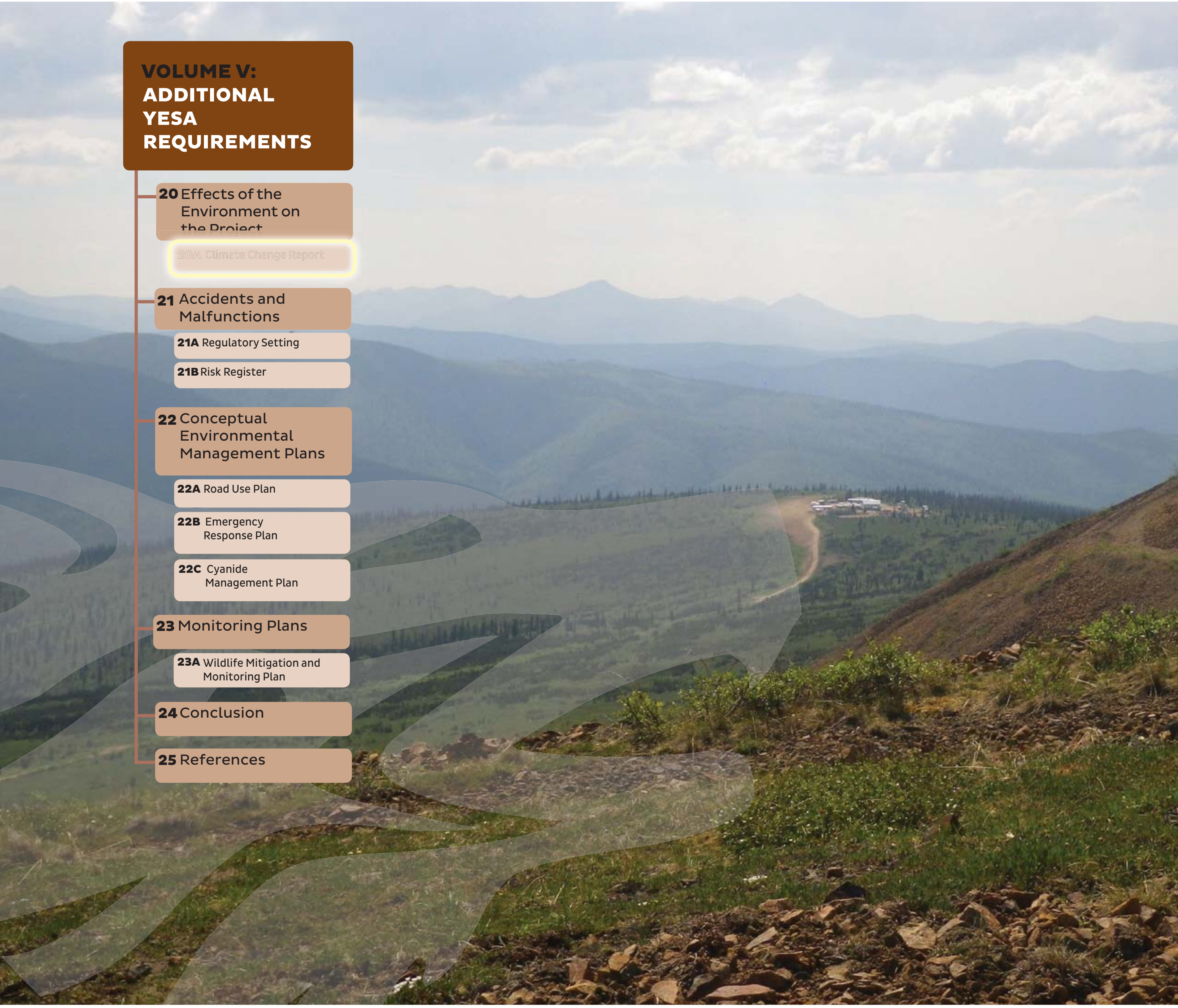
APPENDIX 20A: CLIMATE CHANGE REPORT



VOLUME V: ADDITIONAL YESA REQUIREMENTS

CASINO MINING CORPORATION
CASINO PROJECT



CLIMATE CHANGE REPORT

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EXECUTIVE SUMMARY

There is a general consensus in the scientific community that the global atmosphere is warming and that climate patterns are correspondingly changing throughout the world, including the Yukon, where substantial increases in average annual temperatures have been observed in the last century throughout the territory. Increases in annual precipitation are also generally stated in the literature, particularly for the winter months. It is not clear, however, how much of these observed changes are indicative of long-term global climate change, since much of the recent warming trend began quite suddenly around 1977, coincident with a shift from a cold to a warm phase of a large-scale cyclical oceanic temperature pattern. Nonetheless, given people's general awareness of climate change, at least as a basic concept, there is understandably some concern about whether or not historical flow and climate records, which are being used to assess the hydrology and climate of the Casino Project, reasonably represent conditions that might be expected over the next 20 to 40 years and beyond. In an effort to better understand the issues and address this concern, a general review of the most relevant literature was conducted and historical trends of annual temperature, precipitation, and discharge were examined for locations in the general region of the Project Site. The key findings of this review are as follows:

- A number of published works on climate change in the Yukon are fairly consistent in stating that:
    - The Yukon's climate has shown a warming trend over the past few decades, with average annual temperatures increasing by approximately 2 °C in the past 50 to 60 years.
    - Temperature increases were greatest in the winter months and lowest in the summer months.
    - Record warm winters have been experienced in the first decade of the 21st Century.
    - Daily minimum temperatures were found to be increasing faster than daily maximum temperatures.
    - The Yukon has generally gotten wetter during the winter over the past few decades, although historical precipitation trends are not particularly strong or consistent.
    - Trends in extreme precipitation for the project region are very slight and not statistically significant.
    - Projected future climate scenarios, as modeled by using emission scenarios outlined by the UN Intergovernmental Panel on Climate Change (IPCC), indicate that over the next 50 years mean annual temperatures in the Dawson region of the Yukon, including the Casino Mine Site, might increase in the order of 1°C to 4 °C, and mean annual precipitation might increase in the order of 5% to 25%, with increases in both rainfall and snowfall.
    - Mean annual temperature will rise by roughly 2.5 °C by 2050, and the rise in temperature will be greater in the winter and smaller in the summer.
- The most pronounced temperature increases at the Mayo Airport appear to be during the spring and summer months, which differ from the findings published for the Yukon in general, which indicate that the greatest temperature increases are during the winter months.
- It appears that temperature changes in the Yukon over the past 50 years can be more attributed to large scale climate oscillations than to climate change.
- It appears that we have recently, or are currently, entering a cooling phase of the PDO. Correspondingly, it is possible that the annual mean temperature trend may actually decline or remain relatively constant over the next two to three decades.

- Annual precipitation data for climate stations in the general region of the Mine Site indicate a generally increasing trend.
- It appears that the proportion of annual precipitation that falls as snow is decreasing, which is consistent with increasing temperatures and IPCC climate change projections.
- It appears that the severity of extreme precipitation events is not changing at a significant rate.
- Regional historical streamflow data indicate that annual hydrograph shapes are changing, with slightly increasing winter flows, decreasing spring freshet and summer flows, and increasing fall flows. These patterns are consistent with the expected effects of increasing temperatures.
- Trends of annual peak instantaneous discharge are relatively flat or stable, but could possibly increase due to potential increases in snowmelt rates during the spring freshet.
- The uncertainty of hydroclimatic conditions are typically considered in the design process for a mine through the use of factors of safety and by incorporating adaptability into the designs and operating plans for the mine. Consequently, mine structures are inherently well-suited to accommodate possible effects due to climate change.
- Warmer temperatures could substantially alter the permafrost conditions in the Casino Project area, most notably affecting the extent of the seasonally thawed permafrost layer (active layer) and thereby altering the foundation conditions of civil infrastructure works, including buildings, roads, railways, airstrips, and pipelines. The most basic risk is the loss of mechanical strength and eventually thaw settlement or subsidence, as well as increased frost heaving potential.
- It is believed that current climatic and hydrologic records provide an appropriate basis for assessing the general conditions in the Project area over the expected life of the mine. Nonetheless, potential climate change effects should be considered and incorporated into climatic and hydrologic assessments when appropriate.

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1 – INTRODUCTION

1.1 GENERAL

The Casino Project is a proposed mining operation located in the Dawson Mountain Range of the Klondike Plateau, approximately 300 km northwest of Whitehorse and 200 km south of Dawson City in the Yukon Territory, Canada. The climate of the project area is characterized by long, cold, dry winters and short, warm, wet summers. Streamflow in the region is typically highest in May due to melting of the winter snowpack. Annual peak instantaneous flows commonly occur in this freshet period on larger rivers, but on smaller streams they may also occur in summer or early autumn due to intense rain or rain-on-snow events. Flows decrease throughout the winter and are typically at a minimum in March or early April.

Understanding of the hydrometeorological conditions in the project area is based on historical climate and streamflow records, but given the generally accepted concept that global climate patterns are changing, there is concern that these historical records may not reasonably represent conditions that might be expected over the next 20 to 30 years, through Project operations, or even longer time scales, through Project closure.

1.2 CLIMATE CHANGE

Climate change "refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer" (IPCC, 2007). Climate change reflects abnormal variations to the expected climate within the Earth's atmosphere, and is currently most commonly associated with increasing temperatures, or "global warming," although related changes in other hydroclimatic parameters, such as increasing atmospheric water vapour content; changing precipitation patterns in terms of intensity and extremes; reduced snow cover and widespread melting of ice; and changes in soil moisture and runoff, also qualify.

The concept of climate change has been pushed to the forefront of public awareness over the past decade, largely as a result of the strongly contested debate in the general media over whether or not climate change is actually occurring, and if so, what are the magnitudes of these changes and how will they be manifested in the future. Additionally, there is the question of whether the causes of climate change are natural or anthropogenic, though this is not particularly relevant to the development and operation of the Casino Project, and therefore it will not be discussed further in this report. The question of whether climate change is occurring has largely been answered, as there is a general consensus in the scientific community that the global atmosphere is warming and that climate patterns are correspondingly changing throughout the world (Bates et. al., 2008), including the Yukon, where notable increases in average annual temperatures have been observed over the last century. It is not clear, however, how much of these observed changes are actually indicative of long-term global climate change, since much of the recent warming trend began quite suddenly around 1977, coincident with a shift from a cold to a warm phase of a large-scale cyclical atmospheric and oceanic temperature pattern (Weller and Anderson, 1998). Nonetheless, given the public's general awareness of climate change, at least as a basic concept, and the fact that actual climate change could have implications for the operation of the Casino Project, an assessment of climate change, admittedly at a cursory level, was conducted. This assessment included a general review of the relevant literature, and examination of historical trends of annual temperature, precipitation, and discharge in the general region of the Project Site. Furthermore, these trends were compared to downscaled predictions developed from global climate models developed for the Intergovernmental Panel for Climate Change (IPCC) in order to assess a full range of possible climate change scenarios.

2 – CLIMATE CHANGE ANALYSIS OVERVIEW

There is a general consensus in the scientific community that the global atmosphere is warming and that worldwide climate patterns are changing as a result. While temperatures are generally increasing across the globe, warming has been shown to be greatest in the northern latitudes and the majority of this warming has taken place in winter and spring (Werner *et al.*, 2009), making climate change predictions particularly relative for development projects in the Yukon. According to the Environment Yukon report "Yukon Water: An Assessment of Climate Change Vulnerabilities" (Goulding, 2011), temperature and precipitation have fluctuated significantly over the last century, but for the period of 1950 to 1998, annual temperatures were generally increasing across the territory, in the order of 2 °C (Lemmen *et al*., 2008), and daily minimum temperatures were found to be increasing faster than daily maximum temperatures (Werner *et al.*, 2009). All regions showed slightly increasing winter precipitation, while summer precipitation decreased in the northern Yukon but increased in the southern Yukon. According to a Pacific Climate Impacts Consortium (PCIC) report "Climate Change in Dawson City, YT: Summary of Past Trends and Future Projections", winter temperatures are projected to increase 2.1°C to 3.5°C by 2050 over baseline climate normal values for 1961 to 1990, and annual precipitation is projected to increase by 10% to 40%, with a 30% to 50% increase expected in the winter and a 10% to 30% increase expected in the summer (Werner *et al*., 2009). Estimates of climate changes predicted for the Dawson Region for 2050 using the PCIC Regional Analysis Tool, based on an ensemble of future emission scenarios, are summarized in Table 2.1, and indicate a median temperature increase of 2.6°C and a median annual precipitation increase of 15%.

Table 2.1 Summary of Climate Change Predictions for the Dawson Region by 2050

Climate Variable	Season	Projected Change in 2050 relative to 1961-1990		
		Ensemble Median	10th Percentile	90th Percentile
Mean Temperature (°C)	Annual	+2.6	+1.6	+4.4
Precipitation (%)	Annual	15%	4%	24%
	Summer	12%	2%	28%
	Winter	17%	3%	37%
Snowfall (%)	Winter	16%	0%	36%
	Spring	6%	-7%	23%

NOTES:
1. SOURCE: PACIFIC CLIMATE IMPACTS CONSORTIUM REGIONAL ANALYSIS TOOL, 2013
2. MEDIAN AND PERCENTILE CALCULATIONS ARE BASED ON RESULTS FOR EMISSION SCENARIOS USED IN THE IPCC FOURTH ASSESSMENT REPORT (AR4).

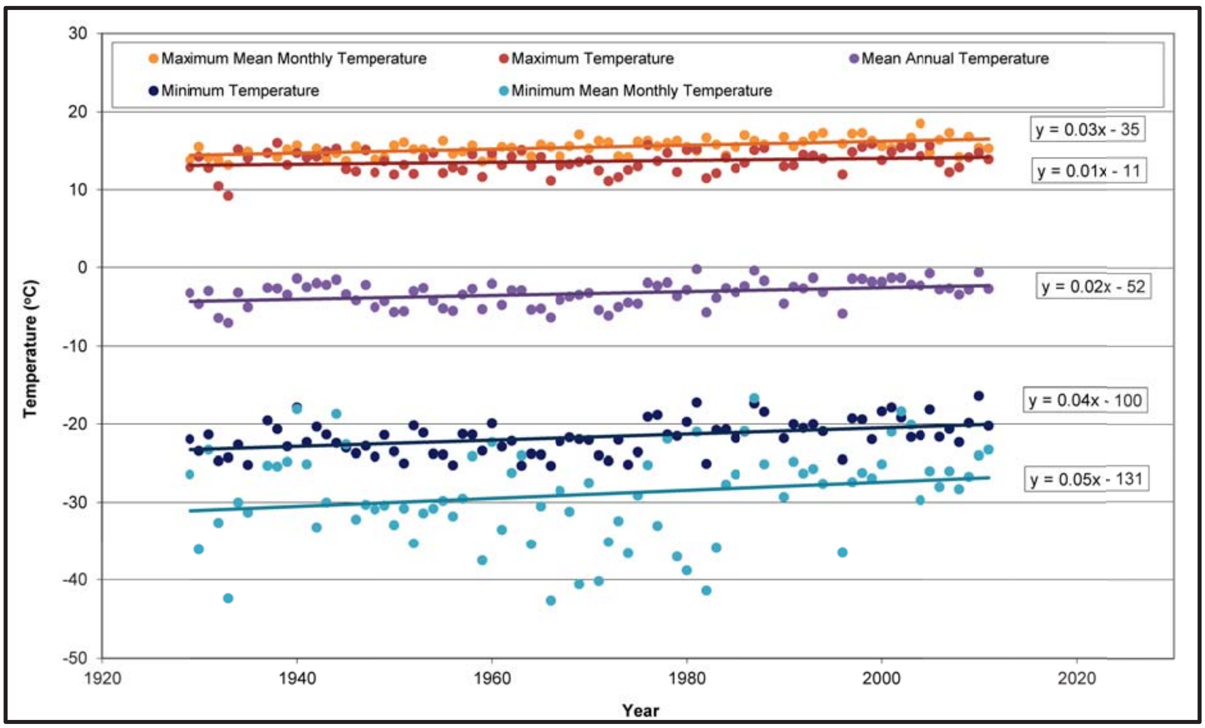
Warmer winter temperatures would raise freezing levels, shorten the period of snowfall, and increase the proportion of winter precipitation that would occur as rain, which combined with an earlier snowmelt, would lead to a smaller snowpack and earlier freshet peak flows. Temperatures are usually well below freezing throughout the winter, but warmer temperatures in the spring and fall shoulder seasons would result in a shorter freezing period. Greater winter precipitation may offset the effects of warmer temperatures on reducing the snowpack, and an increase in summer precipitation in the central Yukon region may result in higher summer flows, but this effect could be offset by higher summer temperatures and correspondingly higher evaporation.

2.1 CLIMATE TRENDS

The Mayo A climate station operated by Environment Canada (EC) has the longest and most complete climate record in the region of the Project, with 81 years of data from 1925 to 2012. The Pelly Ranch climate station has a shorter record, with 51 years of data from 1951 to 2012; however, the site is closer to the project site and was used to develop both the long term synthetic precipitation and temperature time series for site. Therefore, both datasets were used to assess long-term regional climate trends applicable to the Project site.

2.1.1 Temperature

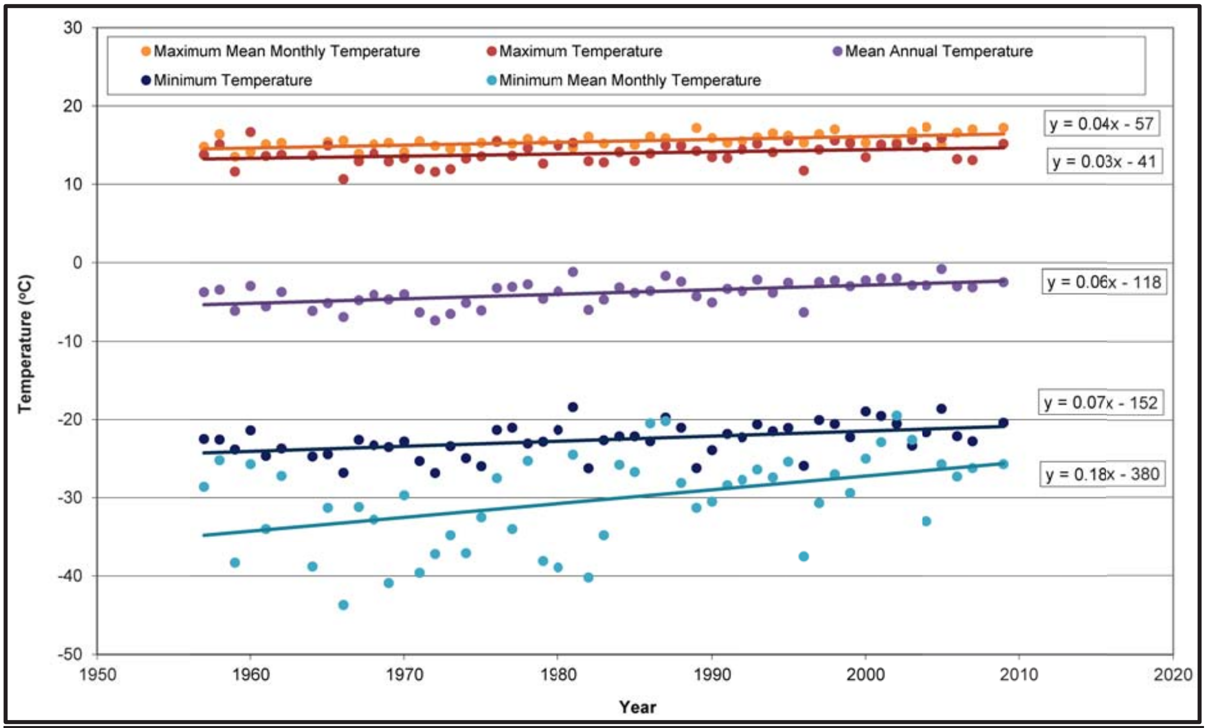
Trend plots of annual temperature at Mayo A and Pelly Ranch stations are presented on Figures 2.1 and 2.2, respectively. All the trends at both stations were found to be positive and to be significant at the 10% level. This significance level means that one can be 90% confident that these trends are not due to random chance. The mean annual temperature trends indicate increases of 0.2°C and 0.6°C per decade at Mayo A and Pelly Ranch, respectively. These values are generally consistent with the predictions in Table 2.1. The strongest increasing trends appear to be in the minimum mean monthly temperatures, with rates of 0.5°C and 1.8°C per decade for Mayo A and Pelly Ranch, respectively.



NOTES:

1. ALL TEMPERATURE TRENDS ARE SIGNIFICANT AT THE 0.10 SIGNIFICANCE LEVEL.
2. DATA ARE FOR THE ENVIRONMENT CANADA MAYO AIRPORT CLIMATE STATION.

Figure 2.1 Mayo A - Annual Temperature Trends

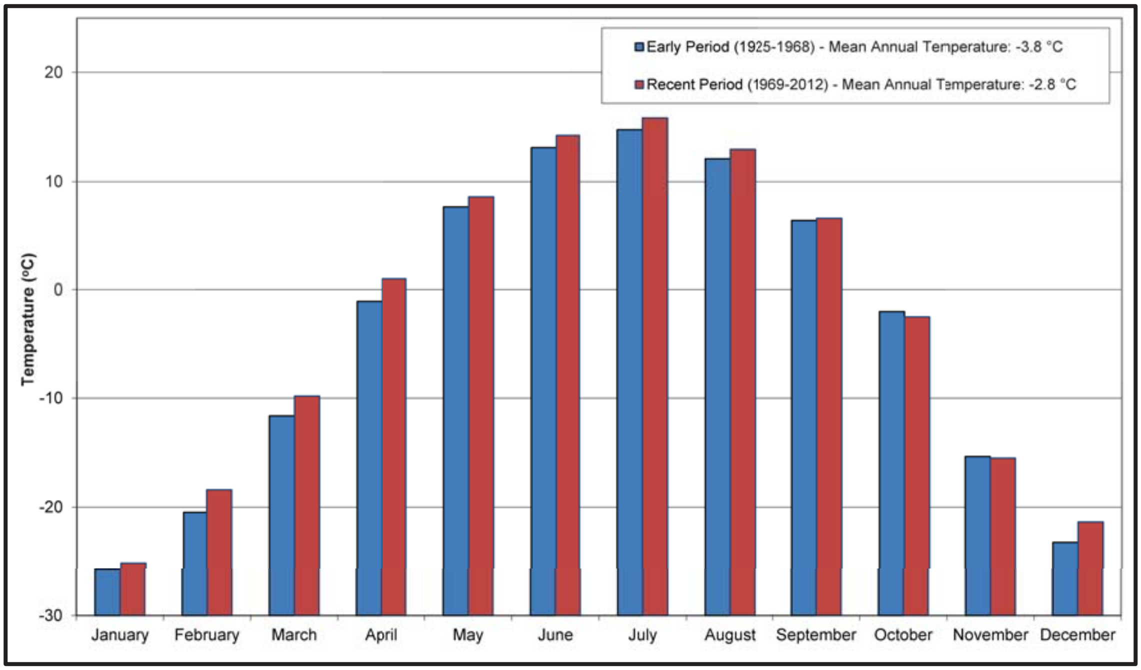


NOTES:

1. ALL TEMPERATURE TRENDS ARE SIGNIFICANT AT THE 0.10 SIGNIFICANCE LEVEL.
2. DATA ARE FOR THE ENVIRONMENT CANADA PELLY RANCH CLIMATE STATION.

Figure 2.2 Pelly Ranch - Annual Temperature Trends

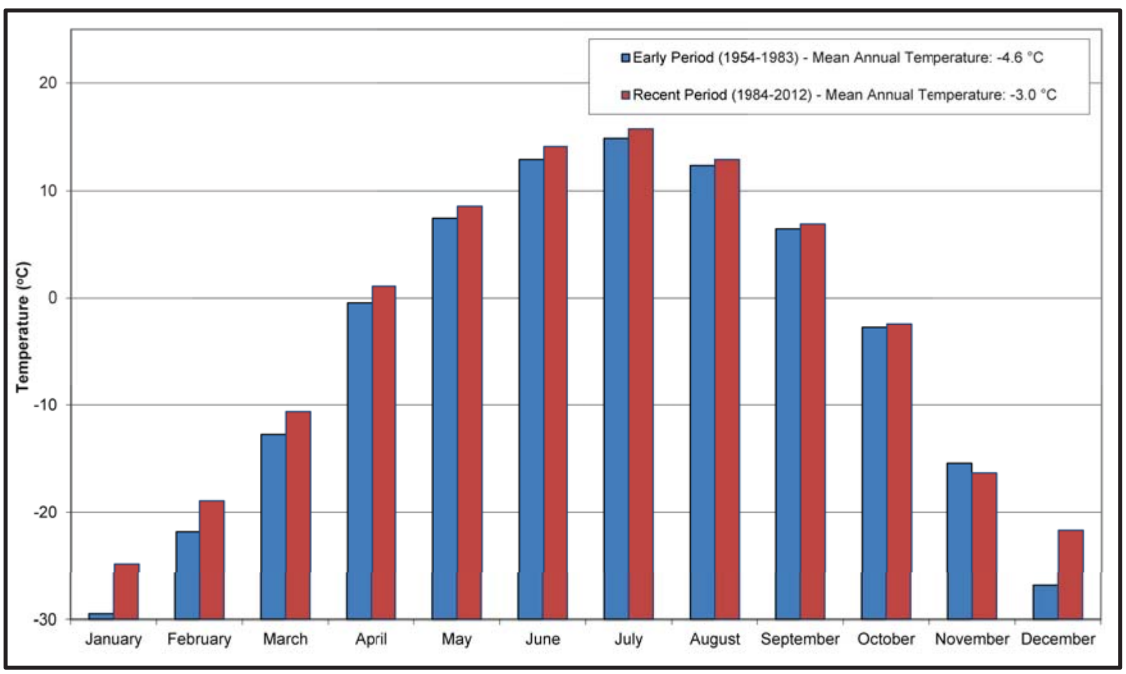
Temperatures appear to be increasing throughout the year, with the exception of the fall months, as indicated on Figures 2.3 and 2.4, which present the average monthly temperatures for the first and second halves of the temperature records, for Mayo A and Pelly Ranch, respectively. The greatest temperature changes for Mayo A occurred in the winter months of December and February through April, with an average difference of approximately 2°C, while at Pelly Ranch it was in December and January, with an average difference of approximately 5°C.



NOTES:

1. DATA ARE FOR THE ENVIRONMENT CANADA MAYO AIRPORT CLIMATE STATION.
2. THE COMPLETE DATA RECORD IS FOR THE PERIOD OF1925-2012, BUT A NUMBER OF YEARS HAVE INCOMPLETE DATA.
3. THE TWO PERIODS SHOWN REPRESENT AN EQUAL SPLIT OF THE DATA.

Figure 2.3 Mayo A – Monthly Mean Temperature



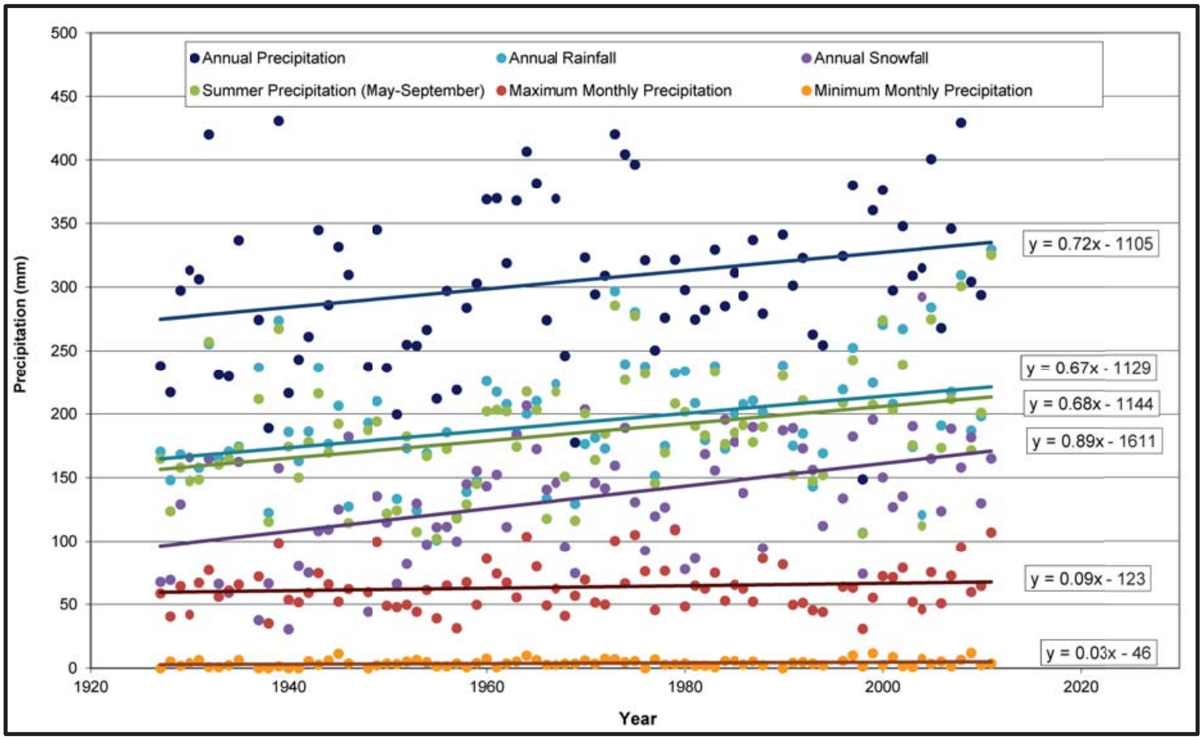
NOTES:

1. DATA ARE FOR THE ENVIRONMENT CANADA MAYO AIRPORT CLIMATE STATION.
2. THE COMPLETE DATA RECORD IS FOR THE PERIOD OF1954-2012, BUT A NUMBER OF YEARS HAVE INCOMPLETE DATA.
3. THE TWO PERIODS SHOWN REPRESENT AN EQUAL SPLIT OF THE DATA

Figure 2.4 Pelly Ranch – Monthly Mean Temperature

2.1.2 Precipitation

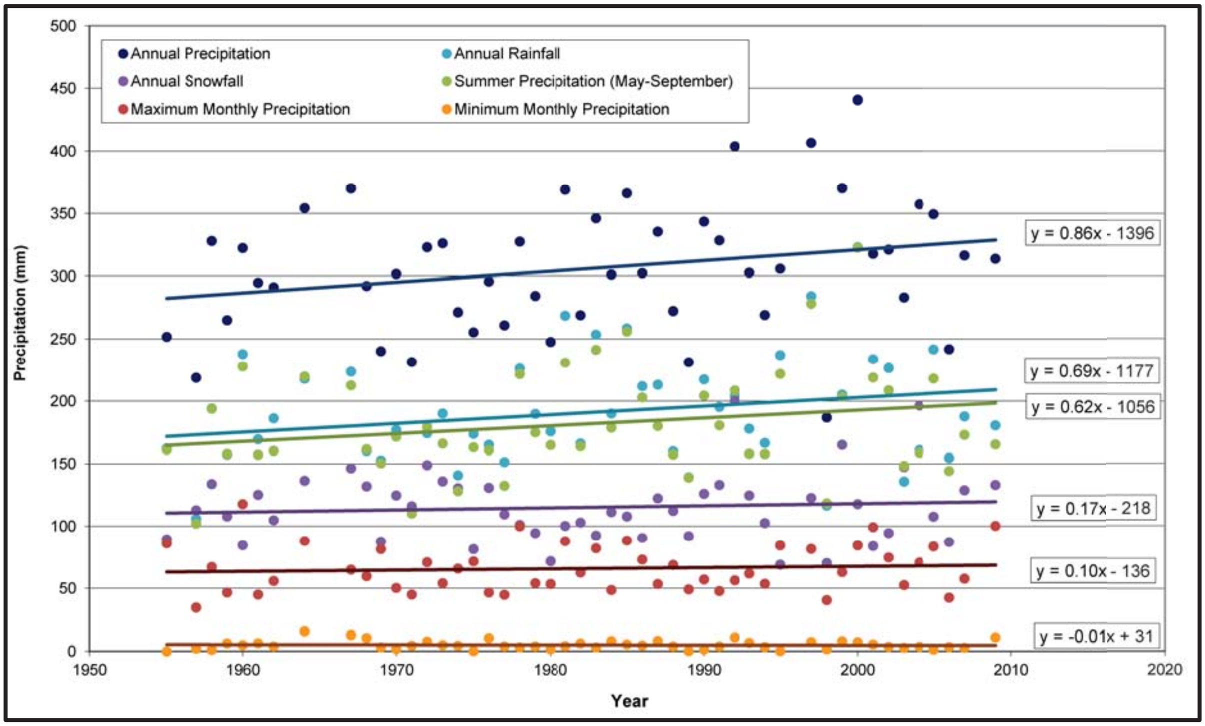
Six precipitation metrics were assessed and plots of annual trends for the Mayo A and Pelly Ranch stations are presented on Figures 2.5 and 2.6, respectively. All of the precipitation parameters except minimum monthly precipitation at Pelly Ranch demonstrate increasing trends. The annual precipitation and rainfall trends are statistically significant at the 10% level at both stations, and trends of annual snowfall, summer precipitation and minimum monthly precipitation at Mayo A are also significant at the 10% level. The annual precipitation trends indicate increases of 7.2 mm and 8.6 mm per decade at Mayo A and Pelly Ranch, respectively, while the annual rainfall trends indicate increases of 6.7 mm and 6.9 mm per decade, respectively. The directions and magnitudes of these trends generally agree with the predications from the PCIC presented in Table 2.1.



NOTES:

1. THE ANNUAL PRECIPITATION, RAINFALL , SNOWFALL, SUMMER PRECIPITATION, AND MINIMUM AND MAXIMUM MONTHLY PRECIPITATION ARE SIGNIFICANT AT THE 0.10 SIGNIFICANCE LEVEL.
2. DATA ARE FOR THE ENVIRONMENT CANADA MAYO AIRPORT CLIMATE STATION.

Figure 2.5 Mayo A – Annual Precipitation Trends

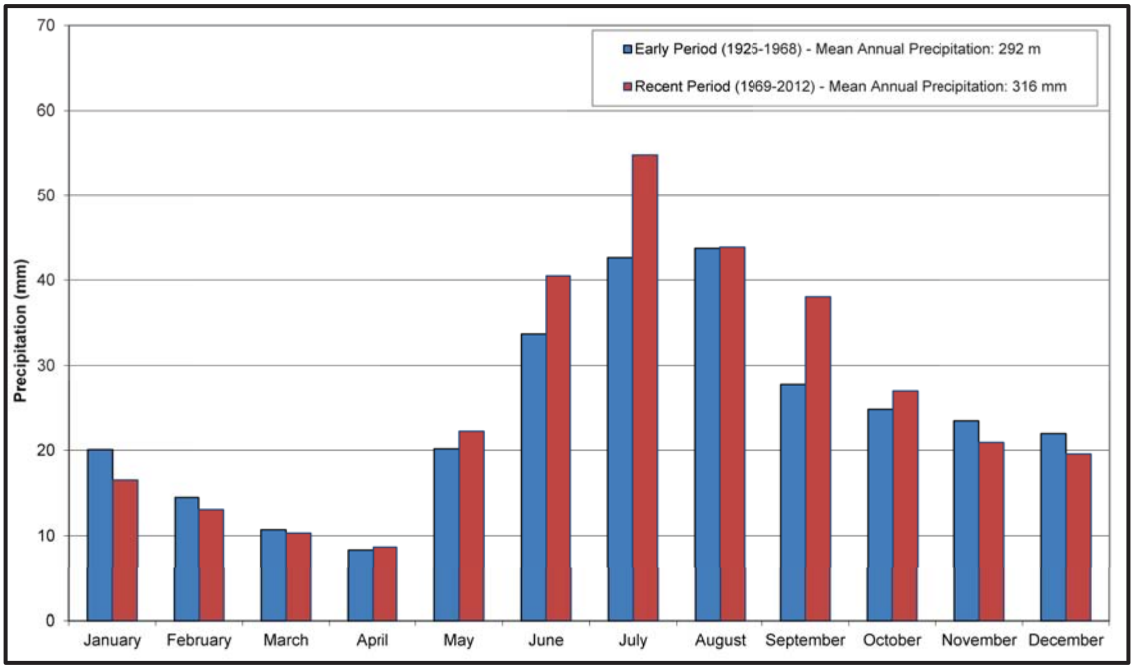


NOTES:

1. THE ANNUAL PRECIPITATION, RAINFALL, SNOWFALL, SUMMER PRECIPITATION, AND MINIMUM AND MAXIMUM MONTHLY PRECIPITATION ARE SIGNIFICANT AT THE 0.10 SIGNIFICANCE LEVEL.
2. DATA ARE FOR THE ENVIRONMENT CANADA PELLY RANCH CLIMATE STATION.

Figure 2.6 Pelly Ranch – Annual Precipitation Trends

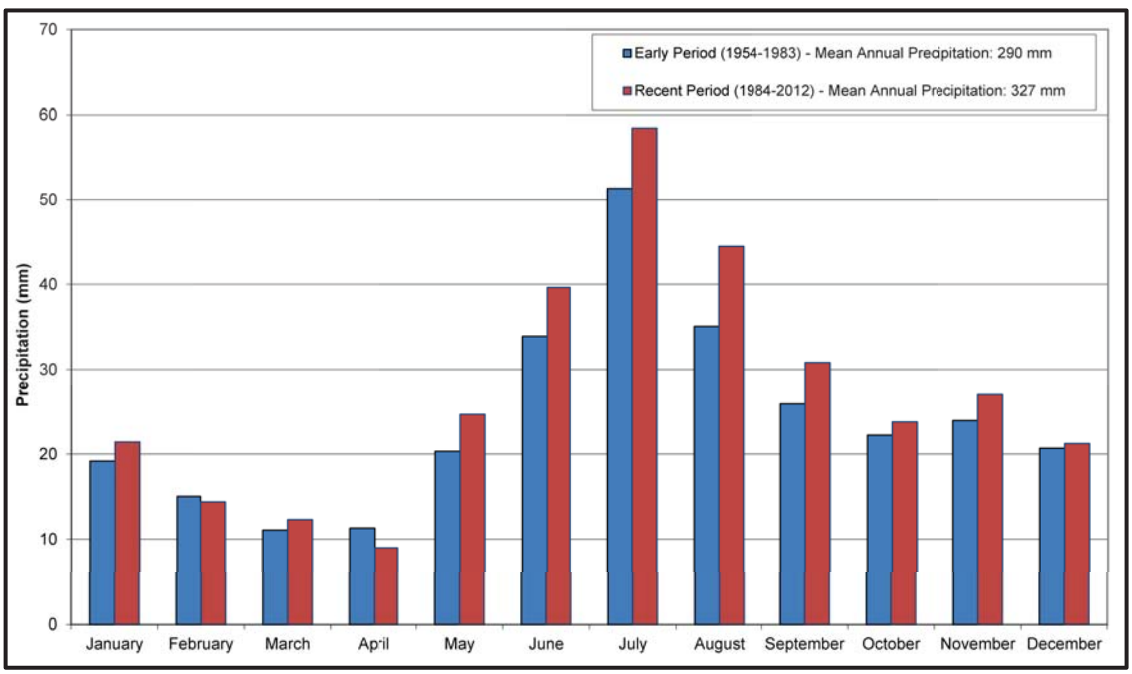
Precipitation appears to be increasing most notably during the non-freezing months of May to September, and only marginally increasing, or in some cases decreasing, during the winter months, as indicated on Figures 2.7 and 2.8, which present the average monthly precipitation values for the first and second halves of the temperature records, for Mayo A and Pelly Ranch, respectively. This result may be an artefact of the difficulty of accurately collecting winter precipitation data and it contradicts the findings of Werner et al. (2009), though it is generally consistent with the climate change patterns reported by Goulding (2011). The greatest increases in precipitation were 37% in September at Mayo A and 27% in August at Pelly Ranch.



NOTES:

1. DATA ARE FOR THE ENVIRONMENT CANADA MAYO AIRPORT CLIMATE STATION.
2. THE COMPLETE DATA RECORD IS FOR THE PERIOD OF1925-2012, BUT A NUMBER OF YEARS HAVE INCOMPLETE DATA.
3. THE TWO PERIODS SHOWN REPRESENT AN EQUAL SPLIT OF THE DATA.

Figure 2.7 Mayo A – Monthly Mean Precipitation



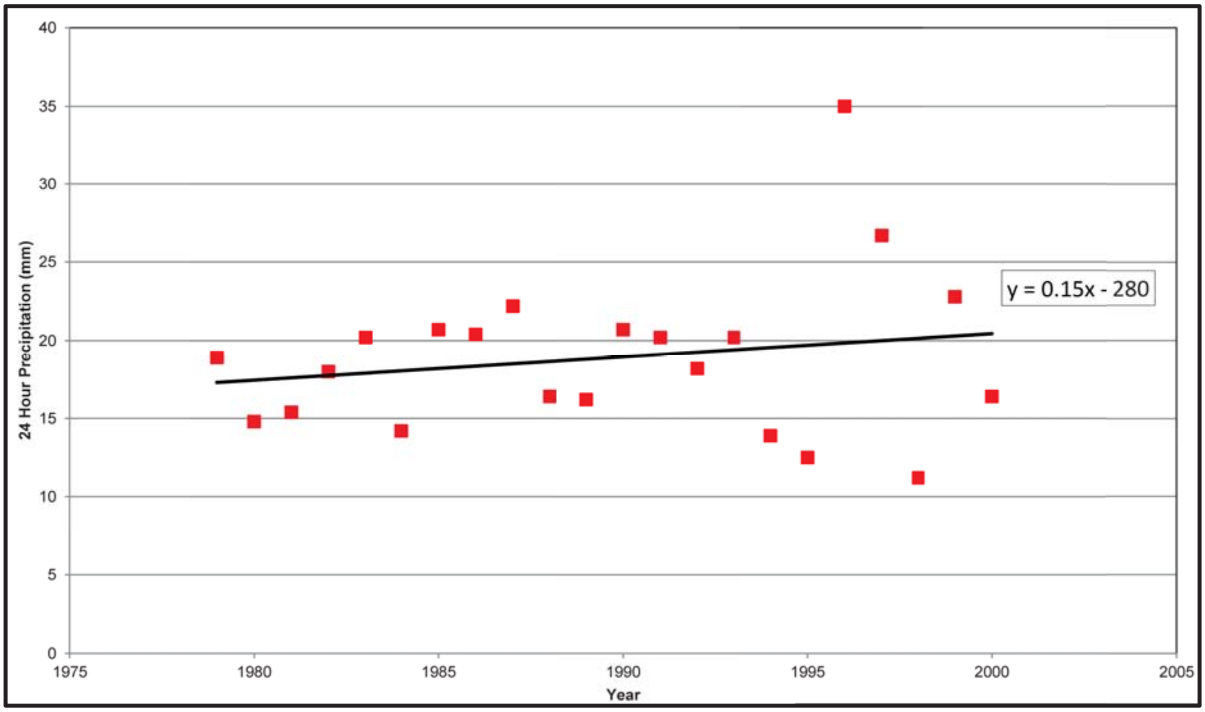
NOTES:

1. DATA ARE FOR THE ENVIRONMENT CANADA MAYO AIRPORT CLIMATE STATION.
2. THE COMPLETE DATA RECORD IS FOR THE PERIOD OF1925-2012, BUT A NUMBER OF YEARS HAVE INCOMPLETE DATA.
3. THE TWO PERIODS SHOWN REPRESENT AN EQUAL SPLIT OF THE DATA.

Figure 2.8 Pelly Ranch – Monthly Mean Precipitation

2.1.3 Extreme Precipitation

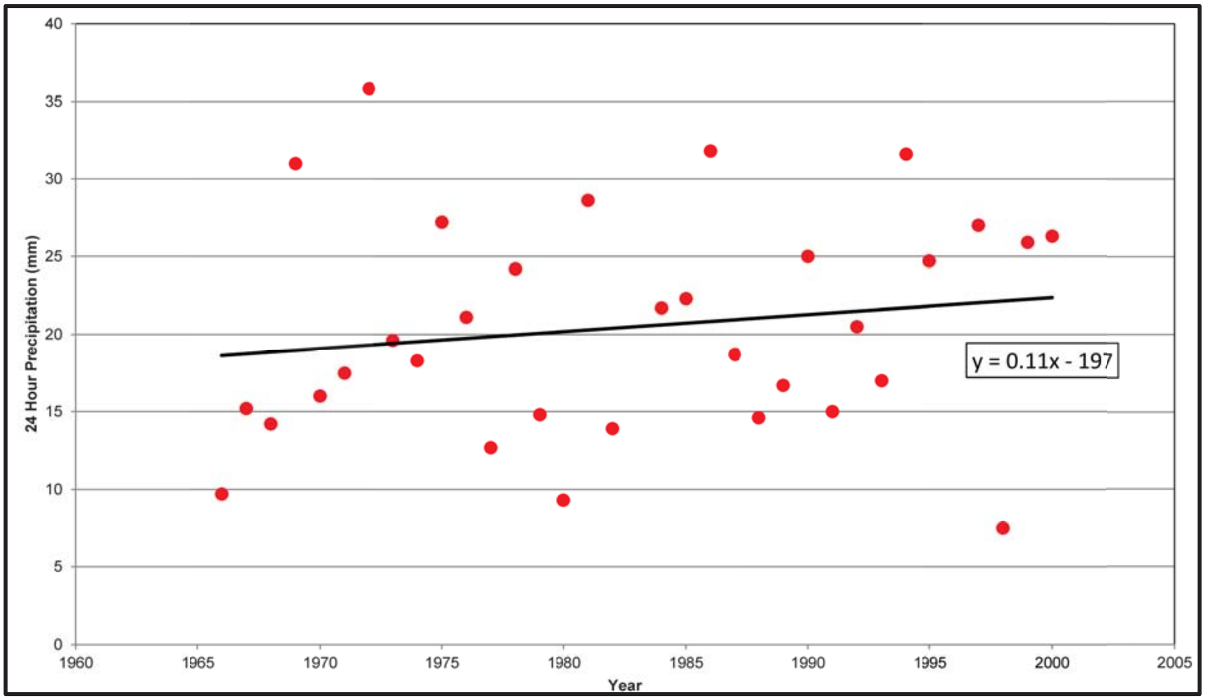
Trend plots of the annual extreme 24 hour precipitation values for Mayo A and Pelly Ranch are provided on Figures 2.9 and 2.10, respectively. These figures indicate increasing trends in annual extreme precipitation, although neither trend line is significant at a 10% level of significance. The increasing trends, however, are generally consistent with predictions of climate models (Dulière et al., 2009) based on the idea that greater atmospheric energy leads to greater climatic variability, including a greater frequency of extreme events.



NOTES:

1. THE TRENDLINE IS NOT STATISTICALLY SIGNIFICANT AT THE 0.10 LEVEL OF SIGNIFICANCE.
2. DATA ARE FOR THE ENVIRONMENT CANADA MAYO AIRPORT CLIMATE STATION.

Figure 2.9 Mayo A – Annual 24-hour Extreme Precipitation Trend



NOTES:
1. THE TRENDLINE IS NOT STATISTICALLY SIGNIFICANT AT THE 0.10 LEVEL OF SIGNIFICANCE.
2. DATA ARE FOR THE ENVIRONMENT CANADA PELLY RANCH CLIMATE STATION.

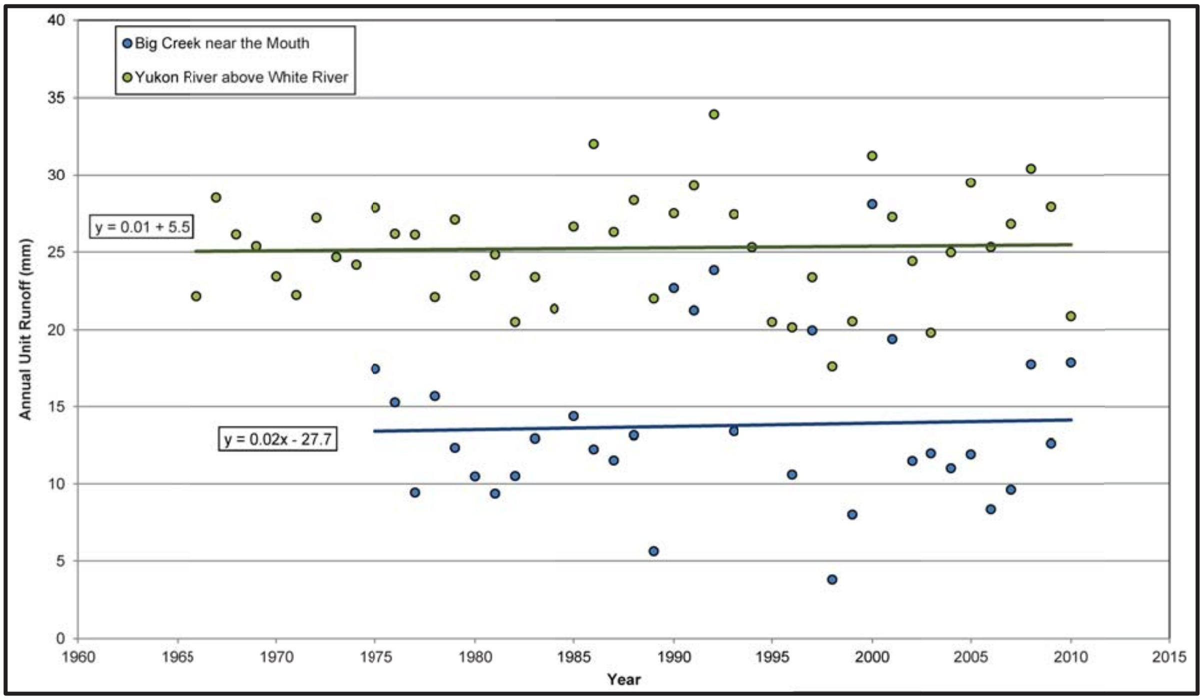
Figure 2.10 Pelly Ranch – Annual 24-hour Extreme Precipitation Trend

2.2 STREAMFLOW TRENDS

Insights into possible long-term climate effects on streamflow in the project area are provided by examining flow records from for the Yukon River above White River (09CD001), which has 45 years of continuous complete record from 1966 to 2010, and Big Creek near the mouth (09AH003), which has 33 years of complete record from 1975 to 2010 (3 years missing). The Yukon River station has the longest regional record available and its very large watershed size of 149,000 km^2 produces flows that are generally representative of overall conditions in the Southern Yukon. Data from the station on Big Creek were used to develop a synthetic flow series for the project. Big Creek has a much smaller 1,800 km^2 watershed and its flows are considered to be more representative of project area conditions. Streamflows in both systems could be affected by human influences like land-use changes, water extraction or logging, as well as natural disturbances like the spruce bark beetle. Accordingly, trends in streamflow, or lack thereof, at these stations cannot be directly attributed to climate trends or variability (Werner *et al.*, 2009). However, no other more relevant streamflow datasets are available, and therefore the data were used for trend analysis, but caution should be applied when interpreting the results.

2.2.1 Annual Runoff

Trend lines for the annual unit runoff at each station are provided on Figure 2.11, and indicate very slightly increasing trends at both stations, although neither is statistically significant at the 10% level. It can be concluded that annual runoff at these stations has not significantly changed over the past three to five decades, which suggests that the effects of increasing precipitation were minimal and/or offset by increasing evaporation associated with higher temperatures.



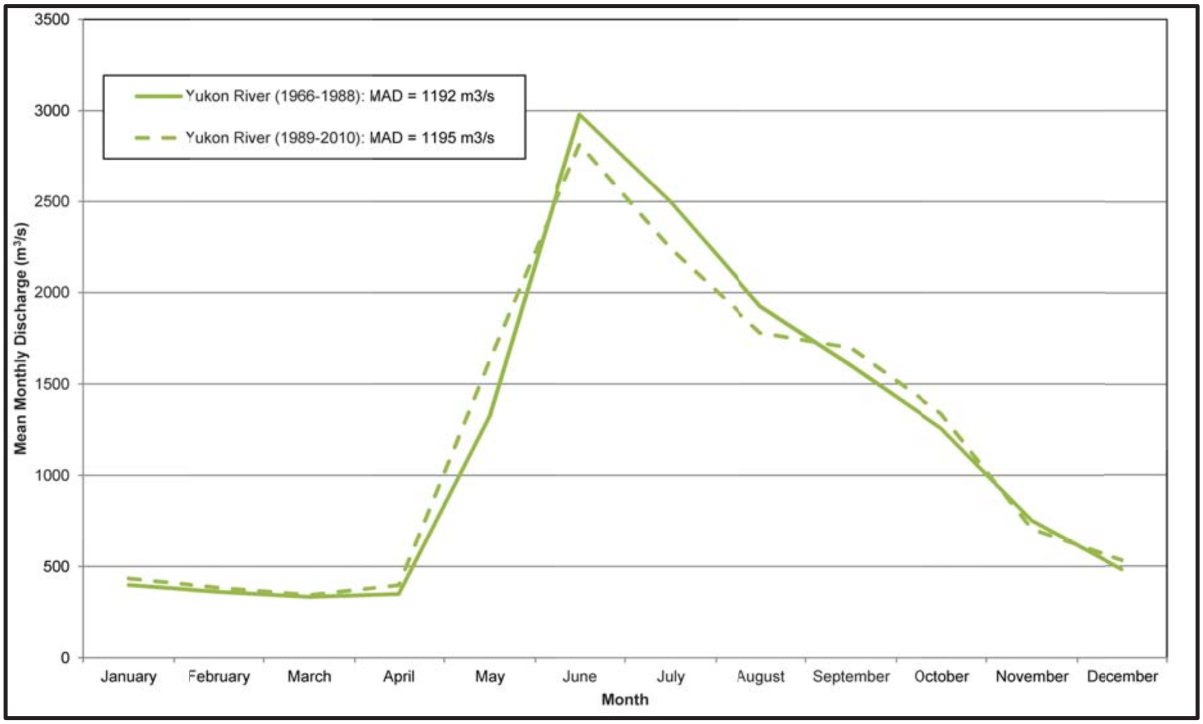
NOTES:
1. THE TRENDLINES ARE NOT STATISTICALLY SIGNIFICANT AT THE 0.1 LEVEL OF SIGNIFICANCE

Figure 2.11 Annual Mean Discharge Trends

2.2.2 Streamflow Patterns

To further investigate possible evidence of climate change effects, the mean annual hydrographs for two time periods were compared, for both the Yukon River and Big Creek. The time periods were selected according to the data available at each site, with the records split evenly at each site. The mean annual hydrographs for the Yukon River for the periods of 1966 to 1988 and 1989 to 2010 are presented on Figure 2.12. The hydrographs have almost identical mean annual discharges and have similar shapes, although the hydrograph for the latter period shows very slightly higher winter flows, slightly earlier and lower spring freshet flows, lower summer flows, and slightly higher fall flows. These changes are likely attributable to warming temperatures, which result in a slightly smaller snowpack and a greater proportion of the fall precipitation occurring as rain.

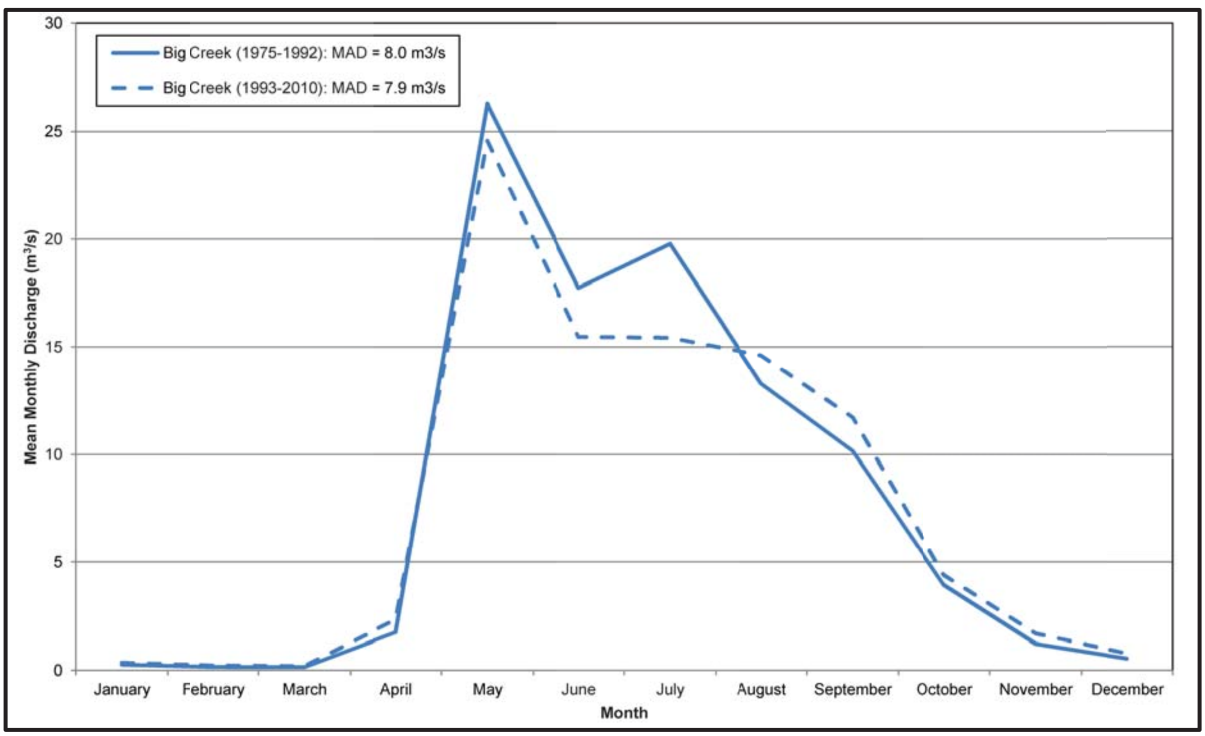
The annual hydrographs for Big Creek for 1975 to 1992 and 1992 to 2010 are presented on Figure 2.14. As for the Yukon River, the mean annual hydrographs for the two periods have almost identical mean annual discharges and the changes in shape are likely attributable to warming temperatures, with higher fall and winter flows and lower spring freshet and summer flows.



NOTES:

1. DATA ARE FOR THE WATER SURVEY OF CANADA STREAMFLOW STATION 09CD001 - YUKON RIVER ABOVE WHITE RIVER.

Figure 2.12 Mean Annual Hydrograph - Yukon River above White River



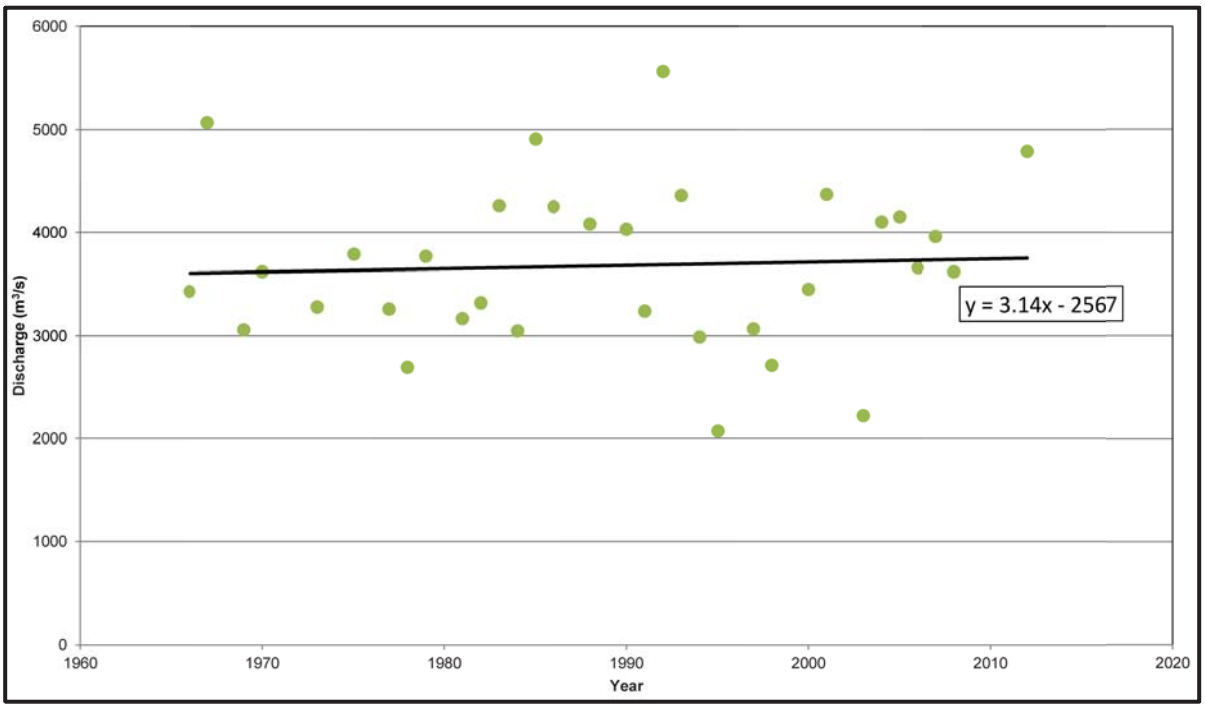
NOTES:

1. DATA ARE FOR THE WATER SURVEY OF CANADA STREAMFLOW STATION 09AH003 - BIG CREEK NEAR THE MOUTH.

Figure 2.13 Mean Annual Hydrograph - Big Creek near the mouth

2.2.3 Peak Flows

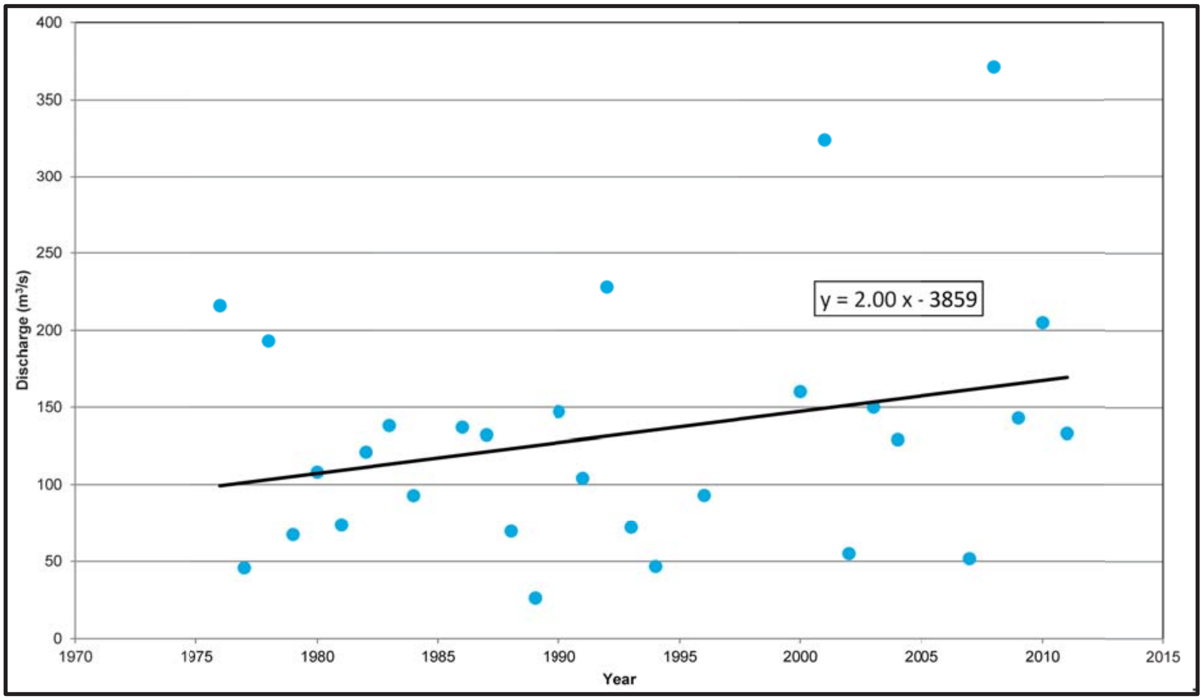
Annual peak instantaneous flows, as shown on Figures 2.14 and 2.15 for the Yukon River and Big Creek, respectively, indicate very slight increasing trends, although neither trend is statistically significant at the 10% level. All of the peak flows for the Yukon River are due to snowmelt, with the exception of the relatively low flow in 1991 that was caused by summer rainfall, and therefore the positive trend for the Yukon River data is possibly attributable to warmer spring temperatures accelerating the rate of snowmelt. However, the change is very minor, with the trend suggesting only a 4% increase over approximately 50 years. The Big Creek data demonstrate a much steeper trend, which is primarily attributable to the two largest events in the record, which occurred in 2001 and 2008. Both events occurred in mid to late summer, and therefore were likely associated with rainfall events. Given the positive trends in both systems, and the fact that most climate change studies predict increasing atmospheric energy and the associated increasing occurrence of high intensity rainfall, it is prudent and appropriate to increase historically based peak flow estimates. Accordingly, a +15% climate change factor was applied in developing the peak discharge design values presented in the project baseline hydrology report (KPL, 2013b). This factor is consistent with APEGBC guidelines (APEGBC, 2012).



NOTES:

1. THE TRENDLINE IS NOT STATISTICALLY SIGNIFICANT AT THE 0.1 LEVEL OF SIGNIFICANCE.
2. DATA ARE FOR THE WATER SURVEY OF CANADA STREAMFLOW STATION 09CD001 - YUKON RIVER ABOVE WHITE RIVER.

Figure 2.14 Yukon River - Annual Peak Instantaneous Flow Trend



NOTES:
1. THE TRENDLINE IS NOT STATISTICALLY SIGNIFICANT AT THE 0.1 LEVEL OF SIGNIFICANCE.
2. DATA ARE FOR THE WATER SURVEY OF CANADA STREAMFLOW STATION 09AH003 - BIG CREEK NEAR THE MOUTH.

Figure 2.15 Big Creek – Annual Peak Instantaneous Flow Trend

2.3 CLIMATE MODEL PROJECTIONS

Many global climate models (GCMs) have been produced by climate modelling centers for the IPCC assessments. These models are coupled atmosphere-ocean general circulation models and simulate physical processes of atmospheric and ocean circulation. The models produce a range of weather and climate variables that represent area averages within their grid reference. The model projections commonly use three greenhouse gas emission scenarios presented in the Special Report on Emission Scenarios (SRES, 2000), namely scenarios A1B, A2 and B1, which represent different population and economic growth projections along with social and environmental characteristics. The A1B scenario represents a convergent world with rapid economic growth, a population peak in 2050, a fast spread of new technology and a balanced emphasis on all energy sources. The A2 scenario represents a divided world with self-reliant nations, a continuously increasing population, a regional orientated economic development and slower technological changes. The B1 scenario represents a more integrated world with rapid economic growth focused on service and information, a population peak in 2050, reductions in material intensity, and a focus on resource efficient technology and global solutions (SNAP, 2013 and EC, 2013).

Regional climate models (RCMs) are used to dynamically downscale GCM results to a finer spatial resolution for specific areas of the world. ClimateWNA is a RCM developed by the Forest Conservation Genetics group at the University of British Columbia (Wang *et al.*, 2012), and calculates climate variables for specified climate normal periods (30 year periods) for locations based on coordinates and elevation in western North America. The ClimateWNA model also downscales and integrates data from a variety of GCMs to predict climate values for future periods in this century. Climate change projections for 2050 (2040 to 2069 climate normal period) were exported from the desktop version of the ClimateWNA program for the project location. The 2050 period was selected for the analysis because it is approximately the time when closure of the Casino Project is projected to take place. The results presented in Table 2.2 were derived from ten models and future emission scenarios recommended to provide a wide range of projected future change in both temperature and precipitation (Murdock and Spittlehouse, 2011). The results are presented as change from the ClimateWNA historic climate values for the period of 1961 to1990.

The Scenarios Network for Alaska and Arctic Planning (SNAP) has developed a statistically downscaled model, similar to an RCM, looking at a large region that includes Alaska, the Yukon, and British Columbia to Manitoba. The model results are provided in terms of a five model average output using the five models selected as the best performing GCMs across Alaska and the Artic. The model provides estimates for a variety of time periods. Projected changes in temperature and precipitation for 2050, relative to the climate normal period of 1961-1990, were estimated from the SNAP model maps for the project location, and are also presented in Table 2.2. The results presented are an average of the five models used within SNAP with separate results for each SRES emission scenario: A2, A1B and B1.

Table 2.2 also presents projected changes in temperature and precipitation at the project site, for 2055 relative to the 1961 to 1990 climate normal period, based on the historical climate trends presented in Section 2.1. The estimated climate normal values were taken from the ClimateWNA model and are similar to estimates from the SNAP model for the same time period. Projected change is only presented for trends that were found to be significant at the 10% level for each station.

Table 2.2 Temperature and Precipitation Projections for 2050 using Various Climate Models and Historical Trends

Source	Modelling Organization	Climate Model	Climate Scenario	Climate Projection	Period	Mean Temperature Change (^oC)							Mean Total Precipitation Change (%)		
						Annual	Warmest Month	Coldest Month	Winter	Spring	Summer	Autumn	Annual	Summer	Snowfall
ClimateWNA	Canadian Centre for Climate Modelling and Analysis	Third Generation Coupled Global Climate Model	A2	CCCMA CGCM3 A2 run 4	2050	3.2	3.3	5.0	4.6	2.6	2.6	3.1	25%	25%	11%
			A2	CCCMA CGCM3 A2 run 5	2050	2.6	3.5	2.7	3.8	1.6	2.5	2.4	16%	17%	8%
	UK MetOffice	Hadley Centre Couple Model v3	B1	UKMO HCM3 B1 run 1	2050	1.4	2.5	-1.0	1.2	0.7	2.2	1.6	15%	13%	11%
		Hadley Centre Global Enviromental Model v1	A1B	UKMO GEM1 A1B run 1	2050	4.5	2.5	5.0	6.0	4.4	2.8	4.9	24%	18%	9%
	CSIRO Atmospheric Reaserach, Australia	Atmospheric Research Mark 3.0 Climate Model	B1	CSIRO Mk3.0 B1 run 1	2050	1.7	1.3	1.9	1.8	1.7	1.3	2.2	5%	0%	2%
	Meteorological Research Institue, Japan	Coupled Global Climate Model v2.3.2A	B1	MRI-CGCM2.3.2A B1 run 5	2050	0.9	0.6	0.9	1.0	1.2	0.5	1.1	1%	-3%	2%
	Max Planck Institue for Meteorology, Germany	ECHAM Model	A1B	MPI ECHAM5 A1B run 3	2050	3.0	2.3	3.5	4.3	3.7	2.0	2.2	18%	16%	10%
	National Center for Atmospheric Research, USA	Community Climate System Model v3.0	A1B	NCAR-CCSM3.0 A1B run 5	2050	4.0	3.1	7.2	5.0	4.2	3.0	3.8	23%	23%	5%
	NASA/Goddard Institue for Space Studies, USA	GISS ModelE-H	A1B	GISS-EH A1B run 3	2050	1.0	0.5	3.5	2.6	0.4	0.3	0.8	5%	8%	0%
	NOAA Geophysical Fluid Dynamics Laboratory, USA	Coupled Climate Model v2.1	A2	GFDL-CM2.1 A2 run 1	2050	2.2	-0.6	3.3	3.8	2.7	0.6	1.9	12%	4%	13%
SNAP	5 Model Average		A2	MPI ECHAM5, CFDL CM2 1, MIROC3.2 (medres), UKMO HADCM3, CCMA CGCM3 1	2050	2.3	-	-	2.4	-0.1	0.3	2.4	5%	22%	-
			A1B		2050	2.4	-	-	2.7	-0.1	0.5	2.4	14%	31%	-
			B1		2050	2.3	-	-	2.0	-0.1	0.3	0.7	16%	17%	-
Historical MSC Analysis - Projected	Pelly Ranch Climate Trends				2055	4.8	-	-	-	-	-	-	20%	-	-
	Mayo A Climate Trends				2055	1.6	-	-	-	-	-	-	17%	27%	43%

NOTES:

1. INFORMATION REGARDING THE CLIMATEWNA MODEL CAN BE FOUND AT THE FOLLOWING LINK: http://www.genetics.forestry.ubc.ca/cfcg/ClimateWNA/ClimateWNA.html
2. INFORMATION REGARDING THE SNAP MODEL (SCENARIOS NETWORK FOR ALASKA AND ARCTIC PLANNING) CAN BE FOUND AT THE FOLLOWING LINK: http://www.snap.uaf.edu/
3. THE KP ANALYSIS - PROJECT VALUES REQUIRED APPLICATION OF A TREND TO THE BASELINE VALUES AND A BASELINE YEAR TO CALCULATE THE PROJECT VALUE. TO ACHIEVE THIS, THE CENTRAL YEAR OF THE 1961-1990 PERIOD (1975) WAS USED AS THE STARTING YEAR AND THE CENTRAL YEAR OF THE 2040-2069 PERIOD (2055) WAS USED AS THE PROJECTION YEAR. VALUES WERE ONLY CALCULATED USING TRENDS THAT WERE ASSESSED TO BE SIGNIFICANT AT THE 10% LEVEL.
4. MEAN WINTER, SPRING, SUMMER AND AUTUMN TEMPERATURES BREAK THE YEAR INTO PERIODS OF THREE MONTHS (IE WINTER INCLUDES DEC., JAN., AND FEB.) WHILE MEAN SUMMER PRECIPITATION INCLUDES MAY TO SEPT.
5. THE ANNUAL PRECIPITATION IS COMPRISED OF MORE THAN JUST SUMMER PRECIPITATION AND SNOWFALL. IT ALSO INCLUDES SPRING AND FALL RAINFALL.

Table 2.3 summarizes the mean projected change from each model or trend for each climate parameter. Although the results from different models within ClimateWNA predict a wide range of temperature and precipitation changes, the mean annual temperature and precipitation change for all 10 models using ClimateWNA and all 3 scenarios using SNAP are fairly consistent. The average seasonal temperature and precipitation results diverge, but show generally increasing trends consistent with regional predictions.

Table 2.3 Temperature and Precipitation Change Projections for 2050 using Various Climate Models and Historical Trends

Source		Period	Mean Temperature Change (°C)							Mean Total Precipitation Change (%)		
			Annual	Warmest Month	Coldest Month	Winter	Spring	Summer	Autumn	Annual	Summer	Snowfall
ClimateWNA	Mean Projected Change	2050	2.5	1.9	3.2	3.4	2.3	1.8	2.4	14%	12%	7%
SNAP	Mean Projected Change	2050	2.3	-	-	2.3	-0.1	0.4	1.8	11%	1%	-
Historical MSC Analysis - Projected	Mean Projected Change	2055	3.2	-	-	-	-	-	-	18%	-	-
Projected Change for Project		2050	2.5	2.0	3.0	-	-	-	-	15%	12%	10%

NOTES:
1. MEAN, MIN AND MAX PROJECTED CHANGE FOR EACH SOURCE PRESENTED AS CHANGE FROM 1961-1990 CLIMATE NORMAL.
2. ONLY MEAN PROJECTED CHANGE PRESENTED FOR SNAP AND HISTORICAL MSC ANALYSIS DUE TO REDUCED NUMBER OF INDIVIDUAL PROJECTIONS.

In general, the values in Table 2.3 suggest the following possible climate changes:
1. Mean annual temperature will rise by roughly 2.5 °C by 2050, and the rise in temperature will be greater in the winter and smaller in the summer.
2. Mean annual precipitation will increase in the order of 15%.
3. Both rainfall and snowfall will increase.

These changes were used to predict possible climate conditions for the project area in 2050, as shown in Table 2.4.

Table 2.4 Temperature and Precipitation Projections for the Project Area in 2050

Source	Period	Mean Temperature (°C)			Mean Total Precipitation (%)		
		Annual	Warmest Month	Coldest Month	Annual	Summer	Snowfall
Baseline	1961-1990	-3.6	11.2	-18.7	490	285	205
	1957-2012	-3.0	11.0	-18.0	460	305	155
Projected Project Conditions	2050	-1.1	13.2	-15.7	550	320	230

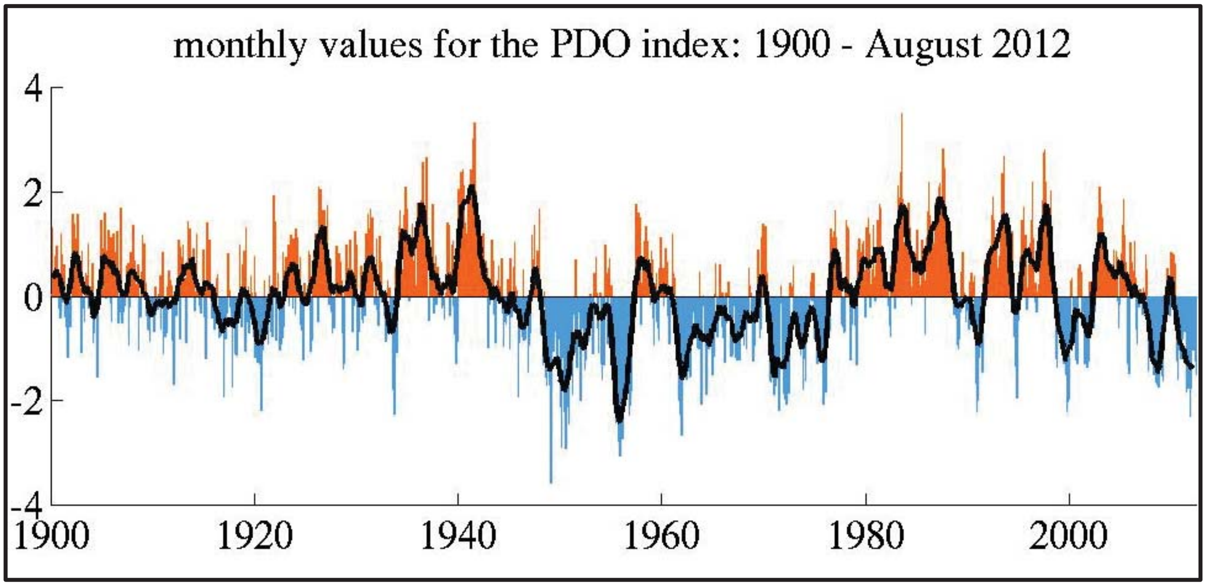
NOTES:
1. BASELINE CLIMATE VALUES FROM KPL, 2013a ARE PRESENTED FOR THE PERIOD 1957 TO 2012. BASELINE VALUES FOR 1961 TO 1990 ARE CALCULATED FROM THE LONG-TERM SYNTHETIC DATASET DEVELOPED IN KPL, 2013a.
2. PROJECTED PROJECT CONDITIONS ARE ESTIMATED FROM PROJECTED CHANGES PRESENTED IN TABLE 2.3 OVER THE BASELINE CONDITIONS FOR 1961 TO 1990.

Further projections about the future climatic and hydrologic conditions in the project region can be inferred from the summary in Table 2.3. For example, an increase in snowfall and warmer spring temperatures will likely result in an earlier onset of the spring snowmelt freshet and an increase in its magnitude, whereas an increase in summer precipitation will likely not produce a corresponding increase in summer runoff due to the offset caused by higher summer temperatures and a corresponding increase in evaporation. Such changes are consistent with regional predictions presented elsewhere (Werner *et al.*, 2009, Goulding, 2011, Hennessey *et al.*, 2011)

2.4 CLIMATE CYCLES

One of the primary factors inhibiting the detection of changing patterns in local climate and streamflow records is the influence of cyclical climate patterns. A number of “normal” cyclical climate patterns occur regularly over both short-term and relatively long-term periods. A variety of different climate patterns have been identified in the literature, but the two most recognized phenomena that influence conditions in the Yukon are the Pacific Decadal Oscillation (PDO), which has both warm and cool phases that typically persist for 20 to 30 years, and the El Nino Southern Oscillation (ENSO), which operates on a shorter time scale with phases typically lasting for 6 to 18 months (Mantua, 2001). Both phenomena are defined by changes of surface water temperatures in the Pacific Ocean, and are associated with corresponding changes in climate. The PDO has the strongest signature, as ENSO influences on climate in a region are strongly dependent on the phase of the PDO (McCabe and Dettinger, 1999). The cool phase of the PDO is correlated with colder temperatures and above average winter precipitation, snowpack and annual runoff (Mantua, 2001). These conditions tend to be even more pronounced if the ENSO is in phase.

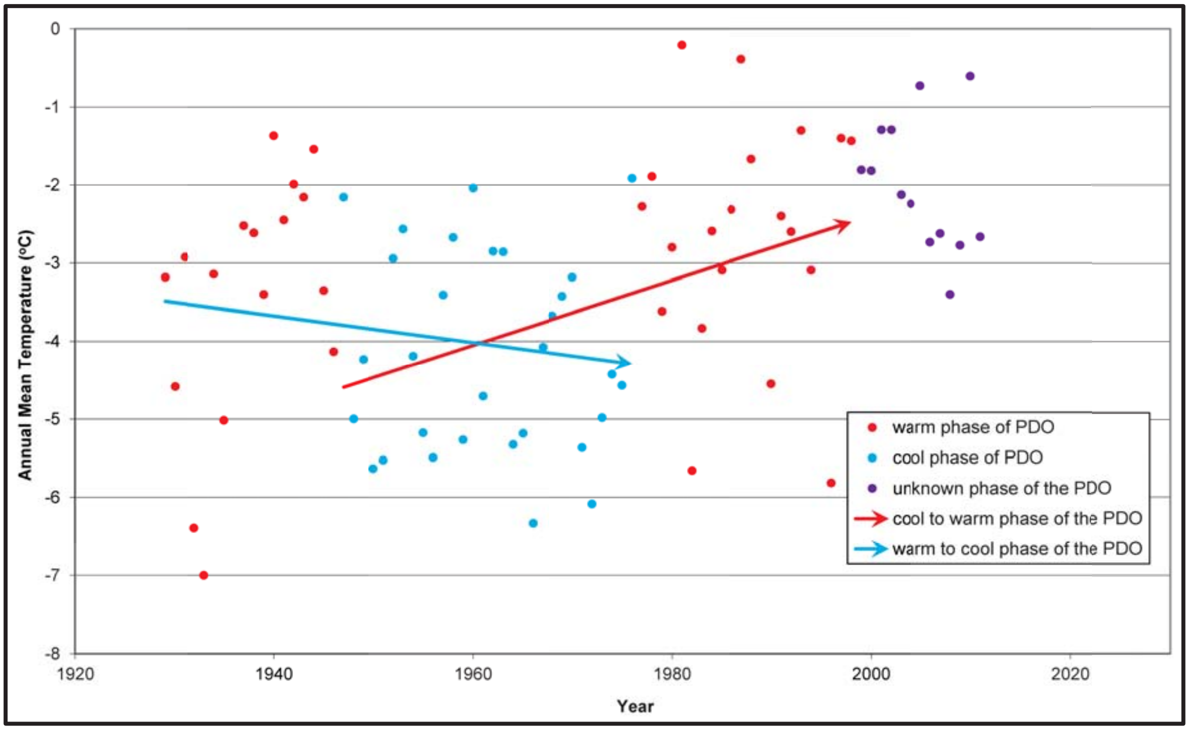
As indicated on Figure 2.16, the 1925 to 2012 climate record for the Mayo A station spans three PDO cycles: a warm phase up to approximately 1946, followed by a cool phase up to 1976, and then finally a warm phase for the period from 1977 to the mid to late 1990s (Werner *et al*., 2009). There is some debate about classifying the past decade or so, but it appears that we have recently, or are currently, entering a cooling phase of the PDO. Correspondingly, it is possible that the annual mean temperature trend may actually decline or remain relatively constant over the next two to three decades.



NOTES:
1. SOURCE: JOINT INSTITUTE FOR THE STUDY OF THE ATMOSPHERE AND OCEAN.

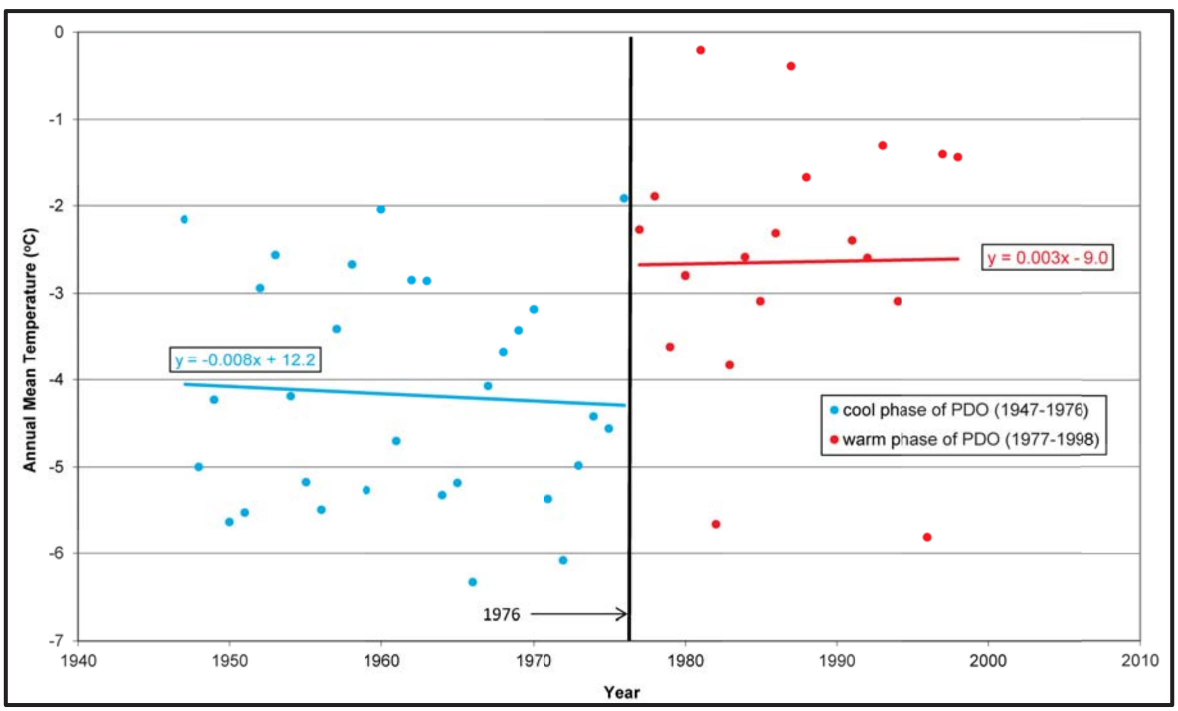
Figure 2.16 The Pacific Decadal Oscillation Index for the 20th and 21st Centuries

As the climate record for the Mayo A station spans at least three PDO phases, it is not surprising that the historical data indicate moderate trends, with the warm and cool phases having offsetting effects. However, if one was to consider a shorter time period, which is commonly done in the literature, one might delineate more pronounced trends, which are often incorrectly attributed to climate change. For instance, if one was to consider the period of 1947 to 1998, which covers a cool phase and then a warm phase of the PDO, it is not surprising that the data indicate markedly rising temperatures, as demonstrated by the red trend line shown on Figure 2.17. In contrast, if one was to consider the period of 1925 to 1976, which covers a warm phase and then a cool phase of the PDO, an opposite trend is apparent, as indicated by the blue line on Figure 2.17. These are examples of climate cycle effects, as opposed to climate change effects. The contention that the PDO is largely responsible for the observed temperature trends is further supported by Figure 2.18, which shows that the temperature trends within the last two PDO phases were remarkably flat, and that there was a sudden shift or step in the temperature patterns that occurred on or about 1976/77, coincident with the shift in the PDO. A similar pattern is evident in the temperature data for Pelly Ranch, as indicated on Figure 2.19.



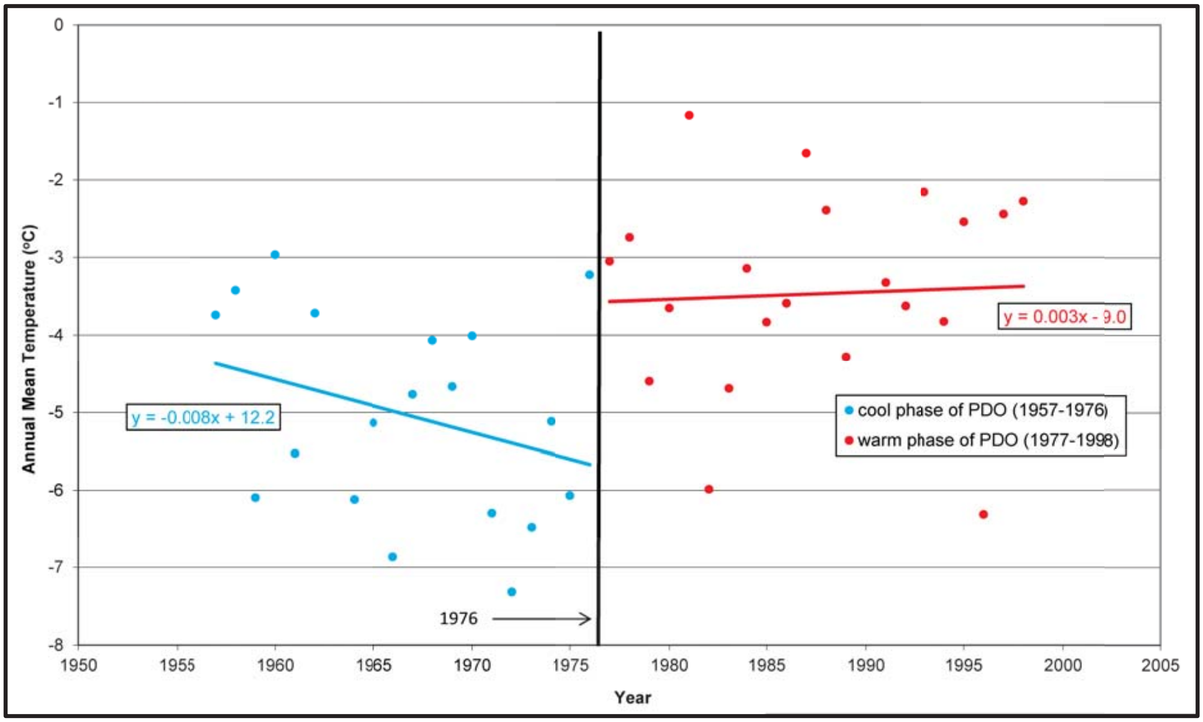
NOTES:
1. DATA ARE FOR THE ENVIRONMENT CANADA MAYO AIRPORT CLIMATE STATION.

Figure 2.17 Mayo A – PDO and Annual Mean Temperature Trends



NOTE:
1. DATA ARE FOR THE ENVIRONMENT CANADA MAYO AIRPORT CLIMATE STATION

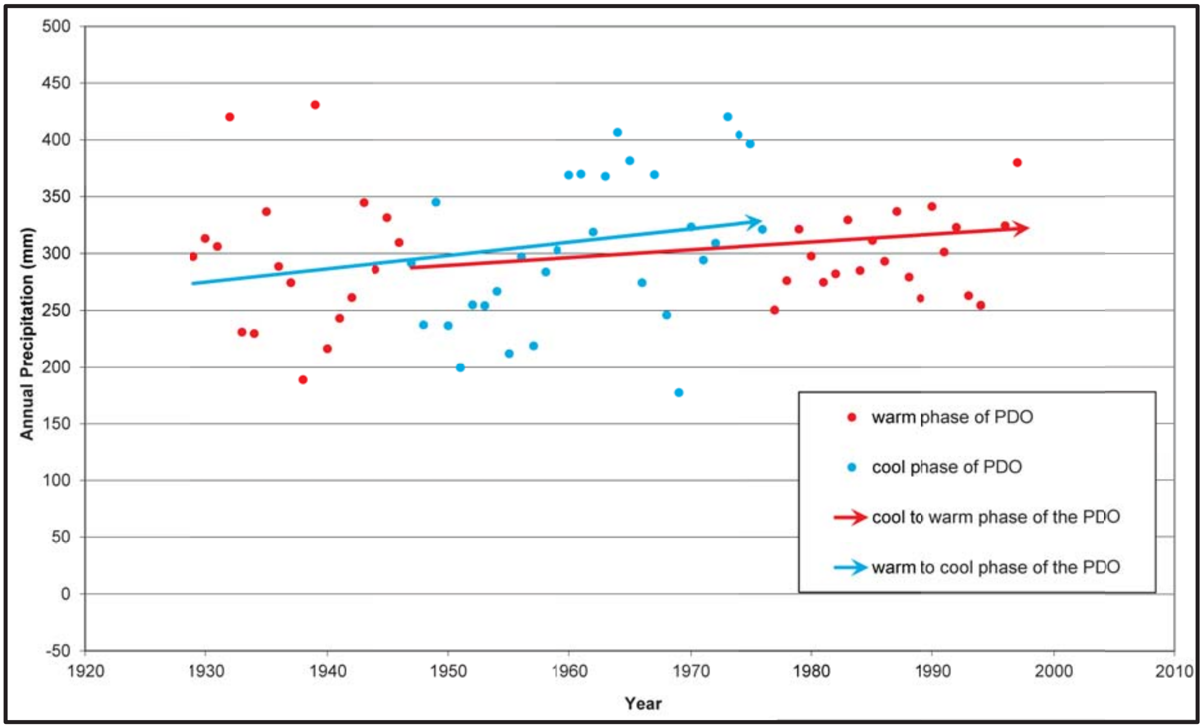
Figure 2.18 Mayo A – Annual Mean Temperatures in PDO Phases



NOTE:
1. DATA ARE FOR THE ENVIRONMENT CANADA PELLY RANCH CLIMATE STATION

Figure 2.19 Pelly Ranch – Annual Mean Temperatures in PDO Phases

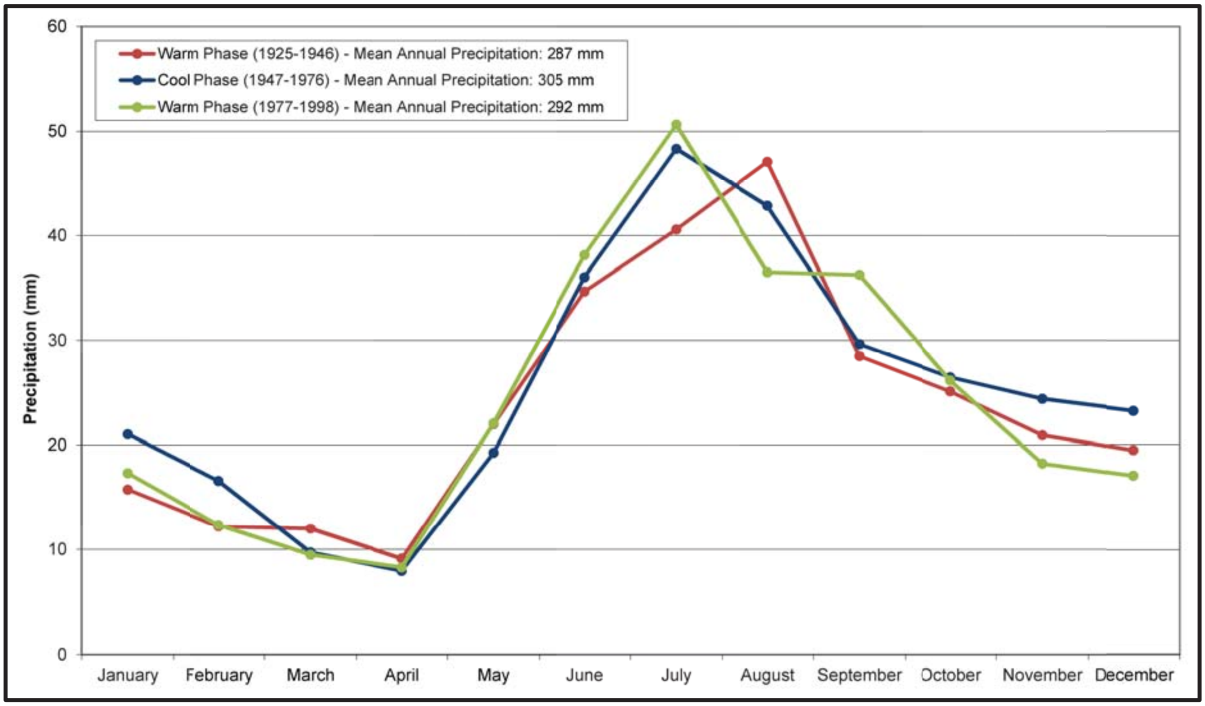
Interestingly, the corresponding plots for annual precipitation at Mayo A, as shown on Figure 2.20, indicate increasing trends for both the 1925-1946 and 1947-1998 time periods, which suggests that precipitation is likely less influenced by the PDO than temperature, and that precipitation consistently has a very slightly increasing trend. A similar plot is not provided for Pelly Ranch because its database only covers one cold and one warm phase of the PDO.



NOTE:
1. DATA ARE FOR THE ENVIRONMENT CANADA MAYO AIRPORT CLIMATE STATION

Figure 2.20 Mayo A – PDO Annual Precipitation Trends

Figure 2.21, which presents distributions of mean monthly precipitation for Mayo A for the three phases of the PDO, illustrates that precipitation conditions were very similar amongst the three phases, with the only notable difference being higher winter precipitation during the cool phase.

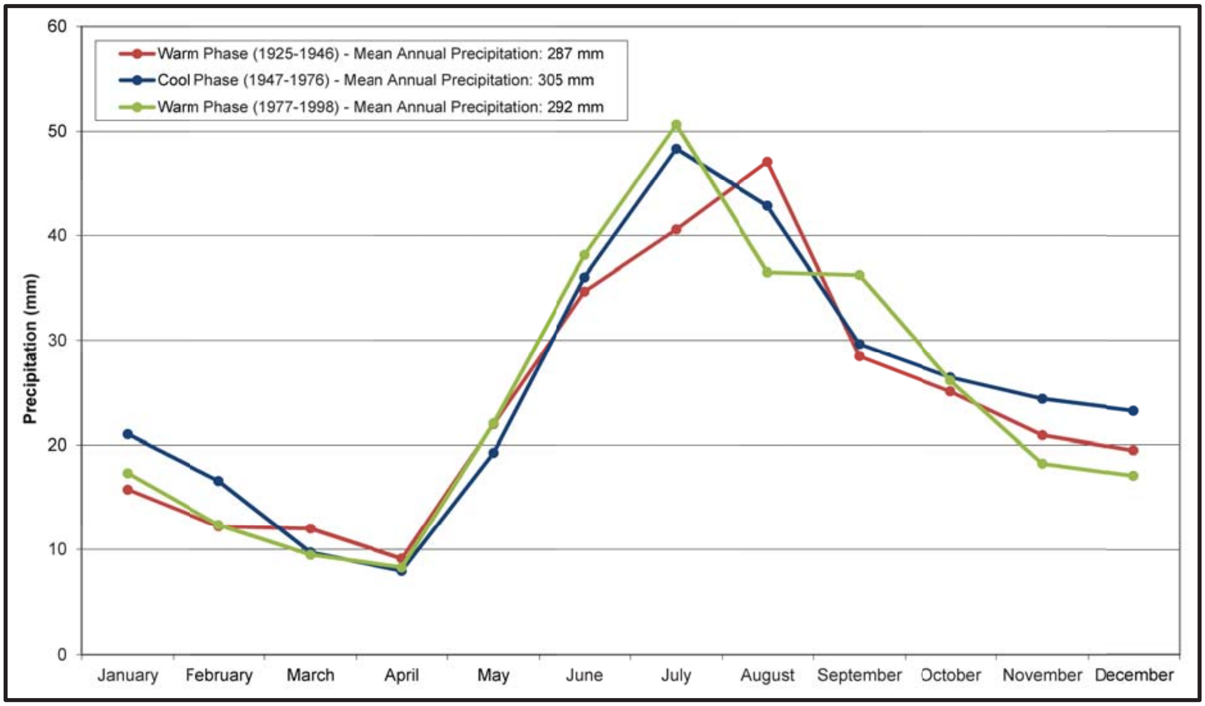


NOTE:

1. WARM AND COOL PHASES REFERE TO THE PHASES OF THE PDO.
2. DATA ARE FOR THE ENVIRONMENT CANADA MAYO AIRPORT CLIMATE STATION.

Figure 2.21 Mayo A – PDO and Monthly Mean Precipitation Patterns

A similar plot of mean monthly temperatures, as shown on Figure 2.22, indicates that with the exception of January, there were almost identical temperatures in the 1925-1946 warm phase and the 1947-1976 cool phase, but that temperatures were notably higher (~ 2 C) during the spring and summer months of the more recent 1977-1998 warm phase. These patterns suggest that recent climate change may be occurring irrespective of the PDO, since the most recent warm phase is annually 0.7 C warmer on average than the previous warm phase, and most clearly warmer from February through August. Also notable is that the most pronounced difference between the temperatures of the warm and cold phases is in January, which suggests that the common conclusion that winter temperatures in the Yukon have experienced the greatest increases, as discussed in Section 2.1, may be more related to the PDO than climate change.



NOTE:

1. WARM AND COOL PHASES REFERE TO THE PHASES OF THE PDO.
2. DATA ARE FOR THE ENVIRONMENT CANADA MAYO AIRPORT CLIMATE STATION.

Figure 2.22 Mayo A – PDO and Monthly Mean Temperature Patterns

2.5 ENGINEERING DESIGN CONSIDERATIONS

The climate at any particular location in the world is never constant, regardless of whether or not climate change, as defined by the IPCC (see introduction), is occurring, and consequently the engineering of a mine must always consider the variability of climate and the potential magnitude of climatic and associated hydrologic extremes. The uncertainty of hydroclimatic conditions, with respect to water supply and water management, is typically considered in a Project design process through the use of factors of safety and by incorporating adaptability into the designs and operating plans for a mine. Consequently, mine structures are inherently well-suited to accommodate possible effects due to climate change. Nonetheless, in order to account for the potential climate change related increases in the variability and magnitude of hydroclimatic events, efforts are made to quantify those changes, such as described in this report, and design factors of safety and stochastic modelling parameters are modified accordingly. For example, the peak design flow procedure for the Casino Project includes a climate change adjustment of +15%, and although this value is somewhat arbitrarily selected, it is consistent with professional practice guidelines (APEGBC, 2012) and with general practices as determined through attendance at various climate change symposiums and discussions with industry experts.

In addition to water management related issues, climate change has implications for the design, operation and maintenance of civil infrastructure (Hinkel *et al.*, 2003; Instanes, 2003). Warmer temperatures could substantially alter the permafrost conditions in the Casino Project area, most notably affecting the extent of the seasonally thawed permafrost layer (active layer) and thereby altering the foundation conditions of civil infrastructure works, including buildings, roads, railways, airstrips, and pipelines. The most basic risk is the loss of mechanical strength and eventual thaw settlement or subsidence, as well as increased frost heaving potential. These factors must be considered in the design of all civil infrastructure for the Casino Project.

3 – CONCLUSIONS

A review of long-term regional climate and streamflow records for the Casino Project area indicates some time dependent changes in hydrometeorological conditions, but the changes are highly variable, and it appears that they are likely the combined result of both climate change and ongoing climate cycles. Climate change models, such as those presented by PCIC and SNAP, include allowances for projected anthropogenic influences on climate that may not be evident in historic records, and consistently predict increasing temperatures and precipitation for the Yukon, with temperatures increasing in the order of 1°C to 4°C over the next 40 to 50 years, and annual precipitation increasing in the order of 5% to 25%.

There is substantial uncertainty associated with predictions of future climate patterns in the Yukon, and though it is believed that available climatic and hydrologic records provide an appropriate basis for generally assessing conditions in the Project area over the expected life of the mine, it is recommended that potential changes be considered in climatic and hydrologic assessments, when appropriate.

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