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16 PROJECT RESPONSES TO THE ENVIRONMENT

The existing environment of the Project area can impact various phases of the Project and to varying degrees depending on the susceptibility of the infrastructure in question and the nature of the activity being undertaken. In the previous chapters, the effect the Project has on the existing environment was assessed. Below is an assessment of how the Project may be affected by the natural environmental factors in the area of the Project.

The response of the Project to environmental factors (climate change, forest fires, floods, freezing rain storms, lightning strikes and seismic events) and mitigation measures to offset the predicted response are presented below.

16.1 CLIMATE CHANGE

Adaptation to climate change is becoming an increasing concern in many sectors of society. It has been suggested that the environmental assessment process include a consideration of climate change for any project with a lifetime greater than a decade (CEAA, 2000). The most important considerations regarding the Taltson Hydroelectric Expansion Project relate to potential changes to river discharge. The interactions between climate and hydrology are complex. In northern regions, changes to the cryosphere (e.g., snow cover, permafrost, and river and lake ice) are important and would likely have an effect on various aspects of the Project, including hydroelectric water management and infrastructure.

This section presents key historical northern climate trends and associated responses by cryospheric components in the study area. Climate change projections specific to the study area are presented along with regionally-based results, and a discussion on climate variability. Expected changes in the cryospheric components and how these may translate to changes in hydrology are also presented. Potential effects on the Project are outlined. Much of the content in this section stems from the document From Impacts to Adaptation: Canada in a Changing Climate 2007, Chapter 3: Northern Canada, released by Natural Resources Canada (NRCAN) (Furgal and Prowse, 2008).

16.1.1 Historical Trends

There is strong evidence from scientists and local residents that Canada's north is experiencing changes in its climate and related environmental factors (Ouranos, 2004; Huntington et al., 2005; Bonsal and Prowse, 2006). Due to the scarcity of data in the north and the inherent variability of the climate, it is necessary to consider a wide geographic area and long time scale to observe trends in climate and related environmental factors. However, some long-term historical data sets are available near the Project area. The trends of the available data sets are also discussed below.

16.1.1.1 CLIMATE

The combination of temperature and precipitation changes can provide a broad idea of climatic changes. Spanning the past several decades over the Arctic, the following observations have been made:

- The western and central Canadian Arctic region experienced a warming of approximately 2°C to 3°C over the past 50 years, and trends have been most pronounced in the last 15 years (Zhang et al., 2000).
- Warming in Northern Canada has been more pronounced during winter and spring. In addition, temperatures have increased by about 1°C more in the north compared to more southern regions of Canada (Furgal and Prowse, 2008).
- Compared to temperature trends, precipitation trends are less clear. However, the entire Arctic has shown a positive precipitation trend of 1.4% per decade for the period of 1990 to 2003, with the largest increases generally occurring during fall and winter (Furgal and Prowse, 2008).
- Similar precipitation trends have been observed over the Canadian north from 1948 to 2005, with largest precipitation increases ranging from 16% to 25% (Zhang et al., 2000).

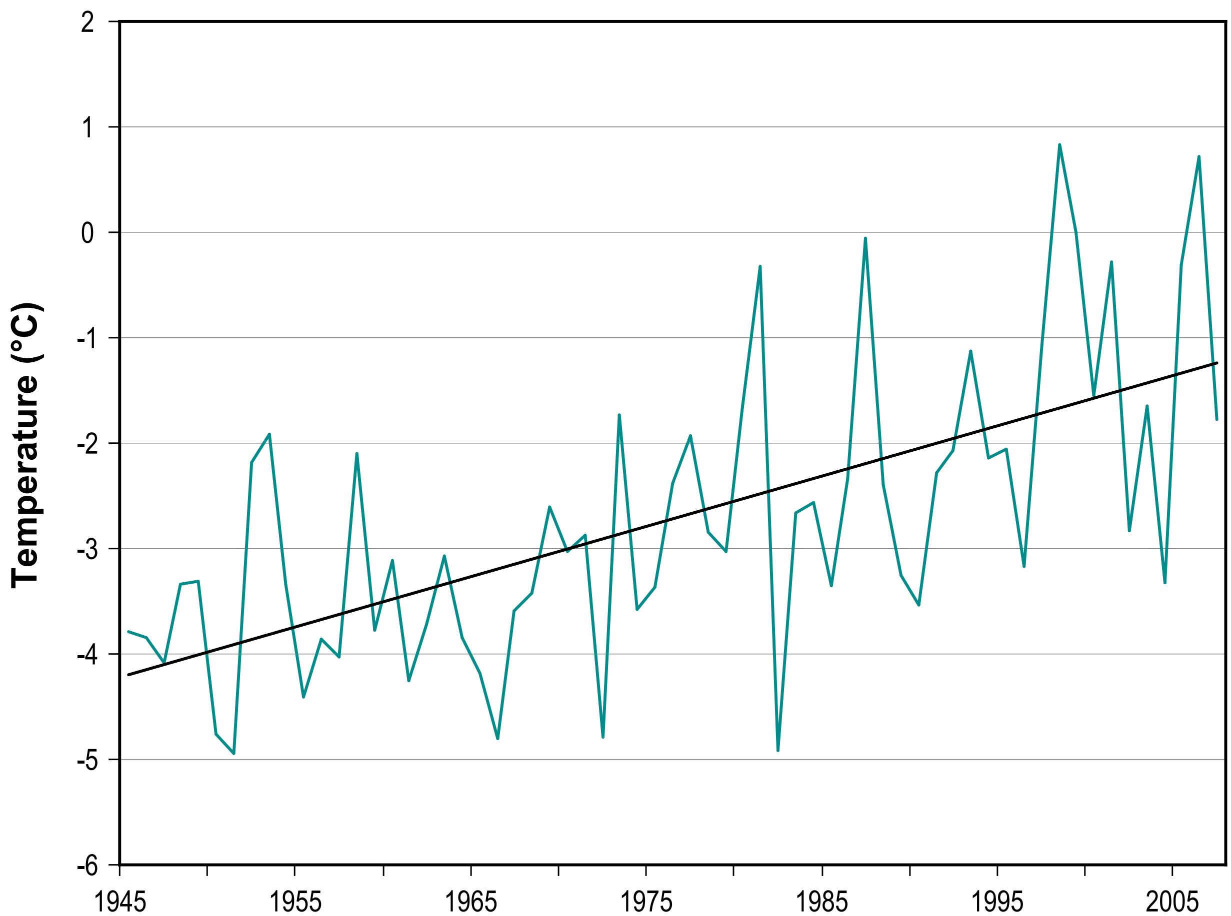
The large-scale temperature trends noted above are similar to those noted for the Project area's main meteorology station, Fort Smith Airport (see Section 9.4.3 – Existing Environment, Climate). Figure 16.1.1 shows average annual temperatures recorded at this station for the period 1945 to 2007. The trend line indicates an average warming of 2.9°C has occurred.

In the north, temperature and precipitation changes have affected cryospheric components such as snow cover, permafrost, and river and lake ice. Changes to these components would affect the Project area, most importantly through subsequent changes to regional hydrology. The hydrological importance of these cryospheric components are outlined below, along with some recent trends.

16.1.1.2 RUNOFF

The existing hydrological database of flow measurements for the Taltson River below the existing Twin Gorges facility and the site of the Expansion Project can be used for assessment of trends in overall basin runoff occurring over the past 45 years (1962 to 2007). As this flow measurement represents a basin area of over 50,000 km^2 these trends may provide an indication of how regional climate change is already affecting the basin, and can be compared to regional trends in factors driving runoff (i.e., precipitation) discussed above.

Figure 16.1.2 shows annual runoff in terms of discharge from 45 years of record for two contiguous gauge datasets below Twin Gorges (also see Section 9.3 – Taltson Basin Hydrology). Figure 16.1.2a shows the mean annual runoff in the basin over this period, and Figure 16.1.2b shows the moving three-year average annual runoff in the basin. Several trends are evident from this data. First, the annual runoff shows a definitive increasing trend, with mean annual flow increasing about 25% to 30% over the period of record (from approximately 170 m^3/s to 220 m^3/s), or a 6% increase per decade. Secondly, annual runoff was much less variable over the past 20 years than it was in the first 20 years of the record, which is most evident in the moving three-year average data. While periods of low flow continue to occur, they have been of much shorter duration than the significant multi-year dry periods in the early record (1969 to 1973, 1978 to 1981). No specific conclusion can be made on trends associated with extreme values of flow – both high and low flow events have continued to occur in a similar range over the period of record, though higher flow events may be occurring more regularly. As the basin is to some degree regulated and has operated under differing conditions through the record, assessment of the timing of flows would not yield reliable information on this issue.

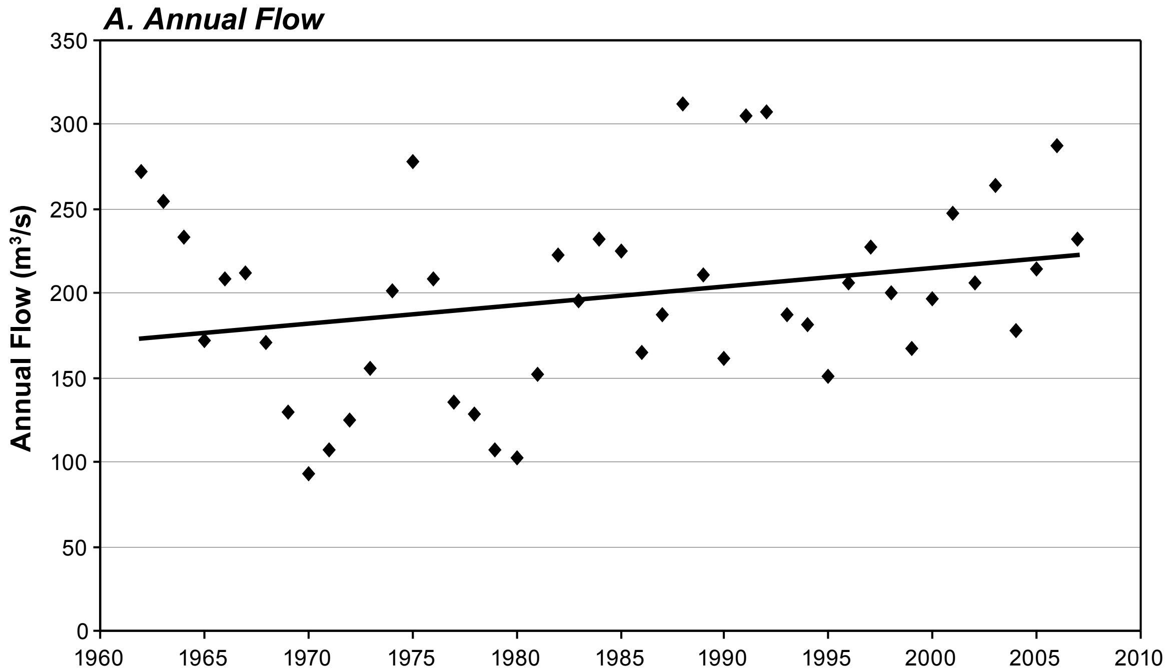


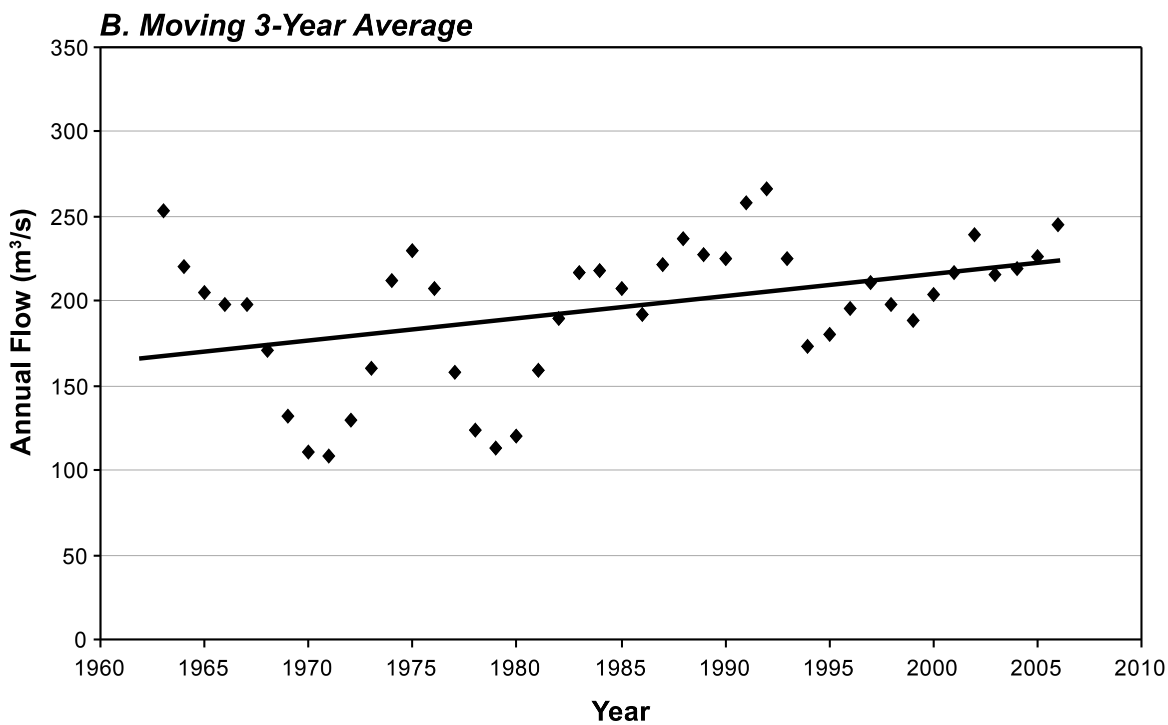
TALTSON
HYDROELECTRIC EXPANSION PROJECT

Developer's Assessment Report 2009

Mean Annual Air Temperature at Fort Smith Airport, 1945 to 2007

Figure 16.1.1





TALTSON Hydroelectric Expansion Project	Developer's Assessment Report 2009	Annual Flow in Taltson River Below Twin Gorges	Figure 16.1.2

The runoff data appears to support the general conclusions of the observed regional climate trends of increased precipitation. In fact, the positive trend in the annual runoff below Twin Gorges slightly exceeds the increases in precipitation (i.e., up to 25% increase in precipitation over a long-period of record within the region).

16.1.1.3 Snow Cover

The extent and depth of snow cover (i.e., snow volume) is strongly related to watershed discharge volume, due to the importance of snowmelt as a runoff-generating process in the north (Marsh, 1990). In the Northern Hemisphere, the average annual snow cover extent decreased by approximately 10% from 1972 to 2003. The largest decreases occurred during spring and summer (Brown, 2000; Walsh et al., 2005). In northern Canada, the largest changes in snow-depth for the period of 1946 to 1995 occurred over the Mackenzie River Basin (Brown and Braaten, 1998). Increasing annual rain-to-snow ratios, related to increasing temperatures, is an important factor in reduced snow cover. In addition to altering water budgets, snow cover changes affect surface radiation balances and permafrost distribution (Gray and Prowse, 1993).

16.1.1.4 Permafrost

Frozen ground influences northern hydrology by controlling infiltration, runoff, and groundwater storage and flow. Over the last thirty years, soil temperatures have increased in many permafrost regions of Canada. Summer thaw penetration has particularly increased since the 1990s (Furgal and Prowse, 2008).

16.1.1.5 River and Lake Ice

Periods of freshwater ice break-up control the timing and severity of many hydrological extremes in northern systems (Beltaos and Prowse, 2001; Prowse and Carter, 2002). Data from 1846 to 1995, at sites over the Northern Hemisphere (including a long-term site on the Mackenzie River), suggest that shorter winter seasons have reduced the duration of ice cover on lakes and rivers. On average, freeze-up has been delayed by 5.8 days per century, while break-up has advanced by 6.3 days per century (Magnuson et al., 2000).

16.1.2 Climate Change Scenarios

Although there is a high degree of uncertainty associated with climate change projections, there is sufficient evidence to suggest that climatic changes currently observed would continue (Kattsov et al., 2005; Bonsal and Prowse, 2006). Climate change scenarios can be used to infer how some of the cryospheric components explained above (and the hydrological processes they control) might change in future.

16.1.2.1 Methods

Climate change effects assessments generally use projected changes in temperature and precipitation to define future climate change scenarios for a given area. These data are calculated by Global Circulation Model (GCM) runs incorporating various greenhouse gas (GHG) emissions projections. GCMs use mathematical equations to describe important physical (and biogeochemical) processes of the Earth system. The equations are applied to cells (ranging in size from 200 km^2 to 500 km^2) in a grid, which represents the globe's surface. Climate change scenarios for any region around the globe may be retrieved by obtaining data that corresponds to the cells that cover the site of interest.

Climate change scenarios (i.e., mean temperature and total precipitation change) were accessed on-line via the Pacific Climate Impacts Consortium (PCIC, 2008). For the Expansion Project area, data was averaged for 4 to 9 grid cells, depending on the GCM. Scenarios data corresponds to three future time periods; namely, the 2020s, 2050s, and 2080s. These thirty-year periods (i.e. 2010 to 2039, 2040 to 2069, and 2070 to 2099) correspond to projected changes in future climate relative to the period 1961 to 1990, which is typically used to represent “baseline” climate. Thirty-year climate normals are said to adequately capture cycles of natural variability, and are considered appropriate for comparisons of mean climate conditions (IPCC-TGCIA, 1999).

To acknowledge the high degree of uncertainty in future projections, an ensemble of scenarios is used (Furgal and Prowse, 2008). In total, data from 21 GCMs were downloaded, and depending on the parameter, output from up to 135 model runs was obtained for a given time period. These same model runs were used in the Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC, 2007).

16.1.2.2 Project-Specific Results

Minimum, median, and maximum projections of annual and monthly air temperature and total precipitation change over the Project area were calculated from the ensemble of predicted future scenarios (see previous section). Table 16.1.1 summarizes the annual projected changes in mean temperature and total precipitation for the three future time periods (relative to the baseline, 1961 to 1990). Median temperature increases for each future period range from 2.3°C to 6.5°C, from the 2020s to the 2080s, respectively. Median precipitation is also projected to increase, and ranges from 7.5% to 23.7% from the 2020s to the 2080s, respectively.

For both parameters, the range of projections increases with each future period, highlighting the increasing uncertainty with time. There is a greater range of precipitation projections compared to those for temperature. Projection uncertainty is attributed mostly to the range of emission scenarios and to differences in GCM algorithms.

Figure 16.1.3a and 16.1.3b presents the monthly mean air temperature and total precipitation changes for the three future time periods (relative to the baseline, 1961 to 1990). The median and range of projections, resulting from the ensemble of scenarios, are shown. Monthly temperature changes are greatest during winter and smallest during summer. Increases in monthly precipitation are fairly uniform, with slightly larger increases during winter.

Table 16.1.1— Projected Annual Change in Temperature and Precipitation for the Three Future Time Periods in the Project Area

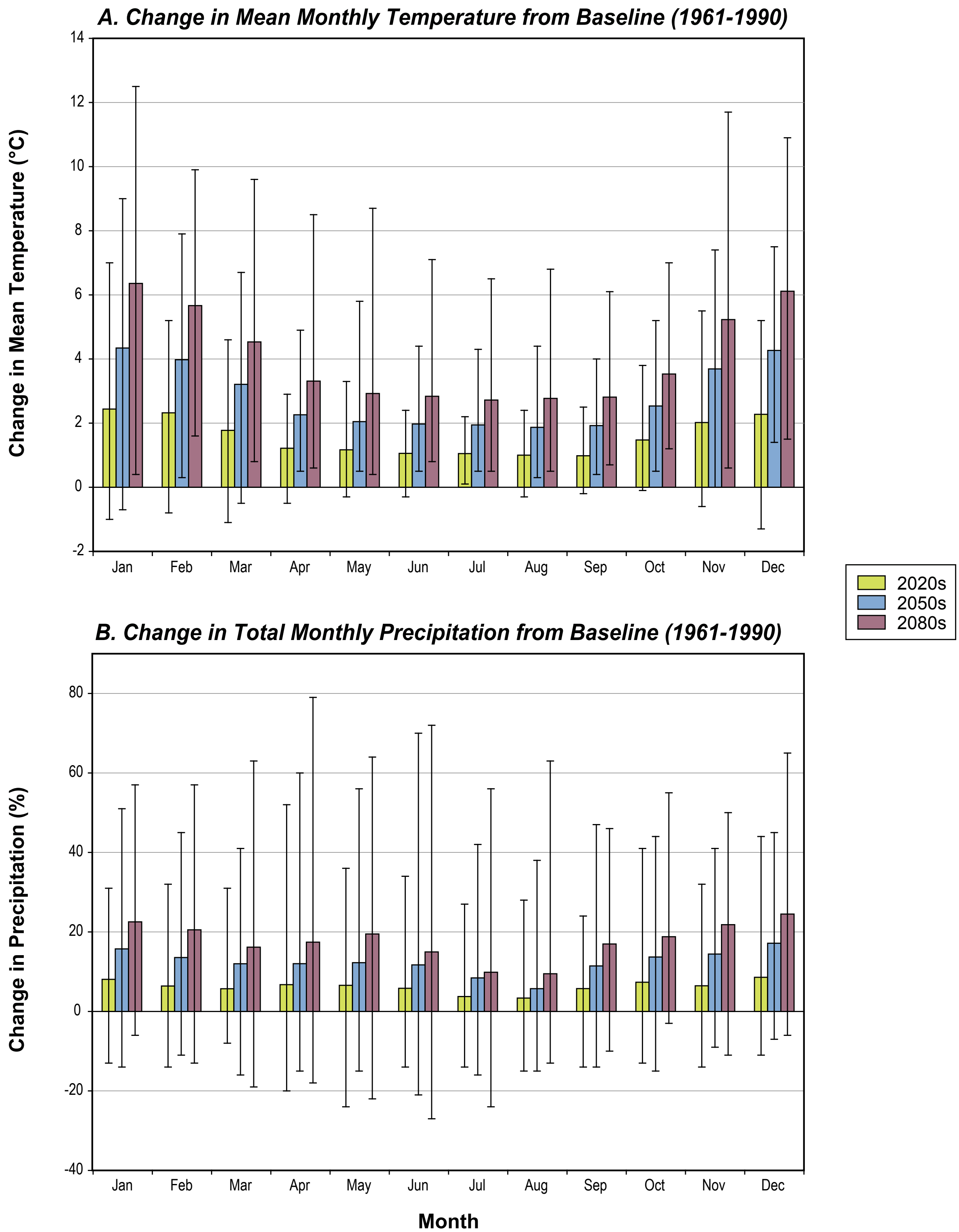
Climate Normal Period	Estimate	Change in Mean Air Temperature (ºC)	Change in Total Precipitation (%)
2020s	Min.	-1.0	-13.2
	Median	2.3	7.5
	Max.	7.0	31.3
2050s	Min.	-0.7	-13.6
	Median	4.4	16.9
	Max.	9.0	51.0
2080s	Min.	0.4	-5.8
	Median	6.5	23.7
	Max	12.5	57.3

16.1.2.3 REGIONALLY-BASED RESULTS

The results specific to the Project area are consistent with those reported for northern Canada in general (Furgal and Prowse, 2008). Based on output from seven GCMs, mean annual temperature change for the 2020s was projected to be approximately 2°C and total annual precipitation increases ranged from 5% to 8%. For the 2050s, Furgal and Prowse (2008) projected mean temperature changes ranging from -2°C to 12°C. Precipitation projections for the same time period ranged from -10% to 60%. For the 2080s, mean temperature changes were projected to be between 0°C and 18°C, while the precipitation change range was -10% to 60% (same as for the 2050s). These results are similar to annual changes shown for the Project area (Table 16.1.1).

A study conducted by Bonsal and Prowse (2006) examined the ability of the seven GCMs used by Furgal and Prowse (2008) to simulate the mean values and spatial variability of the baseline period (1961 to 1990) temperature and precipitation over northern Canada. Their analysis revealed considerable inter-regional and seasonal variability, with temperatures being more accurately simulated than precipitation. In addition, annual precipitation was overestimated by all GCMs. These findings are important, and should be considered when interpreting the results from the Project-specific analysis.

Bonsal and Prowse (2006) also analyzed natural variability over the baseline period. They noted that the projections during all future periods fall outside the range of modelled natural variability. Along with a likely change in the mean conditions exceeding those of the realm of natural variability, there is likely to be a change in natural climate variability itself.



Note: Solid bars represent median projections; lines indicate the range between minimum and maximum projections.

16.1.2.4 CLIMATE VARIABILITY

The earth's climate system is dynamic and subject to natural variability, which is defined by the IPCC as the departure in mean state of the climate, including the occurrence of extremes, on all temporal and spatial scales beyond individual weather events (IPCC, 2001). Global warming is likely to lead to increased extreme climate conditions (Katz 1999; Kharin and Zwiers 2000; Hansen et al. 2007), and has already been observed globally for surface temperature extremes (e.g. change in the annual number of frost days) (Hegerl et al. 2007, Trenberth et al. 2007).

Large-scale trends in natural variability have been linked to atmospheric and ocean circulation patterns. In the Arctic, phenomena such as the Northern Annular Mode (NAM), the North Atlantic Oscillation (NAO), the Pacific-North American (PNA) pattern and the Pacific Decadal Oscillation (PDO) have been linked to regional temperature and precipitation extremes (Christensen et al., 2007). Effective prediction of future climate variability thus requires an understanding of how such patterns may change in future; however, presently very little is known on the subject. In the Arctic, the understanding of natural variability is complicated by the added low-frequency variability in climate that is influenced by atmosphere and ice parameters (Polyakov et al. 2003a, b).

Due to the lack of knowledge regarding future changes in patterns of natural variability, no specific predictions have been made regarding long-term (i.e., decadal) changes in natural variability at northern latitudes. However, a series of studies relying on GCM results for northern regions offer insight into possible year-to-year changes in climate variability. For example, Christensen et al. (2007) predict that such changes would be manifested through an increase in the frequency of very warm and wet winters and summers. In addition, while precipitation intensity is expected to increase, the frequency of precipitation events is expected to decrease (Kundzewicz et al., 2007). On annual timeframes, this means that both high flow and low flow events could become more common. On the one hand, heavy precipitation events could produce large volumes of runoff in a short time period. On the other hand, periods in between precipitation events could become longer, creating unusually dry conditions.

16.1.3 Effects on Cryospheric Components

The predicted changes in mean temperature and total precipitation would affect the key cryospheric components. Changes would be interconnected and have opposing effects on hydrological processes. These would be discussed in order to better explain potential changes in discharge response.

16.1.3.1 SNOW COVER

Greater temperatures would result in more precipitation falling as rain rather than snow. Warmer temperatures would also likely increase the incidence of melt periods, and reduce the snow accumulation period. These factors would combine to decrease snowpack accumulation. However, increases in precipitation (especially in winter) would have the opposite effect. Greater winter snowfall could contribute to greater snowpack accumulation during the cold season (despite being shorter). The result of these two opposing factors is unclear, but the effects would likely be most obvious through changes in snow cover during fall and spring.

16.1.3.2 PERMAFROST

Furgal et al. (2003) classify the permafrost distribution zone within the majority of the Project area as “discontinuous”. The near-surface ground temperature is estimated at >-0.5°C (Smith and Burgess, 2004). Thus, there is a high potential for this permafrost to thaw under climate change projections. Settlement and ponding may also occur as ground ice thaws, leading to changes in drainage and the distribution of surface water (e.g., lakes and wetlands). Areas of permafrost degradation may experience increased infiltration, greater groundwater storage, lower spring runoff and increased base flow (the “background” river flow, sustained from groundwater sources) (Woo et al., 1992).

16.1.3.3 RIVER AND LAKE ICE

A decrease in below-freezing days under warmer conditions is likely to lead to reduced ice build-up. Changes in snow cover would also affect ice build-up, due to its insulating properties over ice surfaces. Accordingly, changes to the severity of river-ice events and related downstream effects, such as ice-jam flooding, is unknown (Prowse and Beltaos, 2002; Walsh et al., 2005).

16.1.4 River Discharge Response

16.1.4.1 PROJECT-SPECIFIC PREDICTIONS

Projected changes in climate and cryospheric components can be used to discuss potential changes in river discharge. From the perspective of runoff potential, several opposing factors need consideration. On the one hand, a likely increase in precipitation would result in greater runoff in watershed systems – greater water input (i.e., precipitation) generally leads to greater water output (i.e., outlet discharge). To a lesser degree, melting permafrost could also contribute to greater runoff potential; draining of lakes and wetlands could be noticeable over the short term.

In contrast to positive potential runoff factors, warmer temperatures could lead to a number of negative potential runoff factors. Larger evapotranspiration rates could result in greater water losses from land and open water bodies such as lakes and wetlands. Warmer temperatures would likely continue to increase annual rain-to-snow ratios. This could decrease runoff, as rainfall runoff is generally a less efficient runoff generating process compared to snowmelt runoff.

Though opposing effects on runoff potential have been outlined above, the magnitude of these effects is difficult to predict. This is compounded by the uncertainty in projections and limited knowledge regarding changes in climate variability. Despite these shortcomings, a description of hydrologic changes that might be expected for a typical watershed within the Project area follows. This is done by presenting potential changes in the annual hydrograph, on a seasonal basis.

Spring

The majority of annual flow is generated during this season, when the accumulated winter snowpack melts. Changes in the spring freshet volume would largely depend on the outcome of opposing factors controlling snow cover (discussed in Section 16.1.3.1). For example, greater winter precipitation (e.g. snowfall) could lead to greater snowpack storage, and greater spring snowmelt runoff. With regards to the timing of the spring freshet, it is likely to occur earlier due to an earlier onset of snowmelt.

The shift in annual rain-to-snow ratios is an important consideration with regards to event floods. Rain-on-snow events, common under spring conditions, occur when warm rain falls on snowpack. Both the rainfall and snowmelt (resulting from the warm rain) generate runoff in a small time period. Such a flood mechanism could become more prevalent in future. Finally, spring ice jamming would be subject to the opposing factors discussed in Section 16.1.3.3 (River and Lake Ice). For example, if ice jamming decreased, due to a shorter ice season and reduced ice build-up, there would likely be a decrease in the likelihood of flooding due to this phenomenon.

Summer

Following spring snowmelt, flows generally decrease during summer with the exception of occasional high flows resulting from intense precipitation events. Warmer temperatures would likely extend the summer period in future. The balance of factors affecting changes in runoff potential, discussed previously, would determine changes in summer streamflow. For example, on the one hand, greater groundwater storage (due to melting permafrost), and even small increases in precipitation, could increase summer streamflow. On the other hand, earlier depletion of a smaller snowpack combined with greater evapotranspiration rates could overcome these factors and result in decreased streamflow.

Fall

Flows occurring during this season reflect the amount of water in groundwater, lake, and wetland storage, which would be affected by changes in summer storage. Increased flows would likely result from increases in precipitation during this season.

Winter

Winter streamflow is primarily supported by receding baseflow contributions, as the majority of inputs (i.e., snowfall) during this season are stored as snow and ice. Streamflow is typically lowest during this season, with the annual minimum flows occurring at the end of the winter baseflow recession period. In future, warmer temperatures would likely cause this season to shorten, resulting in higher winter minimum flows.

None of the climate change scenarios for the Project area (see Section 16.1.2.2 – Project Specific Results) suggest that temperatures would rise above freezing during the months of December, January and February. For example, average daily maximum temperature in January at the Fort Smith meteorological station is -20°C (see Section 9.4.3 – Existing Climate), while the median temperature projection for the 2080s is +6.5°C. However, mid-winter warming events that can result in rainfall and snowmelt runoff and which are currently rare, would likely become more frequent, adding further to an increase in average winter flows.

16.1.4.2 Regionally-Based Predictions

Given the complexities between climate and hydrology in the north, there is considerable uncertainty in predicting changes in discharge for such watersheds. Arnell (1999) used climate change projections for the 2050s to predict changes in Mackenzie River discharge, relative to the 1960 to 1990 baseline runoff conditions. Precipitation was projected to increase 10% to 15%, along with small increases in potential evaporation (5% to 10%). Accordingly, annual runoff increased between 12% and 20%. Arora and Boer (2001) conducted another study using climate change scenarios yielding results for the Mackenzie River Basin. In addition to increases in annual runoff, winter discharges were simulated to increase between 50% and 80%. The changes predicted by Arnell (1999) and Arora and Boer (2001) suggest that positive runoff potential stemming from greater precipitation would overwhelm negative runoff potential as a result of greater evapotranspiration.

Predicted changes reported in these studies, supporting those made for the Project area, may be described as a "flattening" of the annual hydrograph. Discharge is reduced during periods otherwise experiencing high flows (i.e., spring), and increased during periods otherwise experiencing low flows (i.e., winter), and with annual flows increasing.

From the perspective of extreme-flow years, expected changes in the type (rain or snow), frequency, and intensity of precipitation events are strong considerations for the Project area (Kundzewicz et al., 2007). In addition to the increased likelihood of rain-on-snow events, individual precipitation events are projected to be more intense (Meehl et al., 2007). Combined with general increases in precipitation, these changes are expected to result in a greater number of high-flow years (Arora and Boer, 2001). With regards to low-flow years, there is comparatively little potential for drought extremes. In similarly dry, but more southerly climates, rising evapotranspiration causes concern as it could exacerbate surface water losses. However, increasing evapotranspiration at northern latitudes would likely be small compared to increases in precipitation (Meehl et al., 2007). Therefore, increasing low-flow periods are unlikely, except for the following condition. As precipitation is projected to become more intense, but less frequent, there could be an increase in the number of dry periods in between rainfall events.

16.1.5 Effects on the Project

Climate change would likely affect the Project in several ways; the likely outcome of increased annual runoff would be the most important. Issues surrounding permafrost melting should also be considered. From an energy demand perspective, warmer temperatures would have the likely effect of reducing heating-related energy needs. Demands at Hay River, Fort Smith, Fort Resolution and Fort Fitzgerald communities would likely decrease; this would also likely be so, to a lesser degree, for the local mining industry. Key effects to hydroelectric water management and infrastructure aspects of the Project's operations are discussed below.

16.1.5.1 WATER MANAGEMENT AND OPERATIONS

The Expansion Project could benefit from the predicted changes in the area's hydrology under climate change in several ways. First, greater annual runoff would result in greater power generation capacity. Second, a "flattening" of the annual hydrograph would allow the Nonacho and Twin Gorges facilities to reach their design capacity on a more regular basis. Likely decreases in average spring flood peaks, and a shorter winter (snow storage) season could translate to more regular flows.

Considering likely increases in high flow events, infrastructure upgrades under both the 36 MW and 56 MW expansion scenarios would allow better management of high flows. In terms of operations, water levels would typically be lower in Nonacho Lake at the start of freshet conditions under the expansion scenarios, providing a much larger storage volume. Larger gates at the Nonacho control structure would allow greater control of releases of water downstream to the Twin Gorges power plant. At Twin Gorges, the new facilities would allow greater volumes of water to flow downstream through the plant, decreasing spill into Trudel Creek. Therefore, in times of extreme high flow, lower water levels in reservoirs and the greater ability to route water downstream would be beneficial in mitigating flood risk within these two key Project features.

Although wetter conditions with greater runoff are expected on average, there is also a greater possibility for short-term dry periods to occur. Such conditions could occur between more infrequent, though likely more intense, precipitation events. During such periods, the Project's ability to meet full power demand could be compromised depending on the duration and severity of the event, and over what sector(s) of the drainage basin the dry event occurs. Increased reservoir live storage capacity resulting from the Expansion Project enables mitigation of some of this risk. In general, due to the storage capacity of the basin system and the ability to respond over a wider range of flows, if the mean annual discharge increases, the Project would tend to benefit with increased annual power generation.

Minimum flow releases into Trudel Creek and below the generating stations can be maintained irrespective of drought conditions within any anticipated scenario. The minimum releases into Trudel Creek would be unrelated to Forebay level in the Expansion Project, and therefore can be maintained continuously regardless of operating levels. The releases have priority over power production. Minimum releases below the generating stations can be maintained by the operation of any one of the existing or new turbines, or through the South Gorge bypass facility, should the plants be non-operational. With ongoing monitoring of inflows into the system, timely release decisions from Nonacho Lake would preclude any shortfall of water at the Forebay to meet minimum release conditions.

Ongoing monitoring of river flows on the Taltson River would continue to inform water management decisions. Four Water Survey of Canada (WSC) stations operating at Taltson above Porter (Q7QD004), Taltson below Hydro Dam (07QD007), Tazin River at the Mouth (07QC007), and Tazin Lake (07QC002) would be extremely useful in observing trends in basin runoff as a result of climate change. Operation schedules may need to be assessed over time, given the potential runoff changes. The analysis of data and the integration of long-term trends due to climate change into Project operations should be easily implemented, as the operating decisions are already informed by continuous and current monitoring of the basin's environmental conditions. In considering extreme conditions, it must be noted few methods exist to quantify changes, and precautions should be taken. Specific modelling for extreme event prediction can be undertaken for this basin as more data is collected.

16.1.5.2 INFRASTRUCTURE

Permafrost conditions present challenges for the design, construction, and operation of infrastructure in northern Canada, and special engineering considerations have been developed for such conditions (e.g. Smith et al., 2001; Couture et al., 2003). Under climate change, thawing of the ground could reduce soil strength, increasing slope instability. Therefore, power lines, buildings, and roads that have been constructed on permanently frozen ground in the Project area may be affected by warmer temperatures. Permafrost monitoring and regular maintenance would mitigate this risk.

Ice roads, such as that between Fort Smith and Twin Gorges, could be affected by warming over the long term. However, it is expected that the ice road would only be used during Project construction. As the construction period would be limited to a few years, no effects are anticipated for ice roads as a result of climate change.

16.1.6 Summary

Despite the clear climatic changes occurring in the north, uncertainty does persist in future projections. However, based on currently available climate change scenarios data (supported by results from regionally-based studies), the Project area would likely experience a warmer and wetter climate in the future. Hydrology of the Project area is dominated by interconnected cryospheric components including snow cover, permafrost, and river and lake ice. Any long-term trends in climate parameters would have an impact on the cyrospheric components; however, the magnitude and direction of the impacts are uncertain. Resultant changes in hydrology are even less certain; however, there is reason to believe that the most likely climatic changes would lead to greater river discharge, with more constant flow occurring throughout the hydrological year. In general, this probable change towards a warmer and wetter climate would be beneficial to the Project due to increased hydropower generation capacity. The adaptive management required to operate hydroelectric facilities would provide an ideal framework to allow for operational changes of the Project in response to climate change.

16.2 FOREST FIRES

The Taltson basin and the 350 km of transmission corridor below the treeline regularly experience forest fires on a reasonably large scale. Fires are typically triggered by multiple lightning strikes. Specifically, a forest fire occurred in the area of Twin Gorges in 1998, and fires have been noted in the basin between Twin Gorges and Nonacho Lake during most fieldwork seasons. Generally, remote fires are allowed to burn without intervention. When fires threaten infrastructure in this region, fire suppression activities based out of Fort Smith are typically employed. In the case of the 1998 fire, fire retardant was deployed near the plant from aircraft. The fire did not damage the facilities or the transmission line from Twin Gorges to Fort Smith nor did it damage the Twin Gorges facilities. Within the design of the expansion plant, clearing of trees in the vicinity of both the existing and new plants would be undertaken to minimize the risk of fires in close proximity to the facilities.

The Twin Gorges facilities could be operationally impacted by a forest fire, most likely through an outage of one or other of the transmission lines. A major fire could cause significant damage to the towers and conductor, resulting in an extended outage. Damage to the actual generation or control facilities is highly unlikely, given the cleared fire border that would be established and maintained around those facilities. At Nonacho Lake, the facilities would also be protected by cleared area surrounding the control structures, and no significant damage would be expected from forest fires in the immediate area. Operations of this facility might be impacted through a failure in the communications system, but this would be quite temporary, and operational logic would maintain the flow release settings in this case. Sensitive equipment would be housed in a robust concrete structure, and impacts from outside environmental conditions would not be expected.

It can be expected that forest fires along the transmission line corridor would occur. Lightning strikes and storm tracking is typically carried out by remote sensing, and this information is available as real-time data from the GNWT. During critical periods when lightning storms are common, operations staff at the Project would be expected to monitor this information, along with reports from aircraft flying over the corridor, to assess the ongoing risk of forest fire damage to the transmission line.

At Twin Gorges, the loss of either of the transmission lines would lead to a reduction in power generation and a necessary redirection of flows into Trudel Creek and/or through the South Gorge Bypass Facility. The scenarios associated with outages have been discussed in detail in Chapter 6 – Development Description. Given the disparate geographic locations of the two transmission lines, a forest fire outage would likely affect only one line and therefore result in only a partial outage. Changes in flows associated with partial outages and the resulting environmental effects are addressed in Chapters 13 and 14 under ramping pathways. .

16.3 FREEZING RAIN AND ICE STORMS

Freezing rain or ice accumulation on transmission lines adds large stresses to the conductor and can increase tower loads dramatically. In extreme events, failures of towers are typically catastrophic, and this in turn can lead to a cascading failure along the line. Line failure of this nature would lead to an outage of major duration.

The proposed transmission corridor in the southern sector of the line parallels Great Slave Lake, and it is anticipated that some potential exists for ice storms to occur in this area. These events would typically occur in late stages of open water on the lake, i.e., the months of October and November. Winter storms, while likely carrying stronger winds, tend to be drier and are not likely to lead to ice build-up on the lines.

The design of the transmission line and towers has accounted for a very significant ice build-up on the conductor and towers. In addition, full scale load testing of the tower design would be undertaken to ensure that the design loads can be reliably carried.

A failure due to ice loading on one of the lines would result in a system outage. At Twin Gorges, the loss of either of the transmission lines would lead to a reduction in power generation and a necessary redirection of flows into Trudel Creek and/or through the South Gorge Bypass Facility. The scenarios associated with outages have been discussed in detail in Chapter 6 – Development Description. Given the disparate geographic locations of the two transmission lines, an ice storm failure would likely occur only in one or the other of the two lines, and thus result in only a partial outage. A partial unscheduled outage caused by an ice storm or icing issues would cause changes to flows. These changes would be similar to a scheduled outage for maintenance purposes. The environmental effects from such an event are addressed under scheduled outages in chapters 13 and 14. In the very unlikely event that an ice storm takes both lines off-line, both plants would be taken off-line. This would cause full ramping of flows on the Forebay and along Trudel Creek. It would also cause a rapid decrease followed by an increase in flow in the Taltson River below Elsie Falls. The environmental effects of such an event are addressed in Chapter 17 – Accidents and Malfunctions, sub-sections 17.4 and 17.5.

16.4 LIGHTNING STRIKES

Lightning strikes near or on the transmission lines would very likely be the single most common form of operational disruption to the Project. Lightning is common in the area from June through August as warm fronts from the south mix with colder air from the north. Storm activity is generally more acute in proximity to Great Slave Lake than in more northern areas. Approximately 200 km of the new transmission corridor is considered to have reasonable exposure to electrical storms.

Lightning strikes near or on the line generate extremely short duration but high voltage conditions leading to electrical instability on the line resembling a major fault. Modern protection systems would allow a certain time for the fault to clear, but would then isolate the line from the potentially affected switchyards to protect critical equipment. Surge protectors are also utilized as energy dissipating devices to protect both the line and equipment. The full design of the lightning protection system for the transmission line would be carried out in the next stages of project technical definition.

Irrespective of the design, lightning-induced outages on either of the transmission lines would be a normal occurrence during the summer season. Typically, these strikes do little or no damage, but would cause a short-duration generation disruption. In more extreme cases, damage to the conductor and/or stringing hardware can occur. Regular inspection of the line would need to be carried out to ensure a high degree of reliability. As noted above in relation to forest fires, lightning strike activity would be monitored by Operations staff, such that potential line damage locations can be logged in relationship to any outages that occur for specific inspection. Modern distance relays typically used in projects of this nature would also isolate the location of most line damage.

Outages from lightning strikes could be partial or full, and they could cause lengthy outages if severe damage is caused. The environmental effects of such an event are addressed in Chapter 17 – Accidents and Malfunctions, sub-sections 17.4 and 17.5.

16.5 SEISMIC EVENTS

The seismic hazard level of the Project area is rated as “LOW” by Natural Resources Canada Seismic Hazards Map (NRCan, 2005). “LOW” is the lowest rating on the seismic activity scale, and generally means that both frequency and severity of seismic events in the regions is low. Although the potential for an earthquake is low, the consequence of such an event could be significant from both an operational and environmental perspective. Assuming an earthquake triggered the failure of the Nonacho dam, the Twin Gorges main dam or the South Valley Spillway, a large surge of water would be mobilized along the Taltson River and Trudel Creek. The water would cause significant downstream erosion and sedimentation, but would be significantly dampened as it routed through Tsu Lake. Water levels upstream of these structures would drop significantly as well. This would cause dewatering of aquatic shoreline habitat and if the event occurred at a critical life stage of the biota (i.e., fish egg incubation) population impacts could result.

The existing rock-fill dam at Twin Gorges has been assessed through a recent standard Comprehensive Inspection and Review study and found to be fully acceptable (Klohn Crippen Berger, 2006). Rock-fill dams tend to be very resilient to ground motions, and generally have high factors of safety against failure as a natural consequence of their construction. The upgraded low rock-fill dam at Nonacho Lake would also be extremely resilient to seismic activity. All new concrete structures would be designed for the peak ground accelerations and methodology in accordance with the most up-to-date building codes or more stringent requirements as deemed necessary. Transmission line structures are generally not impacted by seismic activity. Seismic activity would therefore present an extremely low hazard to the Project.