves per year. As such, extremely cold days are still expected to occur at the Project.

3.2.5.5 Freeze Thaw Cycles

Definition

The average number of days with a maximum daily temperature above 0°C and a minimum temperature below 0°C define a day of freeze thaw conditions.[10]

Table 3-10: Summary of Freeze/Thaw Days

Description	Days/Year			
	Historic[1]	2020[2]	2050[2]	2080[2]
Number of days with a maximum daily temperature above 0°C and a minimum temperature below 0°C	82.2	85.9	83.8	81.7

Sources: Environment Canada (2013a); WCRP (2009).

Historical Climate

Daily temperature data for Chapleau, obtained from Environment Canada's Climate Data Online (Environment Canada, 2013a), was analysed for the occurrence of freeze/thaw days. On average, 82.2 freeze/thaw days per year (see Table 4-10) were recorded over the period 1930 to 2012.

Trends

Historically observed freeze-thaw cycle frequencies for Chapleau for the period 1950 - 2006, based on observed temperatures, are illustrated in Figure 4-7. Analysis of the historical data indicates an upward trend in winter freeze-thaw cycles for Chapleau, a trend that is likely to continue with expected initial winter warming. This is considered a short term phenomena as

[10] Source: http://cccsn.ca/?page=bioc-help

long term annual frequency of freeze/thaw cycles is expected to decline with rising temperature. As illustrated in Figure 4-2 and Figure 4-4 there is a historic upward trend in winter temperatures. The relatively small increases experienced in recent history (see Figure 4-2) have propagated increases in the frequency of freeze thaw days with Chapleau winter temperatures, moving from previously below zero temperatures to the freeze/thaw range.

Climate Projections

A specific analysis of Freeze/Thaw Days was completed using the WCRP CMIP3 database. The results of this analysis are summarized in Table 4-10. The analysis indicated a near term increase in Freeze/Thaw Days with a subsequent decreasing in average occurrence in 2050 and beyond.

3.2.5.6 Precipitation

Design Rainfall in Ontario

Three different rainfall definitions are used for design purposes in Ontario, as outlined below. Each supports different aspects of design and regulation and each have the potential to be influenced differently under anticipated climate change:

- Firstly, stormwater management planning in Ontario is based on Ministry of Environment (MOE) guidelines which direct the use of 2 through 100 year intensity-duration-frequency (IDF) curve based rainfall estimates for design. An IDF curve is a tool that characterizes an area's rainfall pattern. By analyzing past rainfall events, statistics about rainfall re-occurrence can be determined for various standard return periods; for example, the size of rainfall event that statistically occurs every 10 years. For context, the current 24 hour 100 year return period[11] design rainfall for weather stations in the vicinity to the Project; namely, Chapleau, Timmins, and Sudbury is 110.1 mm, 113.9 mm and 98.6 mm, respectively.

  It should be noted that the published IDF relationships are computed for a single station based solely on historical data and do not include any element of trend analysis or climate change projection. The last update of the IDF data for stations across Canada was completed in February 2012.

  The selected design rainfall event for stormwater management at the Project will depend on the type of feature (e.g., culvert, emergency spillway) and the guidelines and legislation associated with the installation of the feature (e.g., Lakes and Rivers Improvement Act).

- Secondly, the Ontario Ministry of Natural Resources (MNR) defines a Regulatory Storm based on a review of all extreme rainfall events in the Province for the purpose of flood plain management. The present definition of the Regulatory Storm, specific to different areas of the Province, is outlined in the Lakes and Rivers Improvement Act (LRIA) as follows:

[11] Source: May 2011 IDF relationships from Environment Canada

- Zone 1: the peak flow resulting from the Hurricane Hazel Storm (using hydrological modelling) or the 100 year flood (based on single event hydrological modelling using the 100 year rainfall as input or a statistical analysis of recorded stream flows to determine the peak flow associated with a 100 year event);
- Zone 2: the 100 year flood; and,
- Zone 3: the peak flow resulting from the Timmins Storm or the 100 year flood, whichever is greater.

The Project is located in Zone 3 for Regulatory Storm definition. The Hurricane Hazel Storm (October 1954) and the Timmins Storm (August 1961) are recorded events with total rainfall volumes of approximately 200 mm over 12 hours.

Currently, the Regulatory Storm is not used as a design basis for infrastructure for this Project. However, the Regulatory Flood will be considered should further detailed engineering suggest that this is potentially a critical storm event.

- Lastly, the World Meteorological Organization defines the Probable Maximum Precipitation (PMP) as “the greatest depth of precipitation for a given duration meteorologically possible for a given size storm area at a particular location at a particular time of year, with no allowance made for long-term climatic trends” (WMO, 1986). It should be noted that the PMP represents a theoretical maximum. The current PMP estimate for Ontario, as defined in the LRIA, is in the range of 405 mm (6 hour event) to 460 mm (48 hour event). The revised draft PMP estimates for Ontario (IBI Group, 2006) define PMP estimates at the Project ranged from about 460 mm (6-hour event) to about 505 mm (24-hour event) and about 520 mm (48-hour event). It should also be noted that, although the revised PMP estimates for Ontario have as yet to be integrated into the LRIA, it is expected that this will occur with a future revision of the LRIA.

The design basis for stormwater management at the Project uses the revised draft PMP estimates for Ontario (MNR 2006).

It is anticipated that the PMP will be used, in the context of the Project development, to evaluate dam safety considerations.

Trends in Design Rainfall – Historic and Projected

Return Period Precipitation

Documenting historical trends in return period precipitation is challenging, but research has revealed a number of complex trends. A literature survey has been conducted and studies suggesting both increase and decreases in rainfall magnitudes have been found. Key studies are summarized below:

- Studies suggesting no change or a decrease in rainfall magnitudes:

- Mekis and Hogg (1999) identified a decrease in the heaviest decile of precipitation events over southern Canada, consistent with evidence identifying lack of precipitation change over this area.
- Stone et al. (2000) found that intermediate and heavy precipitation events remained constant after 1970 in Southeastern Canada, but increased on a seasonal basis in autumn and summer, respectively.
- Zhang et al. (2001) examined the spatial and temporal characteristics of heavy precipitation events for the period 1900 - 1998. At each location examined, an extreme event was defined as a particular precipitation threshold that was only exceeded three times per year. No identifiable trend in either intensity or frequency of extreme precipitation events was found. Precipitation was found to have increased between 5% and 35% in southern Canada, but with most of the increase prior to 1970. Increases in precipitation over the period were mainly due to an increase in the number of small to moderate rainfall events.
- AMEC (2009) notes that while annual precipitation increased in southern Canada over the past century (approximately 12%), it was largely before 1970 when GHGs were less of a concern. Studies show that more complex factors are in play on a seasonal basis. There appears to be a consensus that the heaviest precipitation events are becoming more frequent during the warm season (spring and summer), while becoming less frequent in winter.

- Studies suggesting an <u>increase</u> in rainfall magnitudes:
  - Karl and Knight (1998) found that in the north-eastern United States, including areas adjacent to the Canadian border, a 12% increase in the overall average of the highest daily precipitation amount was identified between 1910 and 1996.
  - Zwiers and Kharin (1998) found that over Canada, 20-year return period precipitation events increased by approximately 14%, or 7 mm. Regions in Canada that were found to have the greatest increase in return period values were Newfoundland, south-western Ontario, and the high north. Note that these are estimates of 20-year precipitation events assuming the amount of carbon dioxide in the atmosphere has doubled (compared to the mid-1990s amount).
  - Studies in regions of the United States closest to Southern Ontario have shown a statistically significant increase in the frequency (22%) of extreme precipitation events between 1931 and 1996 (Kunkel et al., 1999).
  - Easterling et al. (2000) discuss the likelihood of a variety of extremes in weather on a global basis due to global warming from an in-depth review of published literature. On a global scale, the literature indicates a very likely possibility of heavier 1-day precipitation events and more heavy multi-day precipitation events by the end of the 21st century.
  - The modelling by Kharin and Zwiers (2005) predicts that current 20-year return period events in North America are likely to become approximately 10-year return period events by the end of the 21st century.

- Coulibaly and Shi (2005) documented study results indicating strong and significant increases for two separate regions in Ontario (about 24% and 35% in average) in the rainfall intensity by the 2050s and 2080s, respectively. It was found that rainfall intensities with X-year return period under current climate conditions are almost equal to those with (X/2)-year return period under predicted climate conditions. As an example, it was shown that actual 10-year stormwater infrastructure will be able to withstand only 5-year storms by the 2050s, whereas a current 50-year stormwater infrastructure will be able to handle only 20-year storms by the 2050s.
- Kharin et al. (2007) project an increase in the 20-year return values of annual extremes of 24-hour precipitation rates for Southern Ontario to be 5% - 10% and 10% - 15% for periods 2046 - 2065 and 2081 - 2100, respectively.
- The City of Toronto has experienced eight 25-year storms in the period 2000 through 2010, with several of those ranging between the 25 and 50-year storm range and one being a 100-year storm (City of Toronto, 2010).
- Cheng et al. (2011a) project possible changes in the frequency of daily rainfall events late in this century for four selected river basins in Southern Ontario. They note that annual maximum 3-day accumulated rainfall totals are projected to increase by 20% – 50%, 30% – 55%, and 25% – 60% for the periods 2001 – 2050, 2026 – 2075, and 2051 – 2100, respectively. The projected increases were noted to be two to four times greater than the modeling uncertainties.
- The Institute for Catastrophic Loss Reduction (ICLR, 2011) performed a review of climate trends and projected values for Canada over the period 2010 to 2050. The review indicates increases in total rainfall and an increase in the frequency of current return period events is also anticipated in the future.
- A study completed for the City of Welland, Ontario showed that increases in the volume of rainfall and intensity are anticipated for the municipality (AMEC, 2012). The more frequent events (2-, 5-year) were anticipated to change more significantly than the less frequent (25-, 50-, 100-year) events.

Probable Maximum Precipitation (PMP)

A literature survey has been conducted and studies suggesting both increase and decreases in PMP magnitudes have been found. Key studies are summarized below.

- Studies suggesting no change or a decrease in PMP magnitudes:
  - The Bureau of Meteorology of the Australian Government (Jakob et al., 2009) conducted a 2-year study to investigate potential effects of climate change on estimates of PMP. The authors note that PMP estimates are not typically based on single outliers, and are thus robust estimates; at the present time, it could not be definitively confirmed that PMP estimates will increase under a changing climate.
  - Collier (2009) makes an interim conclusion that as the climate warms, current estimates of PMP in the United Kingdom will likely remain valid. However, it is further noted that detailed analysis is needed to confirm this conclusion.

- Alberta Transportation (2004) concluded that “there is no solid basis for increasing [PMP] estimates based on historical data in order to account for climate change.”

- Studies suggesting an <u>increase</u> in PMP magnitudes:
  - Global Climate Models show an increased northward transport of moisture from the tropics and some models also show an increase in the amount of precipitation for the most extreme precipitation events over southern Ontario (AMEC , 2009).
  - Easterling and Kunkel (2011) indicate in a subsequent study that initial results from global and regional climate model simulations strongly indicate the possibility for large future increases in maximum moisture, by about the same amount as increases in mean moisture content. This would lead directly to substantial increases in PMP values (as much as 10% - 50% increase in a simulation performed for central Illinois corresponding to temperatures increases of 1.5°C - 7.5°C by the end of this century).
  - Schreiner and Riedel (1978) describe that PMP estimates are calculated by maximizing the output of precipitation events even if they are meteorologically impossible. This is performed by scaling the observed precipitation relative to the maximum available moisture in the atmosphere.
  - It can be inferred from Schreiner and Reidel’s work that if the atmosphere warms as expected, the amount of available moisture in the atmosphere must also increase due to the increased saturation vapour pressure and increased rates of evaporation. Therefore, in future PMP studies, the storms are likely to be maximized to greater extents than in past studies and future PMP estimates will increase. It should be noted that this increase is a function of how a PMP is calculated and not necessarily a true reflection of future storms as those storms may not actually be more severe (in a given area or region) in the future.

The availability of literature focused on the subject of anticipated climate change influences on PMP is very limited. The message from the literature review as a whole is mixed. No certain relationship can be established between warmer temperatures and the maximum available moisture in the atmosphere without further study into the issues regarding the specific geographical area, the amount of expected warming and where that warming occurs (to name a few factors). Thus, an estimate of future PMP values cannot be made at this time.

<u>Rainfall Surrogates</u>

As noted previously, three categories of design rainfall are used in Ontario, namely:

- return period rainfall;
- regional storms; and
- probable maximum precipitation.

Also discussed above:

- climate change influences have the potential to affect estimates of return period rainfall;
- regional storms are not being used in the assessment for design of infrastructure for the Project; and,
- there is presently no basis upon which to change current PMP estimates to reflect potential climate change influences.

The development of a projected IDF relationship is considered beyond the scope of the present assessment. As such, a review of readily available rainfall variables is provided below which documents anticipated changes to the nature of rainfall for the Project. The rainfall variables reviewed are:

- 1-Day Total Rainfall;
- 5-Day Total Rainfall; and
- winter rainfall.

3.2.5.7 1-Day Total Rainfall

Definition

Heavy rainfall warnings are issued by Environment Canada when more than 50 mm of rain is expected in a 12-hour period. However, for the purpose of this study, heavy rain conditions were considered when 50 mm of rain (or more) was recorded in one day, as this data was more accessible and is still considered to represent an extreme rainfall event. It should be noted that for the purposes of this assessment rain occurring in one day is consider analogous to 24-hour rainfall.

This definition of heavy rain represents (approximately) a 24-hour 2-year design rainfall event as defined from the Environment Canada 2011 IDF data for Chapleau (gauge # 6061361). Similarly, 50 mm of rain in a 12 hour period would represent approximately a design rainfall greater than two years and less than five years.

Table 3-11: Summary of 1-Day Total Rainfall

Description	Days/Year			
	Historic[1]	2020[2]	2050[2]	2080[2]
Number of days with rainfall >= 50 mm	0.33	0.36	0.38	0.43

Sources: Environment Canada (2013a); WCRP, 2009.

Historical Climate

Daily precipitation data for Chapleau was obtained from Environment Canada Data Online (Environment Canada, 2013a) and analysed for the occurrence of heavy rain from 1971 to 2000. A total of 10 heavy rainfall events, as defined above, occurred in the 30-year period resulting in a frequency of occurrence of 0.33 (10/30) (see Table 4-11). A secondary assessment was also completed using the Environment Canada CDCD Extract program database and analysed for the occurrence of heavy rain over the period 1930 to 2012. A total of 24 heavy rainfall events were recorded for the 83-year period resulting in a frequency of occurrence of 0.29 (24/83), which approximates a 3-year return period event but which is only significantly different from the 1971 to 2000 period. Similarly, a frequency of occurrence of 0.30 was experienced over the period 2000 to 2010.

The maximum daily rainfall recorded for Chapleau was 182.2 mm on September 1, 1999 (Environment Canada, 2013a).

Trends

Zhang and Burn (2009) completed a trend analysis on extreme precipitation data for stations near London, Ontario for the periods of 1974 to 2003, 1969 to 2003 and 1964 to 2003. It was concluded that the 40 year period had no significant trends, the 35 year period had a few positive trends and the 30 year period showed a number of negative trends.

The former Atmospheric Hazards – Ontario Region website offered the following trend information for Chapleau:

- the trend in the 'Number of Days with ≥ 95th Percentile Rainfall[12]' showed a non-significant increase (Vincent and Mekis, 2006);
- the trend in the 'Single Day Intensity Index for Rain (ratio of annual total rainfall to number of days with rain)' showed a non-significant decrease (Vincent and Mekis, 2006);
- the trend in the 'Highest 1 Day Rainfall' showed a non-significant increase (Vincent and Mekis, 2001 and 2006); and
- the trend in the 'Number of Days with Precipitation ≥ 20 mm' showed a non-significant increase (Vincent and Mekis, 2006).

Research by the Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR, 2010) focused on data from the Chapleau weather station, illustrated in Figure 4-8, and demonstrates varied upward trends in Annual and Seasonal Precipitation for summer, fall and spring. However, average winter precipitation is decreasing.

Climate Projections

A specific analysis of 1-Day Total Rainfall was completed using the WCRP CMIP3 database. The results of this analysis are summarized in Table 4-11.

[12] 95th Percentile Rainfall represents about 24mm (Atmospheric Hazards – Ontario Region website)

The trend for 1-Day Total Rainfall in the near term (i.e., 2020) suggests a steady increase from the historic average occurrence and through the mid-term (i.e., 2050) and long terms (i.e., 2080). However, as noted in Table 4-11, average annual occurrence of 1-Day Total Rainfall in recent years (2000 to 2010) is about 0.3 (or about once every three years). The future projection of about 0.43 heavy rainfall events per year (or about once every two years) does not represent a significant concern.

The ‘Localizer’ reporting tool now available at the CCCSN website (and CCCSN 2009) is a quick way of determining the multi-model mean projected change of temperature and precipitation on a monthly, seasonal and annual timescales for locations across Canada. The Localizer uses the climatology of an observation station for the period of 1971 - 2000 as the baseline climate in all cases. The model projected changes for the period 1971 - 2000 and the future time periods (2020s, 2050s and 2080s) are then added to the observed baseline. This results in a projected future scenario which is 'bias-corrected' to the location.

IPCC recognized climate model outputs available on the CCCSN for the grid cell encompassing the study area, project increases in annual precipitation for the Gogama area (CCCSN, 2009) as summarized in Table 4-12 (based on data from the weather station at Timmins Airport (#6078285). Increases in seasonal precipitation are also expected for the winter and spring, with significant increases further into the future. Projected increases for the 2050 time frame are very sensitive to the base ensemble, but point to potential significant increases in total precipitation over the winter and spring, and decreases in total precipitation over the summer months in some cases.

Table 3-12: Summary of Total Precipitation for Gogama

Time Period/ SRES Scenario	Total Precipitation (mm)				
	Annual	Winter	Spring	Summer	Autumn
1971 - 2000	833.0	151.9	181.4	264.0	235.8
SR-B1 (Low)					
2020’s	862.1 ± 25.7	162.0 ± 7.6	193.0 ± 9.9	265.1 ± 16.1	241.2 ± 12.0
2050’s	883.6 ± 43.9	167.6 ± 8.8	201.2 ± 11.8	268.5 ± 27.3	245.2 ± 16.8
2080’s	898.3 ± 29.3	173.8 ± 8.7	206.1 ± 12.5	266.7 ± 18.1	248.6 ± 13.7
SR-A1B (Medium)					
2020s	868.5 ± 29.9	162.5 ± 7.1	193.6 ± 10.1	269.0 ± 15.6	242.9 ± 16.2
2050s	897.5 ± 37.8	171.4 ± 10.6	204.6 ± 15.6	267.5 ± 23.1	252.3 ± 16.1
2080s	921.0 ± 48.7	177.9 ± 13.5	217.5 ± 19.8	265.1 ± 32.5	257.4 ± 19.5
SR-A2 (High)					
2020s	865.7 ± 26.7	159.5± 5.6	194.9 ± 12.8	268.8 ± 12.2	241.4 ± 15.0
2050s	897.7 ± 33.8	173.9 ± 9.0	205.1 ± 13.2	262.6 ± 19.3	252.2 ± 15.5
2080s	932.6 ± 62.3	187.4 ± 13.9	224.1 ± 25.7	257.1 ± 37.2	259.1 ± 23.9

Source: CCCSN Website.

The CCCSN has produced a summary of findings from the most recent IPCC AR4 (2007) modelling assessment for Canada[13]. Twenty-four international modelling centres have contributed to the international dataset. The output used in this analysis is a mean ensemble from all available international modelling centres, although not all centres have produced runs for all emission scenarios. Results for the grid in which the Project is located are summarized in Table 4-13. The two sets of results are consistent in suggesting that precipitation in the summer months will not change significantly, will only increase marginally in the fall months, but will increase significantly in the winter and spring.

Again, it should be noted that annual average rainfall and heavy rainfall (as defined for this analysis) are not the same; nonetheless, the expectation of increased seasonal rainfall in the future suggests the potential for more extreme rainfall events, particularly in the winter and spring.

Table 3-13: Projected Changes in Precipitation

Time Period	Change in Total Precipitation (%)				
	Annual	**Winter**	**Spring**	**Summer**	**Autumn**
National AR4-A1B Ensemble Seasonal and Annual Precipitation Change (1971 - 2000 base line)					
2020's	4.1	7.0	6.5	1.8	2.5
2050's	7.6	12.8	12.5	1.3	6.7
2080's	10.5	17.6	19.5	0.5	8.7

[13] Available at http://www.cccsn.ec.gc.ca/index.php?page=ensemblescenarios

Time Period	Change in Total Precipitation (%)				
	Annual	Winter	Spring	Summer	Autumn
2050s Ensemble Seasonal and Annual Precipitation Change (1961-1990 base line)					
Low	5.9	10.5	10.8	1.0	4.4
Medium	6.5	11.9	11.5	0.5	5.3
High	7.0	13.0	11.8	0.5	5.8
CRCM[1]High	12 to 14	25 to 30	25 to 30	10 to 15	0 to 5

CRCM – Canadian Regional Climate Model
Source: CCCSN Website.

3.2.5.8 5-Day Total Rainfall

Definition

Heavy 5-day rainfall was defined as a total rainfall exceeding 100 mm in a five day period. The period of rainfall was chosen to be consistent with other rainfall research (as referenced below) and to be reflective of a prolonged rain period. The volume of rainfall was chosen subjectively to represent a substantial amount of rainfall in a relatively short period of time.

Table 3-14: Summary of 5-Day Total Rain

Description	Days/Year			
	Historic[1]	2020[2]	2050[2]	2080[2]
Number of 5 day periods with rainfall >= 100 mm	0.19	0.19	0.25	0.31

Sources: Environment Canada (2013a); WCRP (2009).

Historical Climate

Daily precipitation data for Chapleau was obtained from Environment Canada Data Online (Environment Canada, 2013a) and analysed for the occurrence of 5-day total rain from 1971 to 2000. A total of 7 heavy rainfall events, as defined above, occurred in the 30-year period resulting in a frequency of occurrence of 0.23 (7/30). A secondary assessment was also completed using the Environment Canada CDCD Extract program database and analysed for the occurrence of 5-day total rain over the period 1930 to 2012. A total of 16 heavy rainfall events were recorded for the 83-year period, resulting in a frequency of occurrence of 0.19 (16/83) (see Table 4-14). No 5-day total heavy rain events, as defined for this assessment, were experienced over the period 2000 to 2010.

Trends

An analysis of Ontario rainfall data for the period 1950-2003 was completed focusing on identifying trends for highest 5-day rainfall (Klaassen and Comer, 2005). It was concluded that the highest 5-day rainfall does not show any consistent pattern of changes over the period of analysis.

Climate Projections

Vincent and Mekis (2004) showed a significant decrease in the intensity of rain (ratio between annual total rainfall and the number of days with rain) in southern Canada from 1950 to 2001, however concluded that there were no consistent changes in the highest 5-day maximum rainfall. A subsequent study by Vincent and Mekis (2006) supported this finding and showed that the number of days with rain increased from 1950 to 2003 throughout southern Canada. They also found a decrease in the intensity of rain.

Information regarding rainfall which has been presented thus far suggests more rain over the year and more days with rain annually. From this information an upward trend for 5-day rainfall into the future can be postulated.

3.2.5.9 Winter Rainfall

Definition

Winter rainfall is defined as the number of days with total rainfall greater than 25 mm during the months of January, February and March in a given year. Environment Canada issues a winter rainfall warning when 25 mm or more of rainfall is anticipated within a 24-hour period when the ground is frozen or snow covered. It was assumed for the purposes of this study that frozen or snow covered ground would most likely occur in January, February or March. Rainfall on frozen ground has the potential to result in significantly greater runoff conditions than during other seasons and has therefore been considered separately for this assessment.

Historical Climate

Daily precipitation data for Chapleau was obtained from Environment Canada Data Online (Environment Canada, 2013a) and analysed for the occurrence winter rain from 1971 to 2000. No winter rainfall events, as defined above, occurred in the 30-year period resulting in a frequency of occurrence of zero (see Table 4-15). A secondary assessment was also completed using the Environment Canada CDCD Extract program database and analysed for the occurrence of 5-day total rain over the period 1930 to 2012. A total of 1 winter rainfall event, which occurred in mid March 1942, was recorded for the 83-year period resulting in a frequency of occurrence of 0.01 (1/83; see Table 4-15).

Table 3-15: Summary of Winter Rainfall

Description	Days/Year			
	Historic[1]	2020[2]	2050[2]	2080[2]
Number of winter days with rainfall >= 25 mm	0.01	0.02	0.03	0.05

Sources: Environment Canada (2013a); WCRP (2009).

Trends

The climate has been becoming gradually wetter and warmer in southern Canada throughout the entire past century, and in all of Canada during the latter half of the century (Zhang et al., 2000).

Annual total precipitation has increased by an average of 12% in southern Canada over the past century generally associated with more rain during the spring, summer and autumn. However, the ratio of snowfall to total precipitation has been decreasing in the winter and spring in distinct areas of the country. As illustrated in Figure 4-9, there was no discernable trend identified in the change from spring snow to rain for the Chapleau area for the period 1950 - 1999. (Barrow et al., 2004).

Climate Projections

A specific analysis of Winter Rain was completed using the WCRP CMIP3 database. The results of this analysis are summarized in Table 4-15. The analysis indicated a trend of increasing frequency of winter rain although the change is considered marginal in the context of potential impacts to the Project.

3.2.5.10 Freezing Rain

Definition

Freezing rain is rain that falls as liquid but then freezes on contact with the ground and other exposed objects to form a coating of ice on these surfaces[14]. Freezing rain days for this study have been identified as a day with freezing precipitation if there is an occurrence of 0.2 mm or more of rain or drizzle, which turns to ice on contact with the underlying surface. This is consistent with the definition used by Environment Canada.

Historical Climate

Climate normal data for the period 1951-1980 and 1961-1990 were obtained from Environment Canada with specific interest in the "days with freezing precipitation" data. For the period 1951 - 1980 an average of about 10 to 20 days with freezing precipitation were recorded. For the period 1961 - 1990 an average of about 19 days with freezing precipitation were recorded.

Environment Canada's Ontario Hazards website provided freezing precipitation data for major recording centers with 24 hour recording capability (Icestorm-Dayswithfrzprecip-e.xls). Hourly data is not recorded for Chapleau, therefore freezing precipitation data was downloaded for the closest recorded locations, namely; Sudbury, Timmins and Sault Ste Marie. The database reports 8.7 days per year with freezing precipitation at Sault Ste Marie, 18.1 days per year at Sudbury and 17.8 days per year at Timmins.

[14] http://canadaonline.about.com/od/weather/g/freezingrain.htm

Trends

In 2003, the Meteorological Service of Canada, Atmospheric Sciences Division-Ontario Region, completed a severe ice storm risks study for south-central Canada (Klaassen et al., 2003). One of the objectives of the research was to determine whether or not there was an increase or decrease in the total number of seasonal freezing rain hours and days observed at a number of sites in Ontario and Quebec station over the period of November to April 1953/54 - 2000/01. The closest stations to Chapleau used in the study were Sault Ste. Marie, Timmins and Sudbury. The results of the trend analysis suggests that the risks of freezing rain occurrence have remained relatively the same or have been slightly decreasing in north-western Ontario, southern Ontario and central Ontario during the period 1953 - 2001.

Climate Projections

Cheng et al. (2007, 2011b) analysed the possible impacts of climate change on freezing rain in south-central Canada using downscaled future climate scenarios. It was concluded that in the coldest months, eastern Canada could potentially receive more freezing rain events in the future than was experienced during the period 1958 - 2007. The increase in the number of daily freezing rain events could be progressively greater from south to north or from southwest to northeast across eastern Canada. The southern region (Region 1), in which the Project is located, showed the potential average increases for severe freezing rain events (≥6 hours per day) to be about 57% and 97% over the historic period for 2050 and 2080, respectively.

3.2.5.11 Drought/Dry Periods

Definition

A meteorological drought is defined in terms of a “significant precipitation departure from normal over a prolonged period” (Klaassen, 2002). To be considered measurable rainfall, 0.2 mm or more must occur before a "day with" is counted. For this study, a drought/dry period was defined as 10 or more consecutive days without measurable precipitation. The 10-day period was defined subjectively.

Historical Climate

Daily precipitation data for Chapleau was obtained from Environment Canada Data Online (Environment Canada, 2013a) and analysed for the occurrence winter rain from 1971 to 2000. Seventy-two drought events, as defined above, occurred in the 30-year period resulting in a frequency of occurrence of 2.4. A secondary assessment was also completed using the Environment Canada CDCD Extract program database and analysed for the occurrence of droughts over the period 1930 to 2012. A total of 205 drought events were recorded for the 83-year period resulting in a frequency of occurrence of 2.5 (205/83) essentially unchanged from the 1971 to 2000 period.

Drought periods lasted from 10 to 25 days and occurred in all months of the year with more frequent occurrence of drought events in March, April and May (see Table 4-16).

Table 3-16: Historic Drought Period Occurrence (1930 – 2012)

Duration (Consecutive Days)	Occurrence by Duration
10	49
11	48
12	28
13	21
14	14
15	14
16	5
17	8
18	7
19	-
20	1
21	3
22	4
23	1
24	1
25	1
26	-
27	-
28	-
29	-
30	-

Month	Occurrence by Month
January	11
February	12
March	28
April	42
May	30
June	12
July	18
August	12
September	5
October	13
November	12
December	10

Trends

Vincent and Mekis (2004, 2005) reported a significant negative trend for the maximum number of consecutive dry days over the period 1900 - 2001. Their statistical analyses showed 51 stations with a significant downward trend for consecutive dry days over the period 1900 - 2001 (23 with no significant trend and 0 with an upward trend). Over the period 1950 - 2001, 35 stations showed a non-significant downward trend, 198 showed no trend and 4 showed a non-significant upward trend. No information for specific stations was provided in their reporting.

Climate Projections

The majority of GCMs indicate major continental dryness in the future for North America (Barrow et al, 2004) and southern Ontario may experience more frequent and more intense droughts during the 21st century (Klaassen, 2002).

3.2.5.12 Snow Accumulation

Definition

For the purposes of this study, snow accumulation is defined subjectively as the number days per year when a snow depth of 25 cm or more is on the ground. The value of 25 cm was chosen subjectively.

Historical Climate

An assessment of historic snow accumulation for Chapleau was completed using data from the Environment Canada CDCD Extract program database for the period 1997 to 2012 (the available data record for snow data). An examination of the data indicated the following:

- the earliest snow occurred on October 5;
- the latest snow occurred on May 27;
- snow accumulation is generally experienced between mid November and mid April;
- the greatest recorded depth of snow was 132 cm;
- snow on the ground can be expected about 42% of the year on average;
- 96% of the time when snow is recorded, the depth is less than 75 cm;
- 72% of the time when snow is recorded, the depth is less than 50 cm;
- about 40% of the time when snow is recorded, the depth is less than 25 cm; and
- the historical average number of days with snow greater than 25 cm is 97.

Trends

Figure 4-10 illustrates a number of metrics related to historical snow data for Chapleau. As can be seen, the historical data suggest a downward trend for each of the metrics illustrated.

A study of Canadian regional snow cover trends for various regions of Canada was completed by the Canadian Cryospheric Information Network for the period 1955/56 to 2002/03 (CCIN, 2011). The regional snow cover series for the study were generated from in situ daily snow depth observations at stations with at least 38 years data in the period since 1955. Table 4-17 provides a summary of snow depth data for Southern Ontario and Quebec documenting a shorter snow season and a decreasing trend in snow depth.

Climate Projections

Projections of warmer temperatures are consistent with observed historic trends in the Chapleau region, where the frost-free period has lengthened and total annual snowfall has decreased. Climate projections for northern Ontario indicate less reliable snow conditions, more rain and less snow (OCCIAR, 2010). Projected increasing cold season temperatures may suggest the historic decreasing snow depth trend will continue.

Table 3-17: Summary of Snow Depth Trends in Ontario

# of Stations	Start Date of Continuous Snow[1]	End Date of Continuous Snow[2]	Snow Cover Days[3]	
			Aug-Jan	Feb-Jul
17	0.18 day/yr	-0.06 day/yr	-0.13 day/yr	-0.18 day/yr

Total SCD[4]	Max Snow Depth[5]	Date of Max Snow Depth[6]	Mean Snow Depth[7]
-0.31 day/yr	-0.12 cm/yr	-0.23 day/yr	-1.26 cm/yr

[1]Date when there were 14 consecutive days with daily snow depth greater-than-or-equal to 4 cm
[2]Date when there were 14 consecutive days with daily snow depth less than 4 cm
[3]Number of days with a daily snow depth greater-than-or-equal to 2 cm
[4]Number of days in the snow cover year with daily snow depth greater-than-or-equal to 2 cm
[5]Maximum daily snow depth during period of continuous snow cover
[6]Date corresponding to maximum reported daily snow depth for snow season
[7]Mean daily snow depth during period of continuous snow cover
Source: CCIN (2011).

3.2.5.13 High Winds

Definition

Wind warnings are issued in Ontario by Environment Canada when sustained winds of 70 km/h or more and/or gusts to 90 km/h or more are anticipated[15].

Historical Climate

Daily data downloaded from Environment Canada's Data Online (Environment Canada, 2013a) website did not consistently report daily wind speeds for Chapleau for the entire period of record. Wind data including both maximum gust speed and direction, were available for the period 1997 through 2008. This data is summarized in Figure 4-11 and suggests that winds originated over a range of directions from north to south, on the western hemisphere, but with the predominant direction being from the south-west.

The maximum gust speed recorded at Chapleau was 89 kph.

Trends

No trend information for high wind was identified.

[15] http://www.ec.gc.ca/meteo-weather/default.asp?lang=En&n=D9553AB5-1#wind

Climate Projections

No projection information for high wind was identified.

3.2.5.14 Climate Parameters Summary

A summary of the historical and future climate parameter probability scores is provided in Table 4-18. Seven parameters (high temperature, heat waves, freeze thaw cycles, 1-day and 5-day rain, winter rain, freezing rain, drought/dry periods) have been identified with increasing probability moving into the future and three winter related parameters (low temperatures, cold waves, snow accumulation) have been identified with decreased probability, primarily related to the anticipation of rising temperatures. Of particular interest are increases in the rain related parameters which could have a direct impact on performance of the subject infrastructure.

Table 3-18: Climate Parameters Summary

Climate Parameter		Historic	Anticipated Changes		
			Future		
			2020	2050	2080
Increasing					
High Temperatures	Days with maximum temperature > 30°C	4.0	6.6	11.4	18.6
	Days with maximum temperature > 35°C	0.2	0.3	0.5	1.5
Heat Wave	Occurrences of 3 or more consecutive days when the maximum temperature > 32°C	0.1	0.4	0.5	0.5
Freeze Thaw Days	Number of days with a maximum daily temperature above 0°C and a minimum temperature below 0°C	82.2	85.9	83.8	81.7
1-day Total Rain	Days with rainfall >= 50 mm	0.33	0.36	0.38	0.43
5-day Total Rain	Number of 5 day periods with rainfall >= 100 mm	0.19	0.19	0.25	0.31
Winter Rain	Number of winter days with rainfall >= 25 mm	0.01	0.02	0.03	0.05
Freezing Rain	Days with 0.2 mm or more of rain or drizzle which turns to ice on contact with the underlying surface	18	n/a	27	36
Drought/Dry Periods	10 or more consecutive days without measurable precipitation	2.5	Data were not available for quantitative projections of future droughts. However, the majority of GCMs indicate major continental dryness in the future for North America and southern Ontario may experience more frequent and more intense droughts during the 21st century.		

Climate Parameter		Historic	Anticipated Changes Future 2020	2050	2080
Decreasing					
Snow Accumulation	Number days per year when a snow depth of 25 cm or more is on the ground	97	Data were not available for quantitative projections of future snow accumulation. However, if historical trends continue it is expected that snow accumulation will decrease into the future.		
Cold Waves	Occurrences of three or more consecutive days with a minimum temperature of -20°C, or colder, and a maximum temperature of -10°C	5.6	4.3	3.2	2.2
Low Temperatures	Days with minimum temperature < -50°C	0	0	0	0
	Days with minimum temperature < -40°C	1.0	0.5	0.2	0.1
	Days with minimum temperature < -30°C	17.1	13.5	10.6	7.7
	Days with minimum temperature < -25°C	33.6	28.7	24.1	19.5
	Days with minimum temperature < -20°C	53.9	48.3	42.8	37.1
Unchanged / Data not available					
High Winds	Days with gusts of 90 kph or greater	0	Data were not available for quantitative projections of future wind.		

3.2.6 Other Climate Change Issues

3.2.6.1 Potential Influences on Groundwater

It is anticipated that climate change will alter the demands placed on, and the availability of, linked groundwater and surface-water resources in Canada, although the ultimate effects of climate change on the distribution of water in Canada are highly uncertain (CCA, 2009). As noted in IPCC (2007) a lack of definitive studies on the relationship between climate change and groundwater resources provides no basis for specific groundwater conclusions for northern temperate zones.

As noted previously, it is anticipated that climate change will result in a longer snow-free season which will in turn produce a combination of greater seasonal evaporation and potentially increased infiltration because of a shorter period of frozen ground. Further, changes in the seasonal patterns of snowfall and rain, especially less frequent summer showers and longer inter-event dry periods, coupled with increased evaporation due to higher temperatures, may reduce the infiltration of surface water into groundwater systems in the summer. The overall result is a situation which may alter ecosystems dependent on the baseflow discharge of groundwater and may result more generally in lower water tables, causing lower surface water levels toward the end of the summer (EPCCA, 2009).

3.2.6.2 Potential Influences on Fish Communities

The following has been reproduced from AMEC (2006):

"Fish communities and the aquatic ecosystems which support them are potentially influenced by two primary climate factors: temperature and precipitation. Changes in air temperature will influence seasonal water temperatures, thermal stratification of the water column, dissolved oxygen levels in some areas, stream temperatures, especially during the critical summer low flow period, and the extent and duration of winter ice cover. Changes in precipitation quantities and storm events will influence water levels in the lakes, which can be critical in wetland habitats, as well as stream flows and resulting stream morphology.

We know that natural ecosystems, both aquatic and terrestrial, exhibit high levels of complexity in the relationships between species, and all physical, chemical and biological components of their environment. Because of this, the effects of physical habitat changes, such as seasonal water temperatures or water levels, can have either direct effects on fish species and communities, or more subtle indirect effects such as through food chains or reproductive systems."

In 2012, the Wildlife Conservation Society Canada (WCSC) brought together 33 participants from provincial government ministries, First Nations communities, research organizations, and academic institutions together to share and synthesize information about the potential impacts of climate change on freshwater fish in the far north of Ontario (WSCS, 2012). The comments below represent some of the discussion from this workshop:

- coldwater fish will generally experience losses in habitat and certain coldwater species (e.g., lake trout) will be more vulnerable than other coldwater fish species;
- within coldwater fish guilds, research has shown that lake trout have a more fixed physiological limit and cannot tolerate warmer temperatures, whereas brook trout may have greater adaptive capacity;
- coldwater species will be more vulnerable in shallow lakes and rivers and areas without groundwater input and less vulnerable in aquatic ecosystems that are deeper and have groundwater input;
- cool-water species may benefit either way with limitations affected by competition and predation with warm-water species as they expand their range;
- warm-water fish will benefit from increased thermal habitats in the north;
- under various emissions scenarios, the northern range boundary of warm-water and cool-water fish is predicted to expand north and the southern range boundary of coldwater fish will contract north;

- suitable habitat for smallmouth bass is expanding north due to climate change and predicted to be throughout most of Ontario by 2050;
- based on MNR's species presence data from 10,000 lakes in the 1970s and 1980s, and sampled again in the 2000s, there is evidence that smallmouth bass have expanded northward, but there was no evidence of range contraction by coldwater fish;
- warm- and cool-water fish have been shifting their ranges northward while coldwater fish have not shifted their range. Many bait fish show signs of contracting their southern ranges northward; and
- eleven of eighteen fish species surveyed shifted their ranges north by approximately 17.5 kilometres per decade. This rate is similar to those recorded for northward shifts by butterflies, birds, and other animals.

4.0 RISK ASSESSMENT

4.1 Overview

The risk assessment focused on the identification of Project infrastructure which is likely to be sensitive to changes in specific climate parameters. This step focused on qualitative assessments based on professional judgment and experience to determine the likely effect of individual climate events on Project infrastructure.

4.2 Risk Assessment Results

4.2.1 Methodology

In establishing conceivable performance responses, this assessment considered the most likely response(s) of an infrastructure or infrastructure component to contemplated climate events based on professional judgment and experience. The following was used to provide guidance for establishing potential interactions between Project infrastructure and climate. For example, would or could any of the following issues be affected by the anticipated changes in a climate variable:

- structural design;
  - safety
    - load carrying capacity
    - overturning
    - sliding
    - fracture
    - fatigue
    - serviceability
  - deflection
    - permanent deformation
    - cracking and deterioration,
    - vibration
  - foundation design considerations
- infrastructure functionality;
  - level of effective capacity (short, medium, long-term)
  - equipment (component selection, design, process and capacity considerations)
- infrastructure performance;
  - level of service, serviceability, reliability
  - materials performance
- watershed, surface water and groundwater;
  - erosion along watercourses
  - erosion scour of associated/supporting earthworks

  - sediment transport and sedimentation
  - channel re-alignment / meandering
  - change in water quantity or quality
  - change in water resources demands
  - change in groundwater recharge
  - change in thermal characteristics of water resource
- operations and/or maintenance;
  - structural aspects
  - equipment aspects
  - functionality and effective capacity
- emergency response;
  - storm, flood, ice, water damage
- insurance considerations;
- social effects; and
- economic considerations.

4.2.2 Potential Climate Change / Project Interactions

The Project interaction matrix was used as the basis for the high level assessment of Project infrastructure and operational components with the projected climate phenomenon/variables. The screening effort to identify potential interactions is summarized in Table 5-1. As can be seen from the information presented in Table 5-1, climate change has the potential to affect the majority of Project elements across all three phases, namely; construction, operations and closure. However, it can be surmised that the more prominent effects may be seen into the 2030's and beyond through the late stages of Project operations and then during closure.

Of particular interest is precipitation for which individual storms are projected to increase in intensity and total volume of rain. However, this is not considered to be a concern since Project drainage infrastructure will be designed to accommodate these predicted increases. As noted previously, current research does not provide a basis for increasing Ontario PMP estimates from current design total rainfall volumes. However, consideration of climate change impacts will be included in establishing associated estimates of these parameters for design purposes.

Table 4-1: Summary of Potential Climate Change to Project Interactions

MINING COMPONENTS	FEATURE	CLIMATE VARIABLE	Construction	Operation	Closure	Potential Interaction
		Development Time Frame	**Construction**	**Operation**	**Closure**	
		Relevant Years	**2015 - 2016**	**2017 - 2032**	**2033+**	
		Projected Data Time Frames	**2012 / 2013**	**2020's**	**2050's, 2080's and beyond**	
MINING COMPONENTS	**FEATURE**	**CLIMATE VARIABLE**	**POTENTIAL FOR CLIMATE CHANGE INFLUENCES**			**Potential Interaction**
Site clearing and site preparation	Schedule	extreme weather	■			increasing frequency/severity of extreme weather may influence construction schedule
Open-pit mining activities including new open pit mine	Dewatering	rain	■	■		increasing rainfall may influence requirements for dewatering infrastructure
	(Infrastructure)	groundwater	■	■		decreasing groundwater levels may influence requirements for dewatering infrastructure
	Filling	rain			■	increasing rainfall may influence schedule for filling of open pit in closure phase
	(Schedule)	groundwater			■	decreasing groundwater levels may influence the level to which the open pit can be filled
Overburden and Mine Rock Management (MRA's)	Dust Mgmt	wind	■	■	■	increasing episodes of wind may increase potential for fugitive dust
		high temp	■	■	■	higher temperatures may influence the volatility of tailings material through drying
		low temp	■	■	■	lower temperatures may influence the volatility of tailings material through freeze drying
	Metal Leaching	rain	■	■	■	increasing rainfall may influence the potential for metal leaching
	Drainage	rain	■	■	■	increasing rainfall may influence requirements for and/or performance of infrastructure
Ore Processing	Operations/Machinery					no climate change influence anticipated
Process Plant Effluent (pipe conveyance for tailings sludge from plant to TMF)	Structure					no climate change influence anticipated
Tailings Management Facility (TMF)	Dust Mgmt	wind	■	■	■	increasing episodes of wind may increase potential for dust
		high temp	■	■	■	higher temperatures may influence the volatility of tailings material through drying
		low temp	■	■	■	lower temperatures may influence the volatility of tailings material through freeze drying
	Containment	rain	■	■	■	increasing rainfall may influence requirements for and/or performance of infrastructure
	Drainage	rain	■	■	■	increasing rainfall may influence the design/performance of drainage features
Project Infrastructure (buildings)	Structure	wind	■	■		increasing wind influence building design
		snow	■	■		decreasing snow loads influence building design
	HVAC	high temp	■	■		higher temperatures may influence the design of air conditioning systems
Water supply and facilities	Supply	drought	■	■	■	increasing inter-rainfall event dry periods may influence available water supplies
Drainage works - stormwater management (not related to TMF or MRA)	Infrastructure	rain	■	■	■	increasing rain may influence drainage infrastructure

		Development Time Frame	Construction	Operation	Closure	
		Relevant Years	2015 - 2016	2017 - 2032	2033+	
		Projected Data Time Frames	2012 / 2013	2020's	2050's, 2080's and beyond	
MINING COMPONENTS	**FEATURE**	**CLIMATE VARIABLE**	**POTENTIAL FOR CLIMATE CHANGE INFLUENCES**			**Potential Interaction**
Aggregate, mining and stockpiles (gravel pit(s) and/or quarry(ies))	Dust Mgmt	wind				increasing episodes of wind may increase potential for dust
		high temp				higher temperatures may influence the volatility of tailings material through drying
		low temp				lower temperatures may influence the volatility of tailings material through freeze drying
Site	Dewatering	rain				increasing rainfall may influence requirements for dewatering infrastructure
		groundwater				decreasing groundwater levels may influence requirements for dewatering infrastructure
Fuel and Materials Management	Supply Chain	extreme weather				increasing severe weather may influence supply chain operations (getting required materials to site)
Explosives, manufacturing, handling and storage	Storage	high temp				higher temperatures may influence the requirements for storage
Solid Waste Management, industrial waste handling/treatment including hazardous materials	Storage	high temp				higher temperatures may influence the design of storage systems
	Supply Chain	extreme weather				increasing severe weather may influence supply chain operations (getting required materials to site)
On-site Power Supply and power infrastructure (including temporary diesel generation)	Supply Chain	extreme weather				increasing severe weather may influence supply chain operations (getting required materials to site)
On-site access roads and related infrastructure	Culverts	rain				increasing rainfall may influence requirements for and/or performance of infrastructure
	Roads	freezing rain				increasing freezing rain may influence operations or design
		freeze/thaw				increasing freeze/thaw periods may influence maintenance or design
Watercourse Realignments and Fish Habitat Compensation	Water Management	rainfall				increasing rainfall could potentially result in changes to the channel form and function which may alter the availability of fish habitat
Water Taking	Supply	drought				increasing inter-rainfall event dry periods may influence available water supplies
Effluent Discharge	Discharge	drought				increasing inter-rainfall event dry periods may influence assimilative capacity at discharge points
TRANSMISSION LINE / PERMANENT POWER SUPPLY COMPONENTS:						
230 kV Transmission Line - Poles/Towers and Overhead Line	Structure	wind				increasing episodes of wind may influence design
		freezing rain				increasing episodes of freezing rain may influence design
	Electrical Equipment	high temp				extended periods of high temperatures may influence design of electrical systems
		low temp				extended periods of low temperatures may influence design of electrical systems

MINING COMPONENTS	FEATURE	CLIMATE VARIABLE	POTENTIAL FOR CLIMATE CHANGE INFLUENCES			Potential Interaction
		Development Time Frame	Construction	Operation	Closure	
		Relevant Years	2015 - 2016	2017 - 2032	2033+	
		Projected Data Time Frames	2012 / 2013	2020's	2050's, 2080's and beyond	
Côté Gold substation	Structure	wind				increasing episodes of high wind may influence design
		freezing rain				increasing episodes of freezing rain may influence design
	Electrical Equipment	high temp				extended periods of high temperatures may influence design of electrical systems
		low temp				extended periods of low temperatures may influence design of electrical systems

Given the Project timeline it can generally be concluded that options to negate or mitigate perceived vulnerability have been sufficiently integrated into the design of the infrastructure and/or operations where necessary. It is also generally considered that sufficient data is presently available to support integration of potential climate change influences into the design process.

The risk assessment also determined the likely effects of climate events on Project administration (personnel, operations), electrical power supply, transportation and communications.

a) Project Administration / Personnel

The primary performance responses considered in regard to Project administration (personnel, operations) were related to their ability to complete normal and emergency operations and maintenance activities specific to the Project. Climate parameters seen to impact these activities included 1-day rain, 5-day rain, freezing rain, snow accumulation, winter rain, and high winds. In general, the noted climate conditions could all contribute to impaired movement of crews and associated resources and equipment.

High temperature and heat waves were noted due to potential impacts on crews to maintain a normal operations and maintenance schedule. Current Occupational Health and Safety requirements in Ontario have protocols for working outdoors in hot and cold weather. This includes availability of fluids, rest/cooling stations, duration of exposure, etc. Increases in occurrence of high temperature days and heat waves may change the nature of working in hot weather perhaps resulting in shorter work days, longer rest/cooling periods, etc. Ultimately, additional staff may be required for a “normal” crew to compensate for the same operations/maintenance efforts.

One aspect of the risk assessment that was not included in the present assessment is ‘Record Keeping’. Planning for the effects of extreme events can be aided by recording not only the weather event data, but also by logging system responses.

b) Electrical Power

Potential impacts to the base electrical transmission system were identified. The climate parameters associated with system responses were generally related to those that could affect damages to the transmission system such as freezing rain and high winds. In light of these findings, IAMGOLD is currently considering backup power generation capacity in the Project design to accommodate off-line power generation for a period appropriate to maintain Project operation.

c) Transportation

The assessment of transportation systems specifically relates to impacts on the ability of supplies to be delivered to the Project. Again, climate parameters that could potentially impact or disrupt ground transport were identified, such as freezing rain and precipitation. Of particular importance was the delivery of fuel for backup power generation at the Project. IAMGOLD is considering stocking essential material for Project operations at levels that are appropriate to maintain Project operation during periods when re-stocking from outside sources cannot be completed.

d) Communications

Communication systems necessary to maintain operation of the Project were not considered to be at serious risk from any of the climate phenomena evaluated for this risk assessment.

5.0 SUMMARY AND RECOMMENDATIONS

5.1 Summary

The objective of this climate change review was to firstly assess the potential interactions between potential climate change and the Project from two viewpoints: i) influences the Project may have on climate change, and ii) influences climate change may have on the Project.

This report documents the regulatory framework, Project boundaries, quantification methods, data and assumptions that were used to estimate the GHG emissions for the Project. Based on the estimated GHG emissions the following comparisons can be made:

- the total emissions from the Project will be above the GHG reporting requirements under the federal and provincial reporting programs and at some point during the Project lifetime. It should be noted that input data used to estimate the emissions is conservatively based on current operating assumptions and may overestimate the actual emissions in any given year. Regulatory reporting requirements will therefore be assessed on a year by year basis once actual consumption data is available; and
- the total emissions from the Project represent 285 kilotonne CO_2e, which is approximately 0.17% of Ontario's GHG inventory for 2011 or 0.04% of the Canadian GHG inventory for that same year.

Since the predicted GHG emissions from this Project are insignificant in comparison to Canadian and global emissions, the Project will have virtually no impact on current estimates of future global climate change.

Once approved, the Project may have GHG reporting responsibilities under various regulatory GHG Reporting Programs. These programs include:

- Ontario's GHG Emissions Reporting Regulation (O. Reg. 452/09); and
- Government of Canada GHG Emissions Reporting Program (Environment Canada).

A climate analysis was conducted in order to i) establish a set of climate parameters describing the climatic and meteorological phenomena relevant to the study area, and to ii) establish a general expectation of occurrence of each climate parameter both historically and in the future.

Various climate parameters were assessed based on perceived relevant climate events and change factors (based on climatic and meteorological phenomena deemed relevant to the Project). Each climate parameter was assessed in detail to provide historical and future climate parameter probability scores. Seven parameters (high temperature, heat waves, freeze thaw cycles, 1-day and 5-day rain, winter rain, freezing rain, drought/dry periods) have been identified with increasing probability moving into the future, and three winter related parameters (low temperatures, cold waves, snow accumulation) have been identified with decreased probability, primarily related to the anticipation of rising temperatures. Of particular interest are increases in the rain related parameters which could have a direct impact on performance of the subject infrastructure.

A risk assessment was conducted to determine the likely effect of individual climate events on Project infrastructure. It was determined that climate change has the potential to affect the majority of Project elements across all three phases, namely; construction, operations and closure. However, it can be surmised that the more prominent effects may be seen into the 2030's and beyond through the late stages of Project operations and then during closure. Of particular interest is precipitation for which individual storms are projected to increase in intensity and total volume of rain. However, this is not considered to be a concern since Project drainage infrastructure will be designed to accommodate climate change predictions.

The risk assessment also determined the likely effects of climate events on Project administration (personnel, operations), electrical power supply, transportation and communications. The primary performance responses considered in regard to Project administration (personnel, operations) were related to their ability to complete normal and emergency operations and maintenance activities specific to the Project. Rain, freezing rain, snow accumulation and high winds could contribute to impaired movement of crews and associated resources and equipment. High temperature and heat waves could also impact crews' abilities to maintain normal operations and maintenance schedules. Potential impacts to the base electrical transmission system were generally related to those that could affect damages to the transmission system such as freezing rain and high winds. In light of these findings, IAMGOLD is currently considering backup power generation capacity in the Project design to accommodate off-line power generation for a period appropriate to maintain Project operation. Climate parameters that could potentially impact or disrupt transportation systems (specifically related to impacts to the ability of supplies to be delivered to the Project) included freezing rain and precipitation. Of particular importance was the delivery of fuel for the backup power generation at the Project. IAMGOLD is considering stocking essential material for Project operations at levels that are appropriate to maintain Project operation during periods when re-stocking from outside sources cannot be completed. Communication systems necessary to maintain operation of the Project were not considered to be at serious risk from any of the climate phenomena evaluated for this risk assessment.

5.2 Recommendations

Given the Project timeline, it can generally be concluded that options to negate or mitigate perceived vulnerability have already been sufficiently integrated into the design of the infrastructure and/or operations where necessary. It is also generally considered that sufficient data is presently available to support integration of potential climate change influences into the design process.

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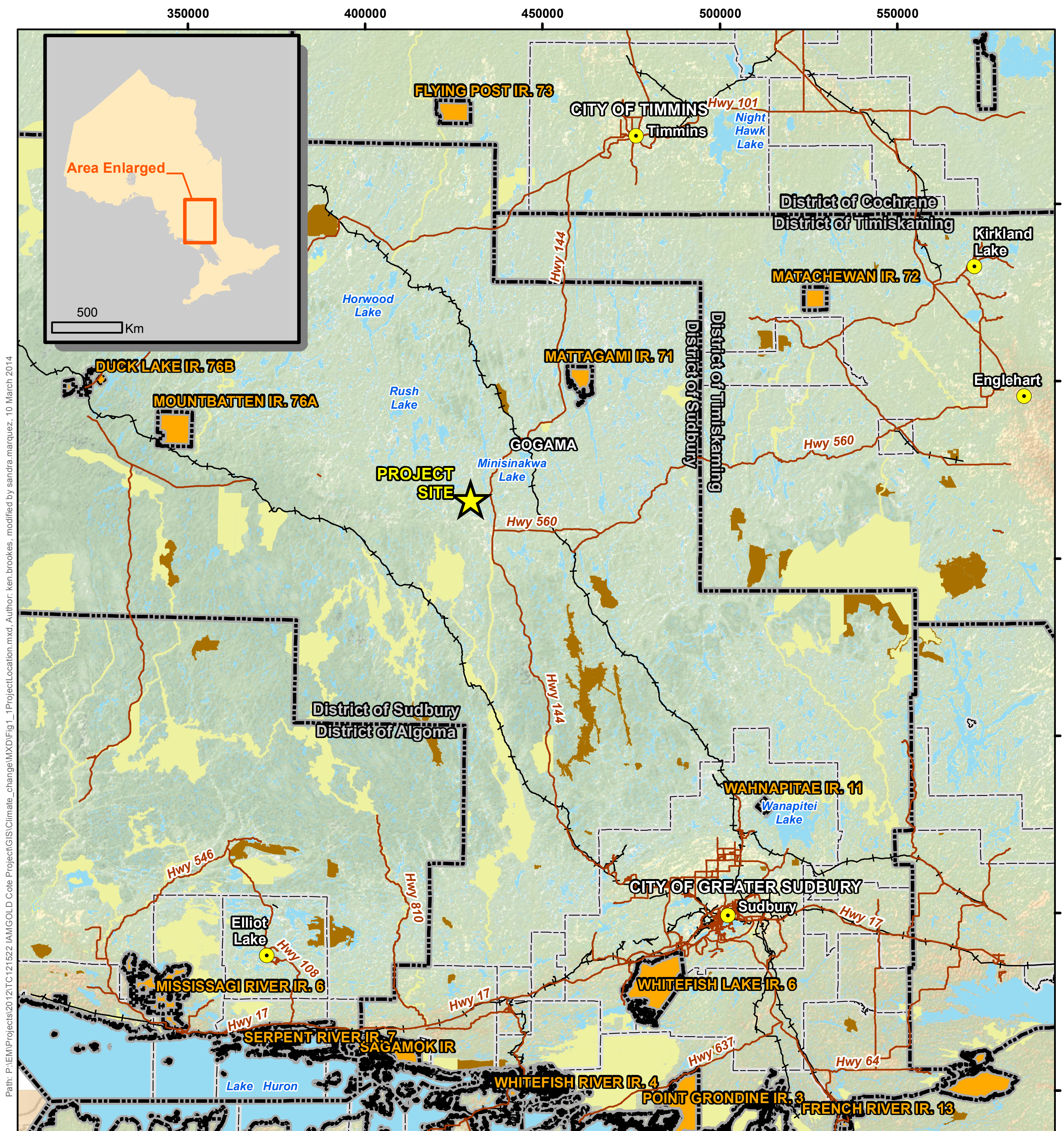
FIGURES



LEGEND

- Project Site Location
- Regional Communities
- Major Roads
- Railway
- Lower Tier Municipality Boundary
- Upper Tier Municipality Boundary
- First Nation Reserve
- Conservation Reserve (Regulated)
- Provincial Park
- Waterbody / Large Watercourse
- Wooded Area

NOTES:
- All base data on this map was extacted from Land Information Ontario, MNDM, OBM Ontario Digital Geospatial Database and Ontario Road Network Database.

Datum: NAD83
Projection: UTM Zone 17N

0 20 40 60 80 100 Kilometres

N S E W

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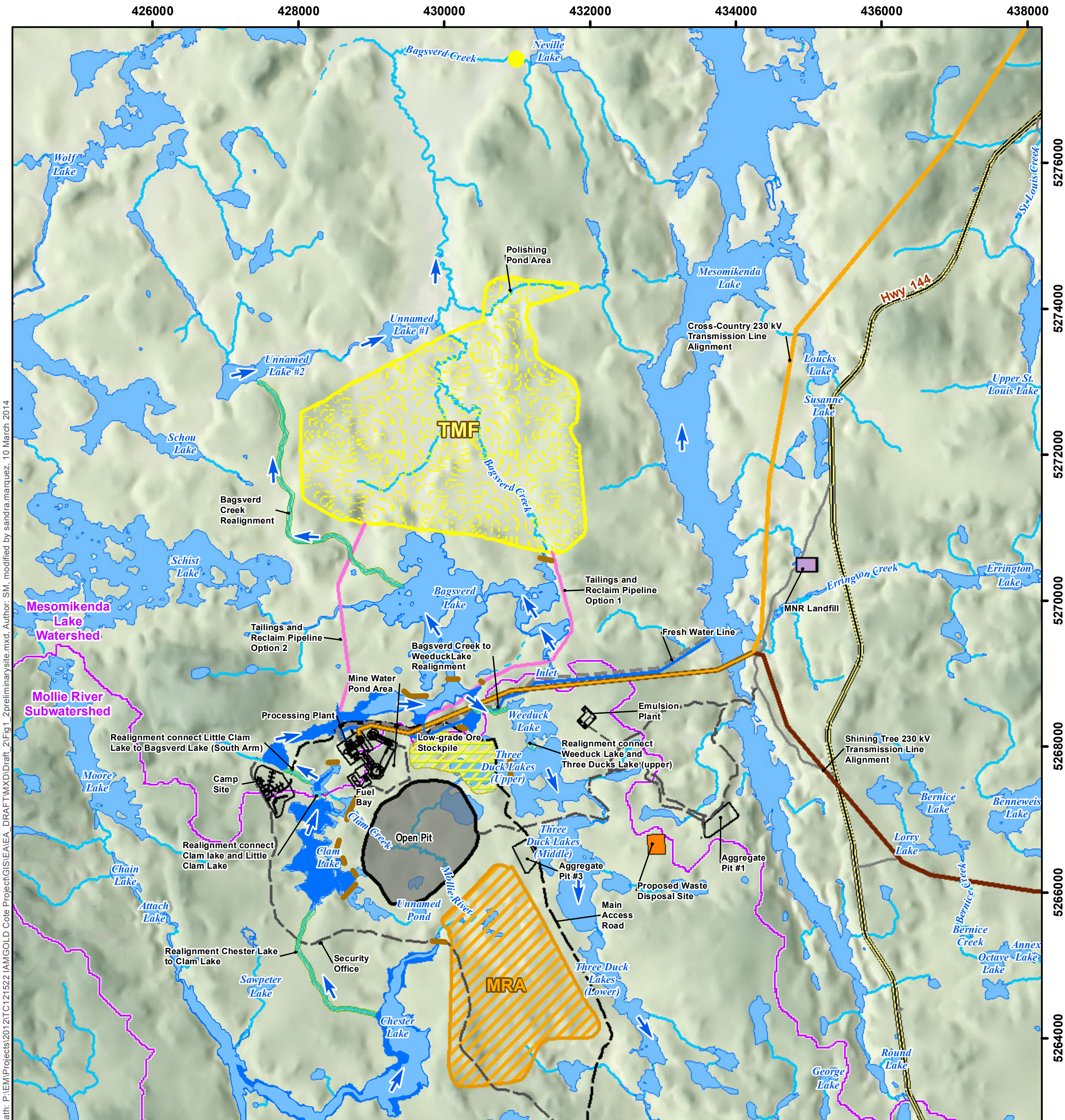
CÔTÉ GOLD PROJECT

Project Location

PROJECT N^{o}: TC121522	FIGURE: 1-1
SCALE: 1:1,450,000	DATE: March 2014



LEGEND

- Existing Intermittent Watercourse
- Existing Permanent Watercourse
- Existing Waterbodies
- Highway
- Local Road
- Subwatershed Boundary
- Wooded Area
- Open Pit
- Potential Discharge Locations
- Facilities
- Dam
- Main Access Road
- Access Road
- Cross-Country 230 kV Transmission Line Alignment
- Shining Tree 230 kV Transmission Line Alignment
- Tailings and Reclaim Pipeline
- Fresh Water
- Water Realignment
- Proposed Water Flow Direction
- Proposed Lake Area
- Polishing Pond
- Low-grade Ore Stockpile
- Proposed Mine Rock Area (MRA)
- Proposed Tailings Management Facility (TMF)
- Proposed Landfill
- MNR Landfill

0 1 2 3 4 5 Kilometres

NOTES:
- Ontario base data extracted from Land Information Ontario (MNR)
- TMF and subwatershed provided by Golder Associates.
- Watercourse realignment and proposed lake area provided by Calder Engineering.
- Surface infrastructure, open pit, landfill, MRA and transmission lines provided by IAMGOLD.

Datum: NAD83
Projection: UTM Zone 17N

N S W E

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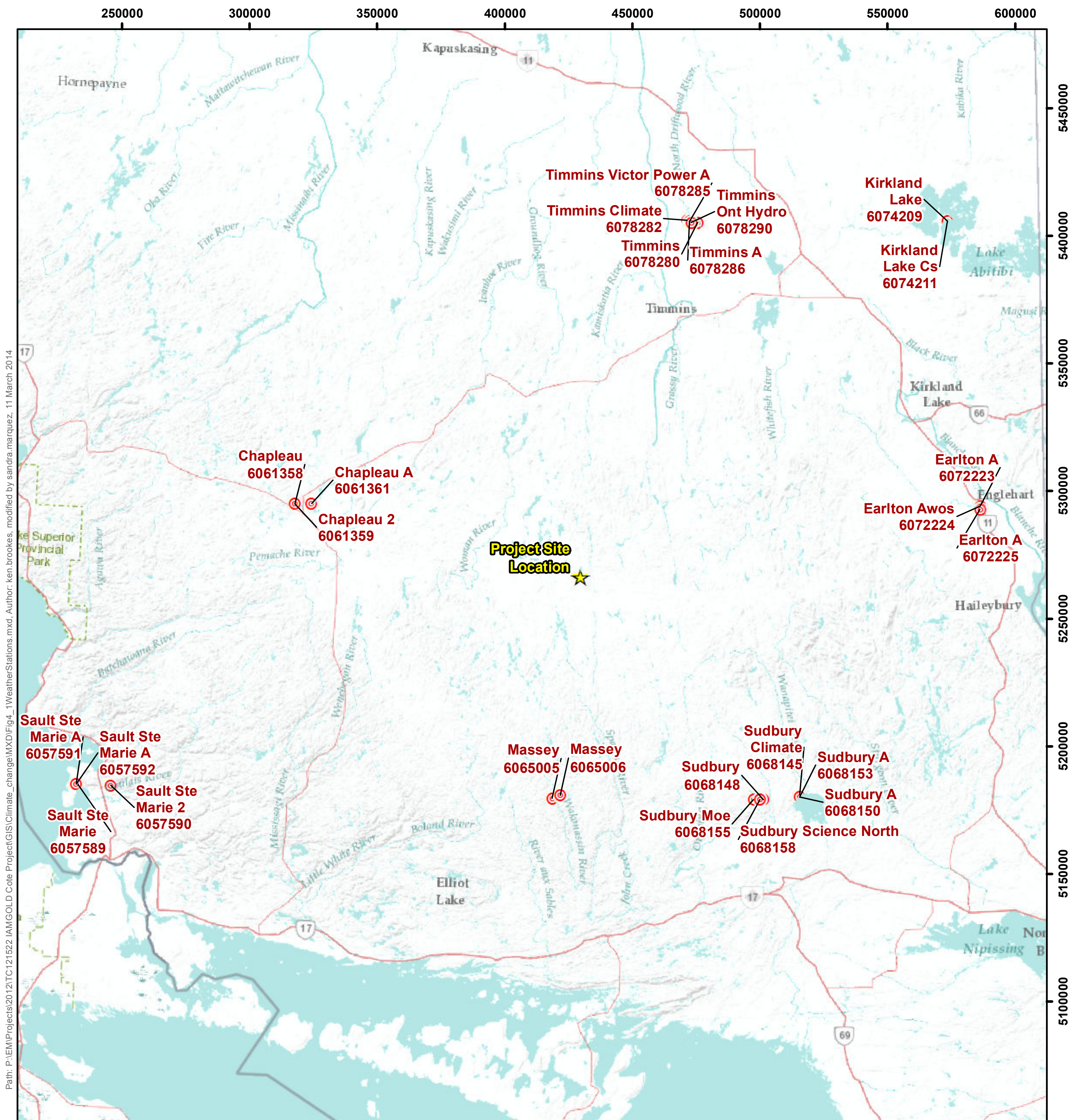
CÔTE GOLD PROJECT

Preliminary Site Plan

PROJECT N°: TC121522	FIGURE: 1-2
SCALE:1:70,000	DATE: April 2014



LEGEND

★ Project Site Location

◎ Weather Stations (Labelled with EC ID)

NOTES:
- Background extracted by ESRI online imagery.
- Weather stations locations from Environment Canada's Climate website.

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CÔTÉ GOLD PROJECT

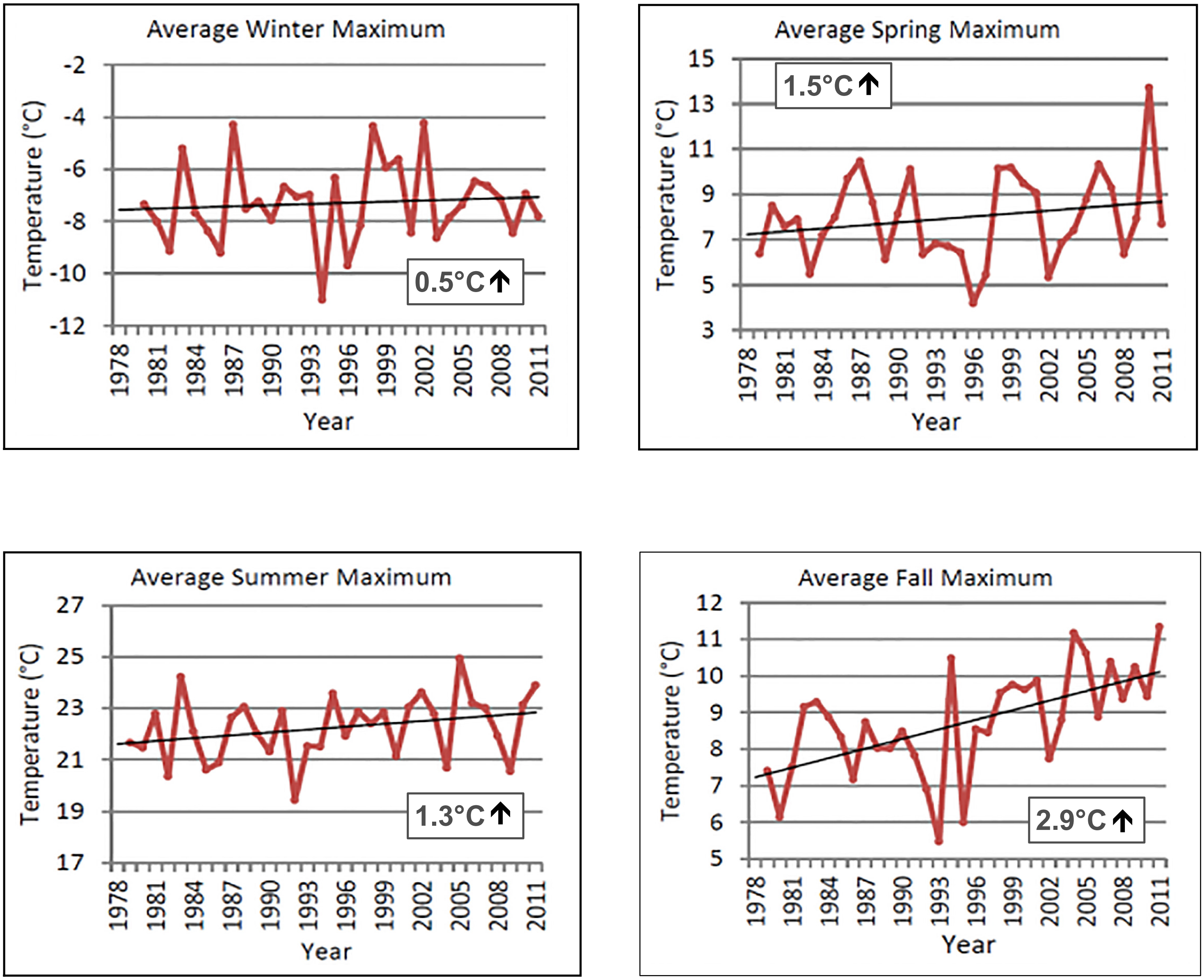
Environment Canada Regional Weather Stations

Datum: NAD83
Projection: UTM Zone 17N

0 30 60 90 120 150 Kilometres

N W E S

PROJECT N^o: TC121522	FIGURE: 4-1
SCALE: 1:2,000,000	DATE: March 2014



Source: Ontario Centre for Climate Impacts and Adaptation Resources OCCIAR, 2012

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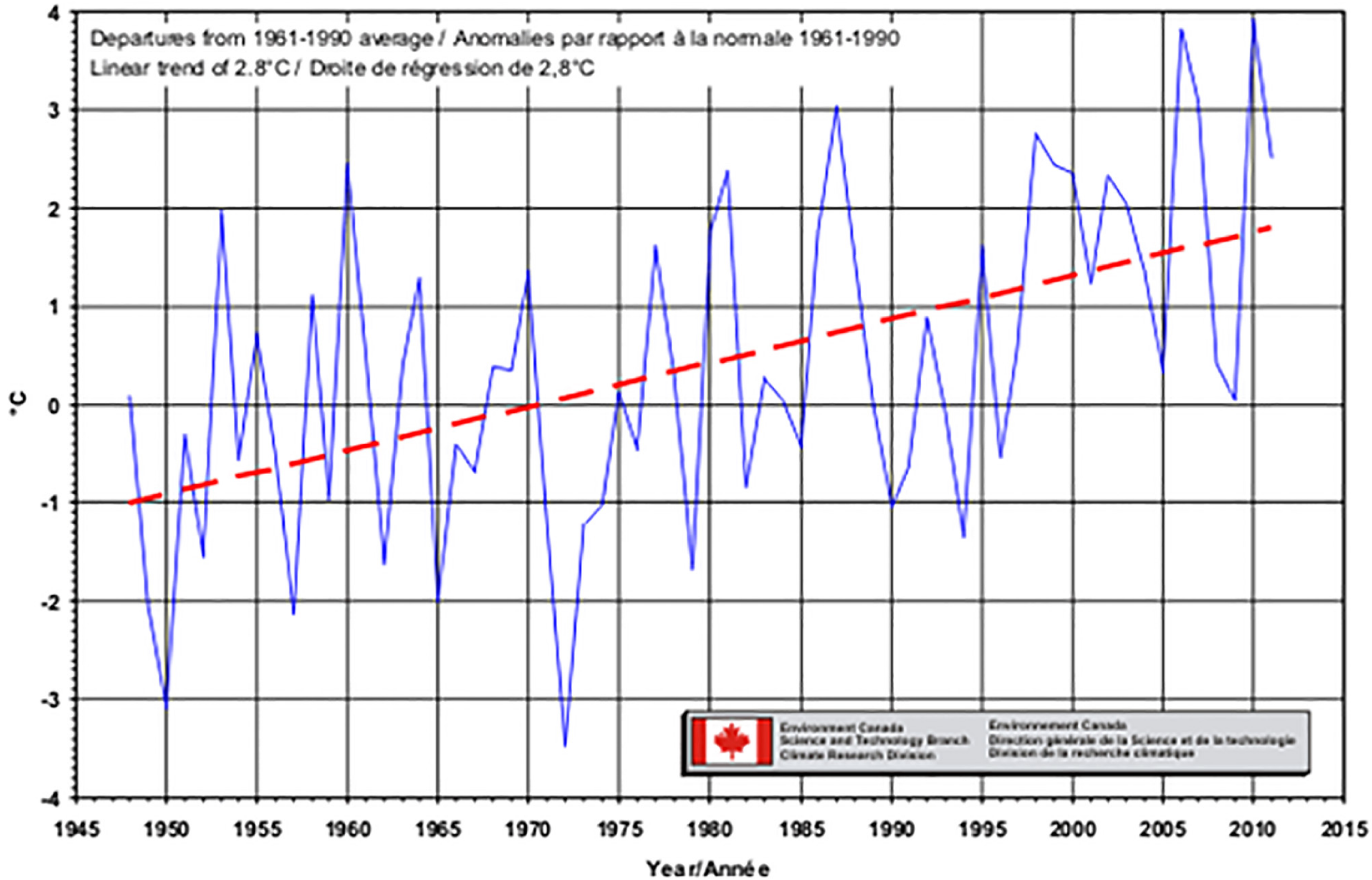
CÔTÉ GOLD PROJECT

Seasonal Maximum Temperatures, Chapleau, 1978-2011

PROJECT Nº: TC121522	FIGURE: 4-2
Not to Scale	DATE: March 2014



Source: Environment Canada, 2011c

Datum: NAD83
Projection: UTM Zone 17N

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CÔTÉ GOLD PROJECT

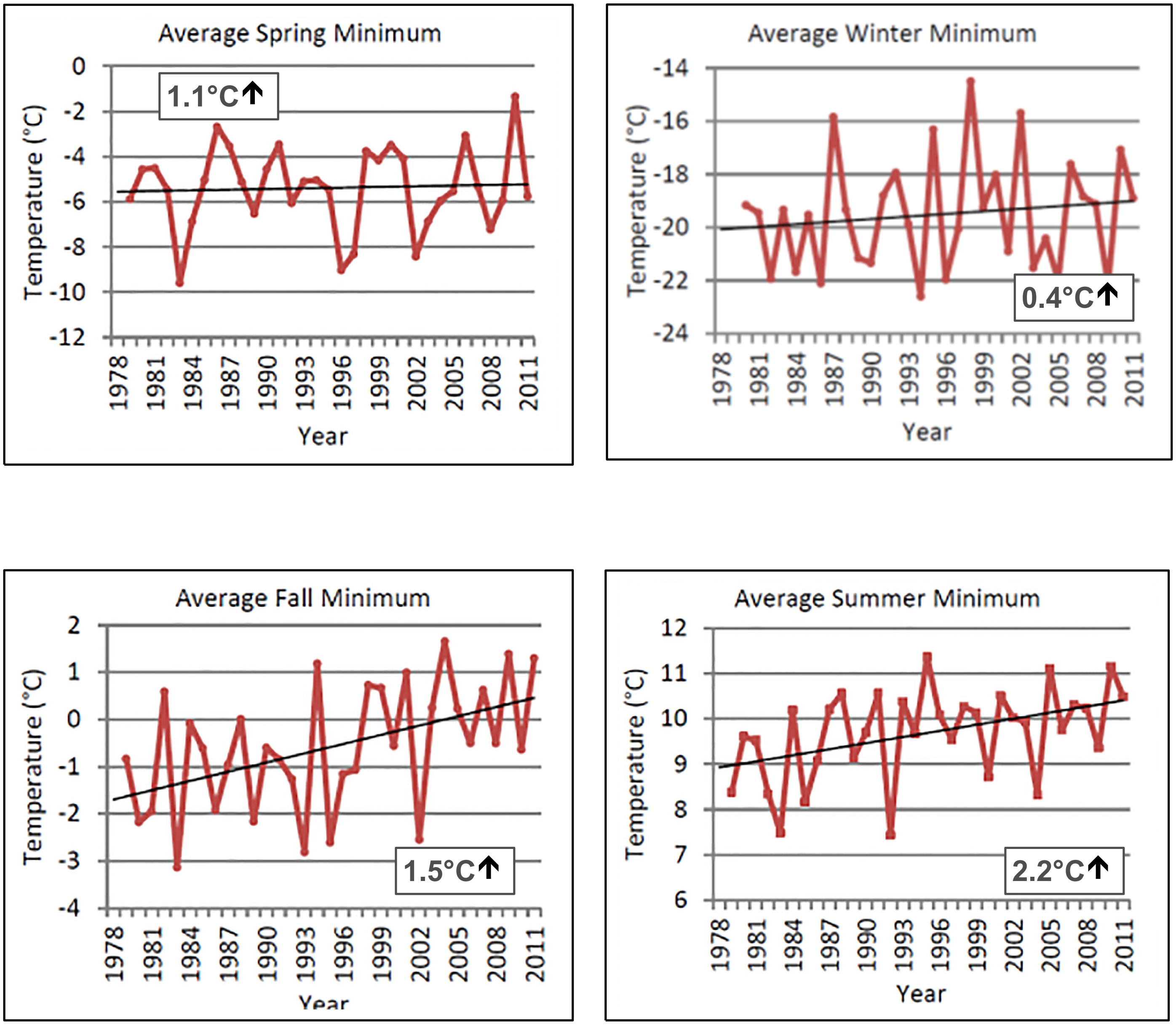
Winter National Temperature Departures and Long-Term Trend, 1948 – 2011

PROJECT N°: TC121522

FIGURE: 4-3

Not to Scale

DATE: March 2014



Path: P:\EM\Projects\2012\TC121522 IAMGOLD Cote Project\GIS\Climate_change\MXD\Fig4_4SeasonalMinTemp.mxd, Author: ken.brookes, modified by sandra.marquez, 11 March 2014

Source: Ontario Centre for Climate Impacts and Adaptation Resources OCCIAR, 2012

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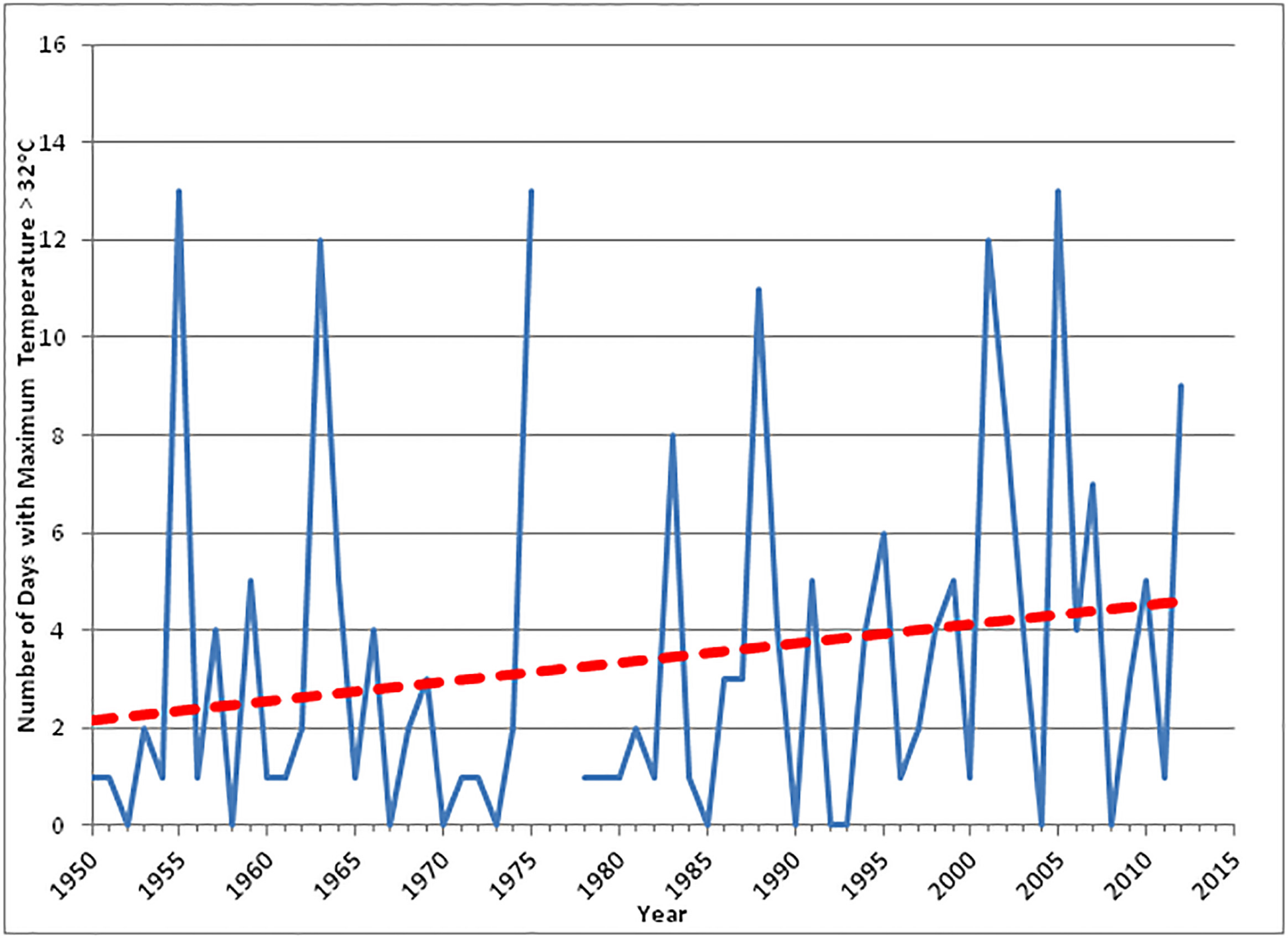
CÔTÉ GOLD PROJECT

Seasonal Minimum Temperatures, Chapleau, 1978-2011

PROJECT N^{o}: TC121522	FIGURE: 4-4
Not to Scale	DATE: March 2014



Source: Environment Canada, 2010

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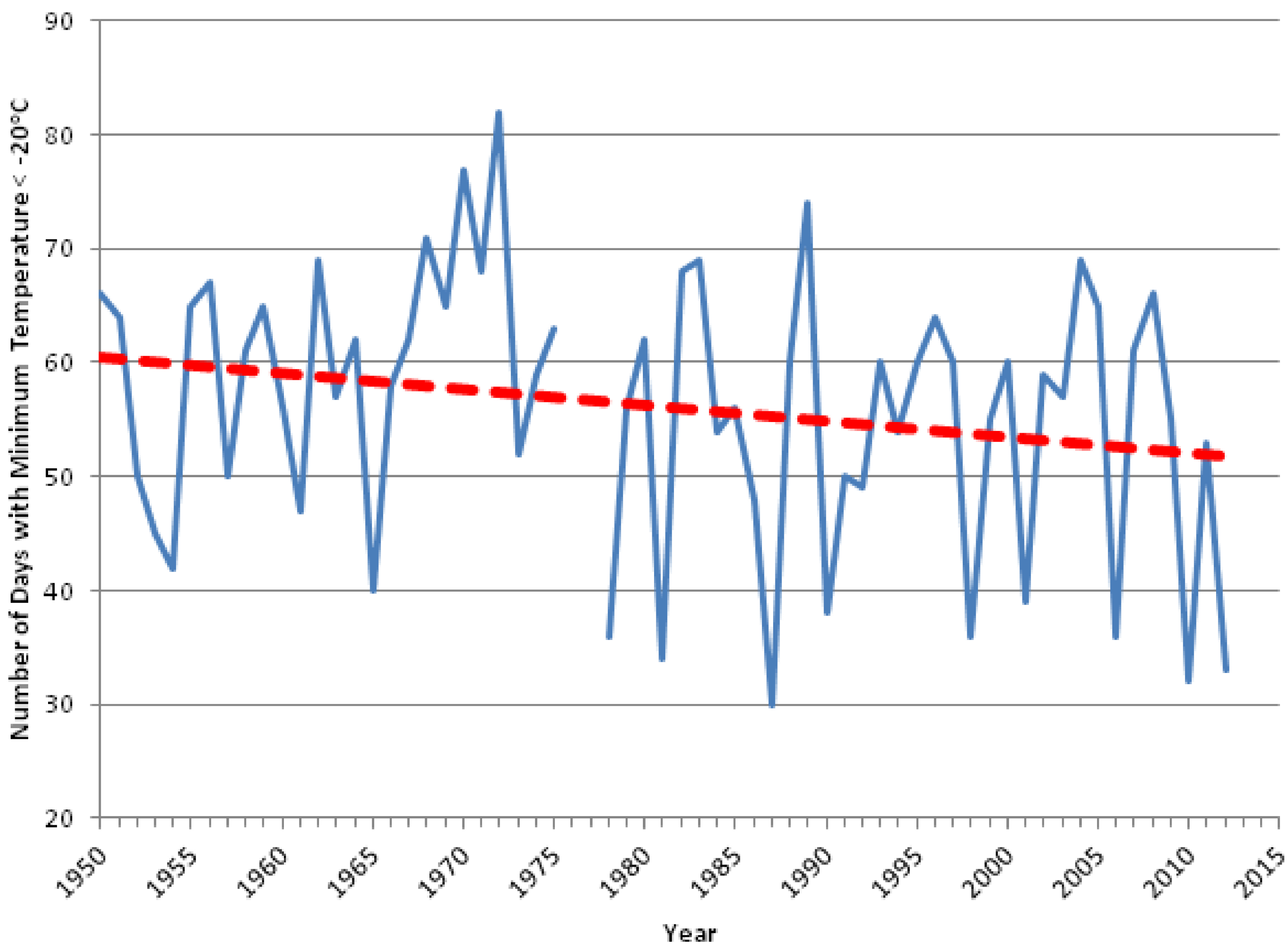
CÔTÉ GOLD PROJECT

Historic Number of Hot Days, Chapleau Weather Station, 1950 to 2012

Datum: NAD83
Projection: UTM Zone 17N

PROJECT N°: TC121522	**FIGURE: 4-5**
Not to Scale	DATE: March 2014



Source: Environment Canada, 2013

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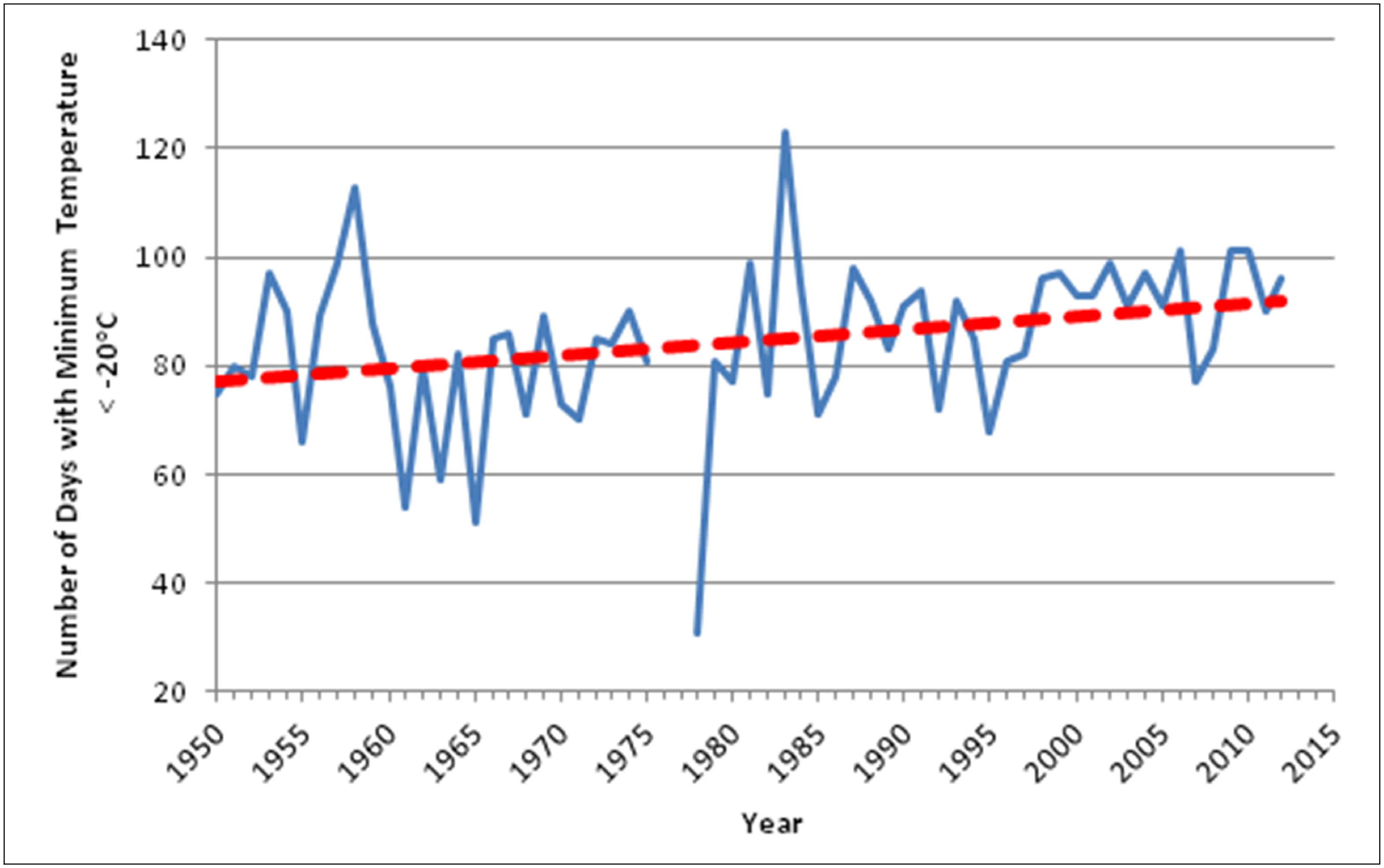
CÔTÉ GOLD PROJECT

Historic Number of Cold Days, Chapleau Weather Station, 1950 to 2012

Datum: NAD83
Projection: UTM Zone 17N

PROJECT N^{o}: TC121522	**FIGURE: 4-6**
Not to Scale	DATE: March 2014



Source: Environment Canada, 2013

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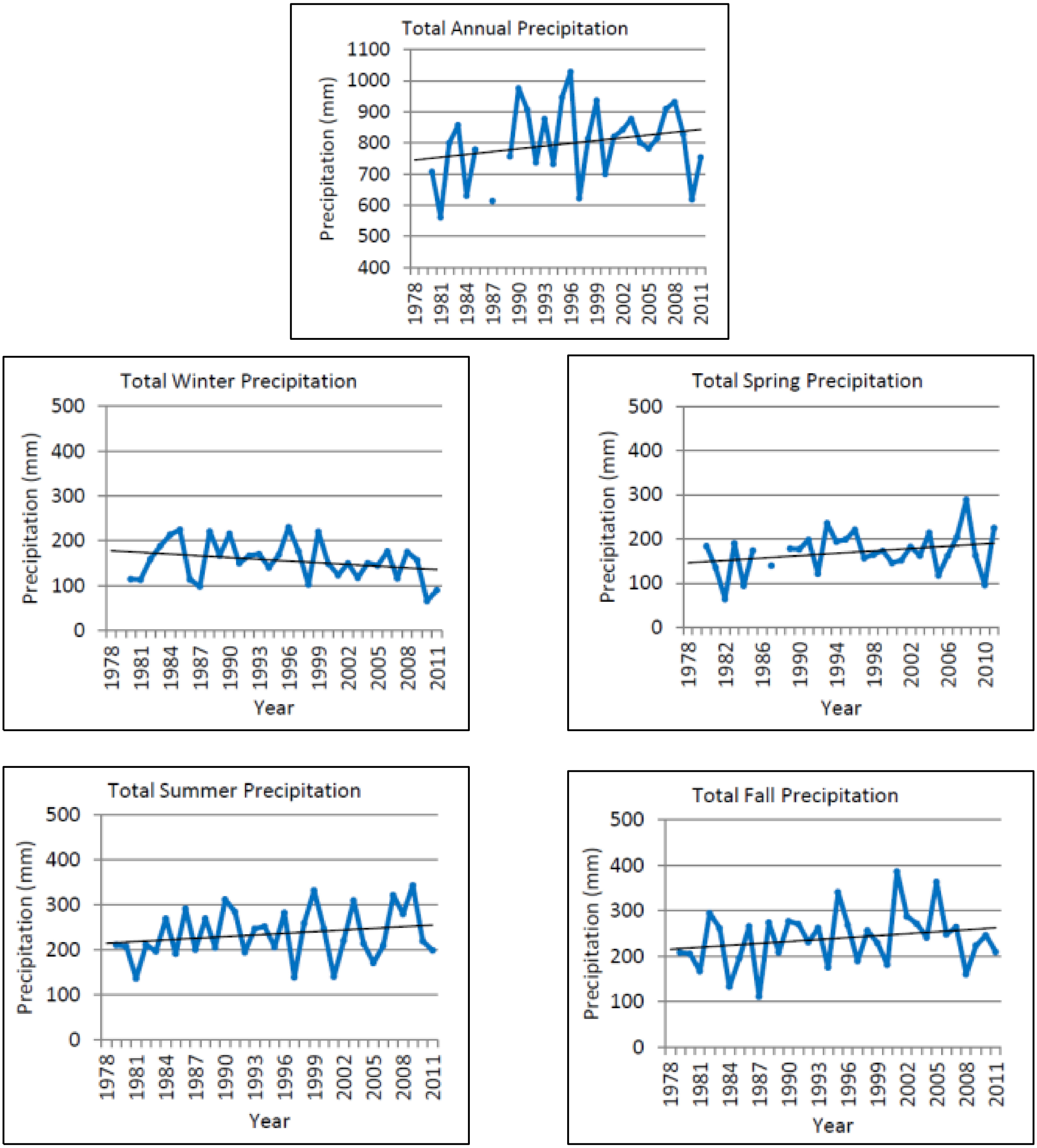
CÔTÉ GOLD PROJECT

Summary of Recorded Freeze/Thaw Days for Chapleau, 1950 to 2012

Datum: NAD83
Projection: UTM Zone 17N

PROJECT N^{o}: TC121522	**FIGURE: 4-7**
Not to Scale	DATE: March 2014



Source: Ontario Centre for Climate Impacts and Adaptation Resources OCCIAR, 2010

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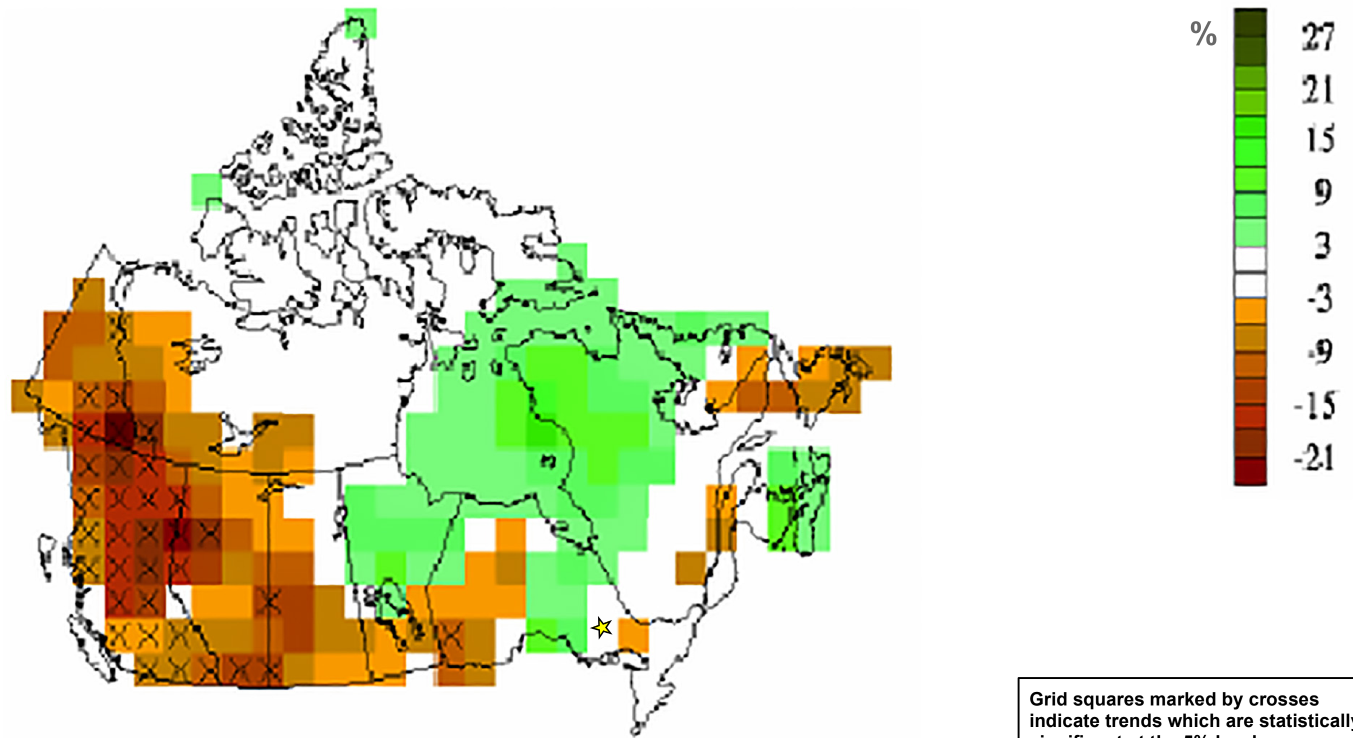
CÔTÉ GOLD PROJECT

Historic Trends in Precipitation for Chapleau

PROJECT N°: TC121522	FIGURE: 4-8
Not to Scale	DATE: March 2014



Grid squares marked by crosses indicate trends which are statistically significant at the 5% level.

LEGEND

☆ Project Site Location

Source: Barrow et al., 2004

Datum: NAD83
Projection: UTM Zone 17N

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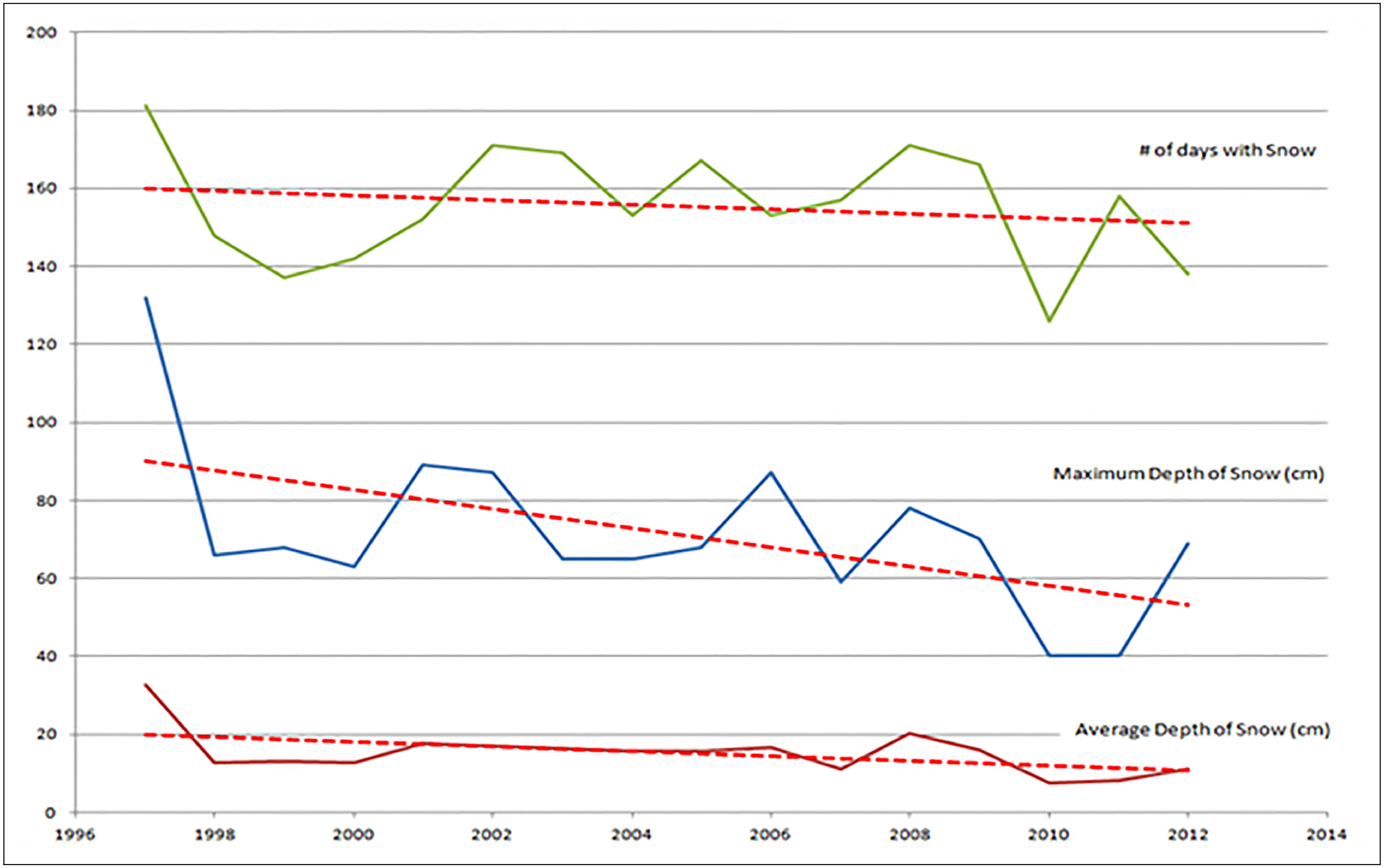
CÔTÉ GOLD PROJECT

Trends in Spring Snow to Total Precipitation Ratio (1950-1999)

PROJECT Nº: TC121522	**FIGURE: 4-9**
Not to Scale	DATE: March 2014



Source: Environment Canada, CDCD Extract program database for the period 1997 to 2012.

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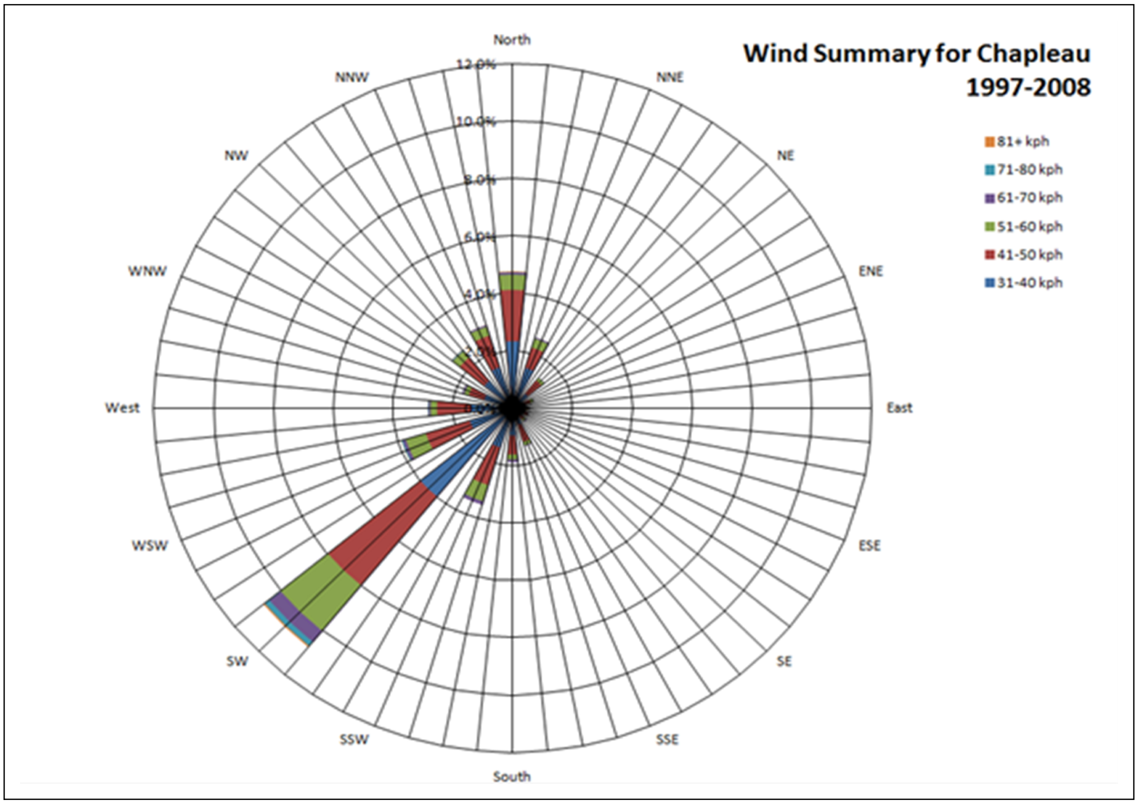
CÔTÉ GOLD PROJECT

Historical Snow Data for Chapleau 1997-2012

Datum: NAD83
Projection: UTM Zone 17N

PROJECT N°: TC121522	**FIGURE: 4-10**
Not to Scale	DATE: March 2014



Wind Direction	Wind Speed Range (kph)								
	Calm	31-40	41-50	51-60	61-70	71-80	81+	Total	%
N		102	79	23	4	0	1	209	4.8%
NNE		64	33	14	2	0	0	113	2.6%
NE		28	27	5	0	0	0	60	1.4%
ENE		18	10	4	0	0	0	32	0.7%
E		16	7	1	0	0	0	24	0.5%
ESE		15	9	0	0	0	0	24	0.5%
SE		13	9	3	1	0	0	26	0.6%
SSE		26	28	5	1	0	0	60	1.4%
S		42	29	7	4	0	0	82	1.9%
SSW		63	60	25	6	0	0	154	3.5%
SW		175	176	88	23	9	1	472	10.8%
WSW		66	67	30	6	2	0	171	3.9%
W		61	50	9	4	1	0	125	2.9%
WNW		44	23	7	4	0	0	78	1.8%
NW		54	46	13	2	1	0	116	2.6%
NNW		65	51	14	3	0	0	133	3.0%
Calm	2504							2504	57.1%
Totals	2504	852	704	248	60	13	2	4383	
%	57.1%	19.4%	16.1%	5.7%	1.4%	0.3%	0.0%		100%

Source: Environment Canada, 2013

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CÔTÉ GOLD PROJECT

Wind Summary for Chapleau 1997 to 2008

PROJECT N^{o}: TC121522	FIGURE: 4-11
Not to Scale	DATE: March 2014

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