

KINROSS

Great Bear

Great Bear Gold Project Impact Statement

Appendix W-3:

Detailed Climate Change Dataset



GREAT BEAR RESOURCES

GREAT BEAR PROJECT DETAILED CLIMATE CHANGE DATASET

FEBRUARY 2025





GREAT BEAR PROJECT DETAILED CLIMATE CHANGE DATASET

GREAT BEAR RESOURCES

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LIST OF ABBREVIATIONS

Abbreviation	Definition
AMS	Annual Maximum Series
AR6	Sixth Assessment Report
BCCAQv2	Bias Correction / Constructed Analogues with Quantile mapping reordering Version 2
CSA	Canadian Standards Association
ECCC	Environment and Climate Change Canada
ERA5	European Centre for Medium Range Weather Forecasts Reanalysis 5
ETCCDI	Expert Team on Climate Change Detection and Indices
GCM	Global Climate Model
ICMM	International Council on Mining and Metals
IDF	Intensity-Duration-Frequency
IPCC	Intergovernmental Panel on Climate Change
MAC	Mining Association of Canada
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
SSP	Shared Socioeconomic Pathway
WMO	World Meteorological Organization

1 INTRODUCTION

WSP Canada Inc. (WSP), was retained by Great Bear Resources Ltd. (Great Bear Resources) to develop a detailed climate change dataset for a proposed gold mine, the Great Bear Project (Project) located in northwestern Ontario. As part of the new Global Tailings Standard (ICMM et al. 2020), requirements are set out to regularly update climate change knowledge for water management plans and the characterization of social, environmental, and economic context of tailings facility sites. Climate change has the potential to shift climatic conditions and the occurrence of extreme weather events on site, due to global emissions magnifying the greenhouse effect resulting in increasing temperature and altered precipitation patterns. These changes have the potential to affect the resilience of the operations and closure designs, including the operation of tailing management facilities and the performance of surface water management infrastructure.

The Mining Association of Canada (MAC) *A Guide on Incorporating Climate Change Adaptation into Decision Making for the Mining Sector* (MAC 2021) provides a stepwise approach that mining facilities such as Project may apply to incorporate climate change adaptation considerations into decision-making and to increase climate resilience. The document aims to help mining companies identify an approach to reduce potential climate change impacts, take advantage of the climate change opportunities, and reduce the need of implementing costly adaptation measures later in the mine life cycle. This report is aligned with guidance provided in Appendix B of MAC (2021), which describes approaches for putting together climate change datasets to support climate adaptation of mining facilities.

In this report, a site-level detailed climate change dataset is developed to support operations and design activities at the Project site. Baseline climate statistics are established using representative data sources to provide an overview of the current climate conditions from which future projections can be referenced. Downscaled global climate model (GCM) outputs are then used to describe how current climate conditions may change in the future. Recognizing the inherent uncertainty with projections, the results in this report are based on multiple projections from multiple models and scenarios, or a multi-model ensemble, as recommended by the Intergovernmental Panel on Climate Change (IPCC; 2021 p.221). The projections across the multi-model ensemble are summarized in terms of percentiles where the 50th percentile represents the median value and higher percentiles (i.e., 90th and 95th percentiles), represent extreme projections for the site. As climate science is continuously improved and new models and scenarios for future climate are released, the detailed climate change dataset for Project provided in this report should be updated as appropriate, acting as a basis for continuous improvement at the site, following the guidance of ICMM et. al. (2020) and MAC (2021).

The climate change dataset developed in this report is developed to support multiple studies within the Project. This report provides a consistent set of climate data and projections to support the incorporation of climate consideration throughout the Project. The projections can be incorporated into technical modelling studies or sensitivity analyses completed by the environmental disciplines as part of the impact statements. The climate information is also used in the Climate Risk and Resilience Assessment issued under separate cover, to inform the likelihood of a climate-interaction event occurring based on the current Project design following MAC (2021) and the Strategic Assessment on Climate Change (SACC): Assessing Climate Change Resilience (ECCC 2022). Outside of the Impact Assessment process, the climate dataset could be used to inform the final Project design and demonstrate that the requirements of the topics listed in the Global Tailings Standard (ICMM et. al. 2020) that require the consideration of climate change are addressed.

This report provides the following sections:

- A review of the *Guide on Incorporating Climate Change Adaptation into Decision Making for the Mining Sector* (MAC 2021) to add context to the report on how this report fits within the ongoing process of climate resilience through the mine life cycle stages.
- Guidance on using the results including the selection of climate change projection percentiles for screening and design purposes.

- A map of the regional climate stations used to establish baseline climate conditions are provided in Appendix A
- A review of the methodology used to characterize the current and future climate conditions at the site. Detailed descriptions of the data sources (with a map illustrating regional climate station locations in Appendix A) and approaches used are provided in Appendix B.
- A summary of the current and future projections for temperature and precipitation (including extreme indices), drought and surplus, probable maximum precipitation, extreme rain and snow statistics, probable maximum flood, potential evapotranspiration and wind speed. Additional future climate statistics not provided in the report for drought and surplus, extreme precipitation and extreme snow statistics are provided in Appendix C.
- A comparison between the modelled depth and snow survey measurements is provided to validate the application of the snow accumulation and melt methodology that is applied to the current climate dataset established for the Project. Details are provided in Appendix D.
- A comparison of methods used to estimate potential evapotranspiration for the Project site was undertaken. Reference or crop coefficients were adjusted to estimates of lake evaporation to provide a means to estimate lake evaporation over time as a function of potential evapotranspiration. Details on this assessment are provided in Appendix E.

2 USING THE RESULTS

This assessment is based on the current available climate science. The nature of the work undertaken is stochastic with substantial inherent uncertainty around any given data points. The uncertainty associated with any projections or forecasts is increased with the duration of the projected period. The projections provided in this assessment are subject to change as new iterations of IPCC future projections are released based on the latest climate science, and as additional observations are included in the baseline.

To acknowledge this uncertainty, rather than provide one projection to represent the future conditions that could be considered as a stationary design parameter, the projections have been described using percentiles across a multi-model ensemble. The projections at 50th percentile level represent the ensemble median projections, while the projections at the 95th percentile represent an outcome where 95% of projects are at or below this value. Where clear to represent, percentiles for each climate projection are provided directly in the report, otherwise the set of percentiles are provided in Appendix B: Additional Climate Projection Statistics. When considering the impact of future projected climate, the level of future risk can be adjusted by using the desired percentile. The selection of future projections for climate change risk assessment should be based on the balance between the conservatism of the inputs into the design parameters and the consequential risks.

Therefore, the results in this report should be used as follows:

- For the initial closure design or as part of a risk assessment of the closure design, the projections at 50th percentile level, of the ensemble mean projections and shown in the figures and tables of this report, should be selected as a starting point.
- Projections are provided to the end of the century in two 30-year periods as described in Section 3.2 (i.e., 2050s and 2080s).
- For critical closure infrastructure or for high risks, selection of future projections at higher percentile may be considered. For example, for critical infrastructure, whose failure is considered unacceptable, a 95th percentile could be considered over the 50th percentile used as part of the initial assessment.
- This work should be evaluated and potentially updated as new climate science is developed, for example after the release of the latest assessment report by the IPCC. As outlined in Section 6 of MAC (2021) consideration of additional climate data can be included in the monitoring and surveillance plan that will form part of the closure.

3 APPROACH AND METHODOLOGY

WSP has an approach for site-specific climate change datasets informed by the MAC guide for climate change adaptation in the mining sector (MAC 2021) and aligned with the Global Industry Standard on Tailings Management (ICMM et al. 2020). The selection of variables and methodologies are aligned with this guidance and have been applied to the development of the dataset for the Project. With the baseline or current climate conditions established, projected changes in climate are provided, which may be applied to the corresponding current climate variables.

The climate variables analysed in this report include annual and monthly temperature and precipitation (including extreme indices), wet and dry year statistics, probable maximum precipitation and climate-driven probable maximum flood (defined below), extreme precipitation, combined rainfall and snow statistics, potential evapotranspiration, and wind speed. The following sections provide a high-level overview of the methodologies followed to develop the current and future climate statistics included in this report for the Project. Detailed information on each methodology is provided in Appendix B: Detailed Methodology.

3.1 CURRENT CLIMATE METHODOLOGY

In this report, baseline climate statistics are established using a climate normal based on the most representative data sources. The recommendation from the World Meteorological Organization (WMO) is to define the climate normal period as the most recent 30-year period finishing in a year ending with a 0 (e.g., 1991 to 2020) (WMO 2017). The climate normal for each variable is taken as the average over that period. In this report, the approach is to define the climate normals using the at least 30 years of observations available, including recent observations. Climate normals are used as a benchmark to describe the conditions mostly likely to be experienced in a given location by removing the influence of shorter-lived meteorological cycles and variability that have more of a year to year, seasonal or daily influence (e.g., El Nino, interannual variability, local weather systems). Over shorter periods of time (e.g., five to 10 years), such cycles and variabilities may influence the estimation of average climate conditions and obscure any climate trends over the climate normal period. By representing the baseline statistics using a climate normal period defined over at least 30 years, the baseline provides a robust benchmark of the current expected climate conditions from which to measure any future projected changes in climate.

After completing a review of available climate stations, the current climate baseline is based on available observations from climate stations in the region of the Project, on-site observations, and reanalysis data. Based on the amount of data available from regional climate stations, the need for infilling is assessed to meet data requirements. Regional climate sensitivity analysis is performed to gauge the similarity between regional climate stations that may be used for infilling. Gridded reanalysis dataset from the European Centre for Medium Range Weather Forecasts ReAnalysis (ERA5) was considered to infill remaining missing values from the regional climate stations as required. However, for extreme value analyses (e.g., probable maximum precipitation and extreme precipitation statistics) only observations are included to avoid introducing potential biases that could impact estimations of low-frequency and high magnitude climate extremes.

The current climate temperature and precipitation is used to calculate the annual and monthly current climate long-term averages, along with 27 extreme indices focused on temperature and precipitation identified by the WMO (2009a). Trends are established for the annual and monthly climate, as well as climate extremes, to help provide a description of the current climate conditions. The trends are calculated using an accepted methodology further described in the Appendix B, that is based on the most recent guidance found in literature and recommended by the IPCC. The trends are used to assess climate changes from long term climate observations. This information forms the daily current climate baseline.

Using the daily current climate baseline precipitation, wet and dry year statistics are used to estimate the frequency and magnitude of wet and dry years relative to the annual average. Based on annual maximum

precipitation amounts, the Probable Maximum Precipitation (PMP; theoretical highest possible precipitation) was calculated according to Hershfield Method (WMO 2009b) for 1 through 3-day durations. Extreme precipitation, and combined rainfall and snowmelt statistics were calculated for various durations (1 through 3 days) and return periods (1 in 2 years through 1 in 10000 years). The Intensity Duration Frequency (IDF) curves for the current climate are calculated by fitting a statistical distribution to the daily annual maximum series (AMS). For estimation of extreme rainfall statistics, the Gumbel distribution is adopted in this study and the parameters are estimated using the method of L-moments (Hogg et al. 1989). The PMF is defined as the largest flood resulting from a combination of the most extreme meteorological and hydrologic conditions that could occur in a given area under idealized conditions. While this event is not defined by climate alone (i.e., dependant on hydrologic components such as flood routing / storage, and abstractions), climate-driven inputs for PMF event estimation is provided including the PMP event (annual period) and by combining the spring PMP event with the 100-year extreme snowmelt (spring period) for the same 1 through 3-day durations as provided for the PMP. PMF estimates would use these climate inputs in a hydrologic model of the site to simulate runoff amounts and align with critical durations for the site to assess peak runoff flow rates and water volumes to be managed.

Potential evapotranspiration was estimated using the Hargreaves equation that uses daily minimum and maximum temperature as inputs (Hargreaves and Samani 1985). Solar radiation and average daily temperature inputs to the Hargreaves method were approximated using the day of the year and midpoint of minimum and maximum daily temperature, respectively. For months with freezing or near-freezing temperatures, the results of the Hargreaves method are adjusted to account for negligible potential evapotranspiration rates during these months. An hourly analysis of wind speed and direction is provided under baseline conditions in the form of a wind rose using available information from regional climate stations. Extreme wind speeds are estimated through a frequency analysis by fitting an appropriate statistical distribution to annual maximum hourly wind speeds for each cardinal direction. Note that values provided for return periods beyond the length of the data inputs in this report represent an extrapolation of the data and should be interpreted with caution and conservatism.

3.2 FUTURE CLIMATE METHODOLOGY

The IPCC is generally considered to be the definitive source of information related to past and future climate change as well as climate science. As an international body, the IPCC provides a common source of information relating to emission scenarios, provides third party reviews of models, and recommends approaches to document future climate projections. Periodically, the IPCC issues assessment reports summarizing the most current state of climate science. The Sixth Assessment Report (AR6; IPCC 2021) represents the most current complete synthesis of information regarding climate change. The future climate projections come from publicly available statistically downscaled future climate projections based on AR6 (IPCC 2021), on a daily scale.

Future climate is typically projected using GCMs that involve the mathematical representation of global land, sea and atmosphere interactions over a long period of time. These GCMs have been developed by various government agencies, but they share a number of common elements described by the IPCC. The IPCC does not run the models but acts as a clearinghouse for the distribution and sharing of the model forecasts. Future climate projection data are available from about 30 GCMs and five Shared Socioeconomic Pathways (SSPs) in AR6. The pathways include a suffix which specifies the radiative forcing projected to occur by 2100. For example, SSP2-4.5 denotes a pathway that is characterized includes climate change mitigation and adaptation options of SSP2, resulting in 4.5 W/m² of radiative forcing by 2100. These SSPs are described more fully by O'Neil et al. (2014) and are summarized in Table 4 of Appendix B.

The data used in this report is obtained from [Climatedata.ca](https://climatedata.ca) (2023). The data is comprised of GCM outputs, which are statistically downscaled using the Bias Correction / Constructed Analogues with Quantile mapping reordering (BCCAQ) version 2 provided by the Pacific Climate Impacts Consortium to correct for systematic biases in temperature (systematic over or underestimation) and precipitation (frequent drizzle and underestimation of extremes). The IPCC describes future emission scenarios using Shared Socioeconomic Pathways (SSPs); however, this report focuses on the three SSPs (SSP1-2.6,

SSP2-4.5 and SSP5-8.5) currently available from [Climatedata.ca](https://climatedata.ca), capturing the lower to upper range of emission scenarios. The statistically downscaled models provide daily global climate scenarios, at a gridded resolution of approximately 10 km for the simulated period of 1950 to 2100 ([Climatedata.ca](https://climatedata.ca) 2023). The climate variables available from this dataset include minimum temperature, maximum temperature, and total precipitation. The selection of this data for this project is based on the available temporal and spatial resolution of the data. The availability of daily downscaled data allows for better characterization of the climate extremes, especially for precipitation. The availability of high spatial resolution (10 km instead of hundreds of km in GCMs) provides better representation for site-specific studies.

Since no one model or climate scenario can be viewed as completely accurate, the IPCC recommends that climate change assessments use as many models and climate scenarios as possible, or a multi model ensemble (IPCC 2021, p.221). For this reason, the multi model ensemble approach is used to delineate the probable range of results and better capture the actual outcome (an inherent unknown). Percentiles are used to express future projections of climate relative to the projections given from each member the multi model ensemble. For example, the 50th percentile, or the median value of the projected values from the multi model ensemble.

The model projections can be summarized for magnitude of change from the climate regime baseline for different time horizons. The time horizons applied to this study include the following:

- 1991 to 2020 (model baseline);
- 2041 to 2070 (2050s or mid-century); and
- 2071 to 2100 (2080s or end-of-century).

The modelled baseline was chosen to represent the most recent WMO climate normal period to represent projected changes in climate from this period to the 2050s and 2080s future periods.

Annual and monthly changes in precipitation and temperature are estimated by calculating the changes between the future climate periods and the baseline period. Projected changes in wet and dry year statistics are estimated by taking the percentage change between those estimated for the model baseline and future periods. Future climate extremes are projected using 27 WMO extreme indices that are based on both temperature and precipitation variables. The future climate extremes are described in terms of changes from the baseline period. The future projected changes in PMP are calculated using the Hershfield statistical method, which is used to estimate projected changes in the climate inputs to PMF for annual and spring (including snowmelt) periods. Extreme precipitation, and combined rainfall and snowmelt statistics were calculated for various durations (1- through 120-days) and return periods (1 in 2 years through 1 in 10,000 years) in the form of Intensity Duration Frequency (IDF) curves.

The IDF curves are calculated by fitting a statistical distribution to the daily AMS. The Gumbel distribution is fitted using the method of moments (Hogg et al. 1989) to estimate projected changes in extreme rainfall across duration and return periods. Potential evapotranspiration was estimated using the Hargreaves method using the minimum and maximum daily temperature. Solar radiation and average daily temperature inputs to the Hargreaves method were approximated using the day of the year and midpoint of minimum and maximum daily temperature, respectively. Qualitative estimates of projected changes in annual mean and 50-year return period wind speeds are provided through literature review, as wind speed projections are not available in the projections provided by [Climatedata.ca](https://climatedata.ca), are typically not well represented in climate models at a local scale, with sparse observations for adjustments to be applied at a site level.

The results of the analyses outlined above are provided in terms of changes from the baseline period (1991 to 2020) to the two future periods (2050s and 2080s). This approach allows for climate model bias (in comparison to observational data) to be mitigated as only the projected changes are presented. Uncertainty in the projections from the multi-model ensemble are presented in the form of percentiles for each analysis. In this report, the 50th percentile is used to describe the projected change assessed for the climate variables. Appendix C: Additional Climate Projection Statistics provides the projected changes from the multi-model ensemble using a set of percentiles to examine the range of results.

4 CURRENT CLIMATE

Development of a current climate baseline dataset using the most representative available information is key to estimating current climate statistics for which future projected changes will be referenced.

The following sections outline the development of the current climate baseline dataset and the statistics which are derived from this dataset. The goal of this section is to develop a climate change dataset that is representative of the project site and is consistent with the data quality and calculation methods used for the future projections.

4.1 CURRENT CLIMATE DATASET DEVELOPMENT

In this section the available data sources considered to develop the current climate baseline dataset for Project are identified. The data sources are then analysed to decide which sources are representative of the site. Climate observations were obtained for stations in the region, consisting of six climate stations within 40 km of the site (Table 5-1). A map illustrating the location of each station relative to the site is provided in Appendix A. The main criteria for the climate station selection are the length of record (typically 30 years of data), similar geographical siting compared to the Project, and the availability of continuous daily observations. Other criteria are listed in Appendix B.

To achieve a continuous record of approximately 30 years for both precipitation and temperature variables, regional climate stations from the ECCC and reanalysis data from the European Centre for Medium-Range Weather Forecasts (ECMWF) Re-Analysis (ERA5) dataset were considered for infilling and extending the on-site data. ERA5 provides hourly estimates of a large number of atmospheric, land and oceanic climate variables by assimilating observations and climate modelling. The data covers the Earth on a 30 km grid and resolve the atmosphere using 137 levels from the surface up to a height of 80km from 1950 to present. As the 30 km grid size of ERA5 may not be representative of point locations such as the Project, a quantile delta mapping bias correction is applied using region climate station observations.

Of the regional climate stations, Red Lake A (6016970), Red Lake A (6016971), and Red Lake A (6016975) are assumed to be co-located as they have the same elevation, and distance to the site. Treating these three stations as one results in a long data length of 94 years (including most recent period) with high data availability overall, and similar elevation to the site. For these reasons Red Lake A stations are taken as the base stations to represent the site, while the remaining regional climate stations are considered to infill missing data from this source to obtain a continuous period of record. Ear Falls (6012198) and Ear Falls (AUT) (6012199) stations are assumed to be co-located as they have the same elevation, and distance to the site. Treating these two stations as one results in a long data length of 96 years (including most recent period) with high data availability for both temperature and precipitation. Red Lake Forestry (6016979) station is close to the site but includes only two years of data with low data availability for both temperature and precipitation.

A regional sensitivity analysis was performed to compare observations between the climate stations listed in Table 5-1, and the ERA5 dataset (reanalysis data) prior to infilling. Comparing annual averaged monthly total precipitation between data sources shows a high degree of variability throughout the year (Figure 4-1). Generally, the month with the highest precipitation amounts was found in June, with lower precipitation amounts in February. Comparison of monthly total precipitation between datasets shows that the corrected ERA5 captures the seasonal variability in monthly mean temperature and total precipitation. Red Lake Forestry (6016979) station does not consistently follow long term precipitation patterns in the region, likely due to the shorter period of coverage. Ear Falls stations generally have higher precipitation amounts, likely due to higher data availability compared to the Red Lake A stations. Monthly mean temperatures on the other hand, are much more consistent across regional climate stations (Figure 4-2). This is typical as temperature generally varies more gradually in space while precipitation events can occur on finer spatial scales. Red Lake A stations experience slightly lower temperatures, particularly in winter months, likely due to their higher latitude position (approximately 0.5 degree north of the Ear Falls stations) and lower data availability in recent years compared to the Ear Falls stations.

Considering both the data availability and sensitivity analysis of the climate data sources, the Red Lake A stations are used to represent the site climate (long period of record including recent years, high data availability, similar geographical sitting, and being consistent with previous assessment of the Project site). Preference is given to the Ear Falls stations for both precipitation and temperature to infill Red Lake A Stations, followed by the regional climate stations and ERA reanalysis data. Due to the variability found across stations for precipitation and temperature variables, a monthly correlation analysis was completed such that linear correction factors may be applied to the data used to infill Red Lake A stations. The baseline period of 1950 to 2022 is used to represent the current climate baseline period to capture the longest continuous period of record (no missing data) including the most recent period.

4.2 CURRENT TEMPERATURE AND PRECIPITATION

The climate normal or average is used to establish the current conditions, while the decadal trend indicates the direction and magnitude of how the indices are changing on average over a 10-year period. The analysis assessed the statistical significance of trends in mean temperature and total precipitation at the 90th, 95th, 99th and 99.9th percentile levels. Below the 90th percentile level a trend is deemed to be not statistically significant, while trends that are 0 when rounded to the first decimal place are labelled as no apparent trend.

Mean daily temperature was used for the calculation of annual and monthly statistics and trends (Table 4-2). The warmest month on average is the month of July with a mean temperature of 18.3°C, and the coldest is the month of January with a mean temperature of -19.2°C. The annual temperature was found to have a statistically significant upwards trend of 0.2°C per decade, significant at the 99th percentile with an average value of 1.1°C (Figure 4-3). On a monthly scale, statistically significant trends were found for the January, March, August, September and December with magnitudes ranging from 0.2°C to 0.7°C per decade. Increasing temperatures in the winter months has the potential to affect minimum extreme temperatures. No statistically significant decreasing monthly average temperatures were found.

Average annual total precipitation over the baseline period was calculated to be 633.0 mm with July being the wettest month (90.4 mm) and February being the driest (20.1 mm) on average (Table 4-2). The annual total precipitation was found to have a statistically significant increasing trend of 17.1 mm per decade, significant at the 95th percentile (Figure 4-4). Statistically significant increasing trend were found for the months of May, September and October, with magnitudes ranging from 3.7 to 5.1 mm per decade. Increasing precipitation amounts in May have the potential to increase combined rainfall and snowmelt events which may be more critical for managing large volumes of water on site, while increased precipitation events in the fall may results in more intense convective storms of shorter durations. Statistically significant decreasing trend of -1.1 mm per decade was also found for the month of February.

4.3 CURRENT WET AND DRY YEAR STATISTICS

Wet and dry year precipitation statistics derived over the current climate baseline period are provided in Table 4-3. Annual total precipitation amounts for both wet and dry year are provided over a range of return periods using the Project current climate baseline. Details on the calculation of annual total precipitation for a given return period is included in Appendix B.

The 5-year return period corresponds to an annual total precipitation value of 724.3 mm and 487.5 mm for the wet and dry years. For the 100-year return period annual total precipitation values for the wet and dry years of 1026.9 mm and 343.8 mm were found. In general, the increase of annual total precipitation with return period is greater for the smaller return periods. For example, in the wet years there is an increase of 78.9 mm from the 5-, to 10-year return periods and a 63.7 mm increase from the 50-, to 100-year return periods.

4.4 CURRENT WORLD METEOROLOGICAL ORGANIZATION EXTREME INDICES

The WMO Expert Team on Climate Change Detection and Indices (ETCCDI 2017; WMO 2009a) recommends using 27 climate extreme indices as a means of summarizing daily temperature and precipitation statistics, focusing primarily on aspects of climate extremes. They have been developed to allow consistent comparison of climate conditions on an international basis. For the following assessment, the WMO climate indices were calculated for the current climate baseline period using the 27 indices, as described in Appendix B. Two analyses for the WMO indices were completed. In the first, the minimum, maximum, mean, and median values for each of the 27 indices were calculated over the entire period (Table 4-4). In the second, the long-term averages and trends were calculated based on the annual values of each of the indices (Table 4-5).

As shown in Table 4-4, the number of heavy precipitation days (R10) (i.e., daily precipitation greater than 10 mm) is approximately 17 days per year on average, ranging from 6 to 35 days during the current climate baseline period. Based on the R10 value, there are at a minimum, 6 days in each year corresponding to precipitation greater than 10 mm. Maximum one day (RX1day) and five-day (Rx5day) precipitation events were 41 mm and 65 mm on average. Compared with the monthly total precipitation in Section 4.2, the average annual maximum five-day event is greater than the monthly averages for most months, with lower values occurring from summer to early fall as the timing of the maximum 5-day events is during the summer season. The precipitation during the extremely wet days (R99p) (i.e., the annual total precipitation when daily precipitation is greater than the 99th percentile) could be up to a maximum of 327 mm. The number of consecutive dry days (CDD) ranges from 11 days to 49 days per year, with an average of 23 days.

The highest recorded daily maximum (TXx) and minimum (TNx) and lowest recorded daily maximum (TXn) and minimum (TNn) temperatures correspond to 37°C and 24°C, and -36°C and -46°C, respectively. The range of extreme daily temperatures is much greater than that shown in the monthly statistics for mean temperature in Section 4.2, especially with regards to the maximum temperature. The length of cold spells appears to be relatively short with a cold spell duration indicator (CDSI) ranging from 0 to 16 days and with an average of 2 days. The location of Project experiences frequent sub freezing temperature with both frost and ice days making up a considerable portion of the year at 200 and 127 days respectively. Summers can be relatively short with summer days (daily maximum temperature greater than 25°C) ranging from 10 to 63 days and average of 33 days over the current climate baseline.

The long-term trends over the current climate baseline period were calculated for the WMO indices using the methodology outlined in Appendix B. For each of the 27 indices, the climate normal, long-term trend, and statistical significance of the trend were calculated. The climate normal is used to establish the current conditions, while the decadal trend indicates the direction and magnitude of how the indices are changing on average over a ten-year period. The analysis assessed the statistical significance at the 90th, 95th, 99th and 99.9th percentile levels. Below the 90th percentile level a trend is deemed to be not statistically significant, while trends that are 0 when rounded to the first decimal place are labelled as no apparent trend. The long-term averages and trends are presented in Table 4-5.

The trends in temperature extremes at Project are consistent with that of a warming climate. Cool days and summer days show a decreasing and increasing trend, respectively. For precipitation extremes, the annual total wet -day precipitation was found to have a statistically significant trend of 13.9 mm per decade. This is consistent with the trends estimated in Section 4.2.

4.5 CURRENT PROBABLE MAXIMUM PRECIPITATION

PMP is calculated with the Hershfield method (WMO 2009b), with adjustments applied based on Hopkinson (2001) to account for the durations of 24-hours to 3-days presented in Table 4-6, as further described in Appendix B. The PMP calculation relies exclusively on observations and the ERA5

reanalysis dataset was not used to infill the missing data to avoid introducing any potential bias in the PMP estimate (see Appendix B). With this approach, the PMP is estimated to range from 319.2 mm to 342.2 mm for 1- to 3-day durations.

The Ministry of Natural Resources provides technical guidance in estimation of the PMP for northern Ontario. The 24-hour PMP for the northern Ontario was calculated as 332.5 mm, based on a series of PMP studies.

4.6 CURRENT EXTREME PRECIPITATION STATISTICS

Extreme precipitation statistics are calculated from the annual maximum series of daily total precipitation by fitting a statistical distribution and extracting precipitation depths over a range of return periods (see Appendix B for details). Greater durations correspond to larger volumes of rainfall accumulated over a longer period, while the return period refers to the frequency of extreme precipitation (longer return period indicates a rarer event). The extreme precipitation calculation relies exclusively on observations and the reanalysis dataset was not used to infill the missing data. Over the current climate baseline, the 100-year event for a 1-day duration corresponds to a precipitation depth of 85 mm (Table 4-7).

4.7 CURRENT EXTREME COMBINED RAINFALL AND SNOWMELT STATISTICS

Combined rainfall and snowmelt statistics are necessary for estimating water volumes generated by during spring freshet when rainfall on frozen ground and snowmelt to manage site drainage and water storage. These statistics are estimated by first separating precipitation into rain and snow, based on mean daily temperature. Snow accumulation and melt are then estimated following the procedure outlined in Appendix B. Annual maximums for combined rainfall and snowmelt are then fitted using a statistical distribution and extracting the combined depths over a range of return periods. The extreme combined rainfall and snowmelt calculation relies exclusively on observations and the reanalysis dataset was not used to infill the missing data. In Appendix D, the method used is validated through comparison to ECCO snow survey measurements.

Across durations, combined rainfall and snowmelt values have a varying composition of rainfall and snowmelt (Table 4-8). Over the shortest durations, rainfall generally makes up a larger portion, as the annual maximums typically result from spring rainfall with a slower contribution of melt. Medium durations generally consist of a larger contribution of snowmelt, as it may occur during periods after rainfall has occurred or between rainfall events. For the longest durations, snowmelt is less of a contributor as snowpack becomes limited for additional melt.

Over the current climate baseline, the 100-year event for a 1-day duration corresponds to a combined rainfall and snowmelt depth of 41.4 mm. For medium durations, snowmelt may make up a larger fraction of the combined rainfall and snowmelt amount, as values between 5 to 30 days are higher across return periods than those estimated for extreme precipitation.

4.8 CURRENT CLIMATE INPUTS FOR PROBABLE MAXIMUM FLOOD ESTIMATION

Climate inputs to estimate the PMF are provided here to support hydrologic modelling studies at the Project site. The climate inputs to PMF align with the durations provided for the PMP event, however critical durations of the PMF for design purposes will need to be assessed. The spring (October through June) climate inputs to PMF are estimated by combining estimates of spring PMP (Section 4.5) and the 100-year snowmelt over the spring period. The annual (all calendar months) climate inputs to PMF

estimation is represented simply as the PMP event (Section 4.5) (Table 4-9). The climate inputs provided rely only on observations and the reanalysis dataset was not used to infill the missing data to avoid underestimation of climate inputs.

The estimated input to PMF ranges from 271.8 mm to 378.9 mm for 1- to 3-day durations in the spring and 319.2 mm to 342.2 mm for 1- to 3-day durations annually (Table 4-9). Climate inputs to PMF for the 1-day duration in the spring period is lower than the annual period, and vice versa for the 2- and 3-day durations. For the 2- and 3-day durations, the spring climate inputs to PMF provides the most critical flood volumes. This could be due to greater contribution of snowmelt in the spring over durations longer than 3 days, causing the spring climate inputs to PMF to surpass the annual period for longer durations. This aligns with the higher values of extreme combined rainfall and snowmelt during medium durations compared to those of extreme precipitation (Section 4.7).

4.9 CURRENT POTENTIAL EVAPOTRANSPIRATION

Potential evapotranspiration rates for the Project site were estimated using the Hargreaves equation (Hargreaves and Samani 1985), which uses minimum, maximum, and mean temperature as inputs (see Appendix B). Adjustments are applied to account for months where temperatures are near or below freezing, as during these months evapotranspiration will be negligible (see Appendix E).

The annual average total potential evapotranspiration was estimated as 584.7 mm (Table 4-10), which is slightly less than the annual average total precipitation of 633 mm (Section 5.2). This indicates that the Project site is likely in a state of water balance equilibrium on average.

Estimates of potential evapotranspiration using four different methods including Hargreaves and Samani (1985), Thornthwaite (1948), Priestley-Taylor (1972), and Hamon (1963) are evaluated against estimated lake evaporation for the Project site (Appendix E). It was found that the Hargreaves method provides a reasonable approximation for lake evaporation, with an average difference of 7% and a close representation of seasonal patterns over the months of May through October.

4.10 CURRENT WIND SPEED

The magnitude and relative frequency of wind speeds across cardinal wind directions were assessed using hourly mean wind observations from Ear Falls (AUT) (6012199) station, with high data availability of 95% from 2000 to 2023. The hourly wind observations are then used to develop a wind rose, which indicates how frequently wind speeds are observed over a set of wind speed categories and cardinal directions (Figure 4-5). Note that according to meteorological convention, the wind rose in Figure 4-5 represents the direction the winds are blowing from. The westerly wind direction is the most common, accounting for approximately 10% of the hourly wind speeds. Windspeeds falling under the west northwesterly direction are slightly less frequent (9.5% of hourly wind speeds) but contain the greatest frequency of windspeed in excess of 5 m/s (18 km/h).

Using the same hourly mean wind observations for the period of 2000 to 2023, a frequency analysis was conducted for each cardinal wind direction to estimate the wind speed associated with a set of return periods (Table 4-11). For lower return periods of 2 to 10 years, the greatest wind speeds are estimated for the west (W) to south southwest (SSW) directions, with magnitudes ranging from 9.4 m/s to 9.8 m/s. For the 100-year return period, the greatest wind speed is estimated for the south southwest (SSW) direction, with a magnitude of 12.4 m/s.

Table 4-1: Regional Climate Stations for Project

Station Name	Climate ID	Coordinates	Distance to Site (km)	Elevation (m)	Time Period	Data Availability	
						Mean Temperature	Total Precipitation
Project	—	50.52°N, 93.38°W	—	405	—	—	—
Ear Falls	6012198	50.63°N, 93.22°W	39.9	361	1928- 1999	76%	79%
Ear Falls (AUT)	6012199	50.63°N, 93.22°W	39.9	363	1999- 2023	95%	92%
Red Lake A	6016970	51.07°N, 93.79°W	24.3	386	2012- 2018	54%	3%
Red Lake A	6016971	51.07°N, 93.79°W	24.3	386	2018- 2023	79%	0%
Red Lake A	6016975	51.07°N, 93.79°W	24.3	386	1930- 2012	67%	74%
Red Lake Forestry	6016979	51.07°N, 93.82°W	25.3	376	1959- 1960	37%	46%

Table 4-2: Current Climate Long-Term Averages and Trends over 1977 to 2021 Baseline Period

Climate Variables	Average	Decadal Trend	Statistical Significance
Average Annual Temperature [°C]	1.1	+0.2	Significant at the 99th percentile
Average January Temperature [°C]	-19.2	+0.7	Significant at the 99th percentile
Average February Temperature [°C]	-15.9	0	No apparent trend
Average March Temperature [°C]	-7.9	+0.4	Significant at the 95th percentile
Average April Temperature [°C]	1.5	+0.1	Not statistically significant
Average May Temperature [°C]	9.3	+0.1	Not statistically significant
Average June Temperature [°C]	15.2	+0.1	Not statistically significant
Average July Temperature [°C]	18.3	+0.1	Not statistically significant
Average August Temperature [°C]	16.9	+0.2	Significant at the 90th percentile
Average September Temperature [°C]	11.0	+0.2	Significant at the 95th percentile
Average October Temperature [°C]	4.1	0	No apparent trend
Average November Temperature [°C]	-5.8	+0.2	Not statistically significant
Average December Temperature [°C]	-15.5	+0.3	Significant at the 90th percentile
Annual Total Precipitation [mm (equiv.)]	633.0	17.1	Significant at the 95th percentile
January Total Precipitation [mm (equiv.)]	29.1	-0.8	Not statistically significant
February Total Precipitation [mm (equiv.)]	20.1	-1.1	Significant at the 95th percentile
March Total Precipitation [mm (equiv.)]	27.1	-0.3	Not statistically significant
April Total Precipitation [mm (equiv.)]	34.3	+0.1	Not statistically significant
May Total Precipitation [mm (equiv.)]	62.8	+5.1	Significant at the 99th percentile
June Total Precipitation [mm (equiv.)]	89.2	-0.3	Not statistically significant
July Total Precipitation [mm (equiv.)]	90.4	+2.7	Not statistically significant
August Total Precipitation [mm (equiv.)]	81.8	+1.9	Not statistically significant
September Total Precipitation [mm (equiv.)]	75.1	+4.1	Significant at the 90th percentile
October Total Precipitation [mm (equiv.)]	53.8	+3.7	Significant at the 95th percentile
November Total Precipitation [mm (equiv.)]	38.7	0	No apparent trend
December Total Precipitation [mm (equiv.)]	30.4	-0.4	Not statistically significant

Table 4-3: Annual Total Precipitation for Wet and Dry Return Periods for the Project Site

Return Period (years)	Annual Precipitation (mm)	
	Wet Year	Dry Year
5	724.3	487.5
10	803.2	439.6
20	874.9	403.6
50	963.2	366.6
100	1026.9	343.8

Table 4-4: Current Climate WMO Extreme Indices over the Baseline Period

ID	Indicator Name	Units	Min	Max	Median	Mean
CDD	Consecutive dry days	Days	11	49	22	23
CSDI	Cold spell duration indicator	Days	0	16	0	2
CWD	Consecutive wet days	Days	3	10	5	5
DTR	Diurnal temperature range	°C	10	12	11	11
FD0	Frost days	Days	171	227	199	200
GSL	Growing season Length	Days	126	205	165	164
ID0	Ice days	Days	98	152	129	127
PRCPTOT	Annual total wet-day precipitation	mm	280	1040	612	610
R10	Number of heavy precipitation days	Days	6	35	18	17
R20	Number of very heavy precipitation days	Days	0	12	5	5
R95p	Very wet days	mm	76	699	327	330
R99p	Extremely wet days	mm	0	327	118	121
R25MM	Number of days above 25 mm	Days	0	8	3	3
RX1day	Max 1-day precipitation amount	mm	14	91	38	41
Rx5day	Max 5-day precipitation amount	mm	29	115	62	65
SDII	Simple daily intensity index	mm/day	4	9	6	6
SU25	Summer days	Days	10	63	33	33
TN10p	Cool nights	% of Days	1	19	11	10
TN90p	Warm nights	% of Days	3	18	9	10
TNn	Minimum of daily minimum temperature	°C	-46	-35	-40	-39
TNx	Maximum of daily minimum temperature	°C	17	24	20	20
TR20	Tropical nights	Days	0	0	0	0
TX10p	Cool days	% of Days	3	22	10	10
TX90p	Warm days	% of Days	4	20	10	10
TXn	Minimum of daily maximum temperature	°C	-36	-21	-28	-28
TXx	Maximum of daily maximum temperature	°C	28	37	33	32
WSDI	Warm spell duration indicator	Days	0	20	0	4

Table 4-5: Current Climate Trends in WMO Extreme Indices

Indicator Name	Climate Normal	1950 – 2022 Trend (Change per Decade)	Statistical Significance
Consecutive dry days	23.2	-0.4	Not statistically significant
Cold spell duration indicator	2.1	0	No apparent trend
Consecutive wet days	5.0	0	No apparent trend
Diurnal temperature range	10.8	0	No apparent trend
Frost days	200.5	-0.4	Not statistically significant
Growing season Length	163.8	+1.4	Not statistically significant
Ice days	126.8	-1.2	Not statistically significant
Annual total wet-day precipitation	610.1	+13.9	Significant at the 95th percentile
Number of heavy precipitation days	17.2	+0.4	Not statistically significant
Number of very heavy precipitation days	5.3	+0.3	Significant at the 95th percentile
Very wet days	330.2	+11.7	Significant at the 90th percentile
Extremely wet days	120.5	+5.1	Not statistically significant
Number of days above 30 mm	3.2	0	No apparent trend
Max 1-day precipitation amount	40.9	+0.7	Not statistically significant
Max 5-day precipitation amount	65.0	+1.5	Not statistically significant
Simple daily intensity index	6.2	0	No apparent trend
Summer days	33.3	+1.3	Significant at the 95th percentile
Cool nights	10.0	-0.6	Significant at the 95th percentile
Warm nights	9.8	+0.6	Significant at the 99.9th percentile
Minimum of daily minimum temperature	-39.5	+0.3	Significant at the 95th percentile
Maximum of daily minimum temperature	19.8	0	No apparent trend
Tropical nights	0.0	0	No apparent trend
Cool days	9.9	-0.6	Significant at the 99th percentile
Warm days	9.8	+0.5	Significant at the 95th percentile
Minimum of daily maximum temperature	-27.9	+0.5	Significant at the 99th percentile
Maximum of daily maximum temperature	32.4	-0.1	Not statistically significant
Warm spell duration indicator	4.4	0	No apparent trend

Table 4-6: Probable Maximum Precipitation for Durations of 1- to 3-Days

Duration	Probable Maximum Precipitation (mm)
24-Hour ⁽¹⁾	360.7
1-Day	319.2
2-Day	319.6
3-Day	342.2

Note:

1 Factor of 1.13 applied to 1-day duration to estimate 24-hour extreme precipitation following WMO (2009b)

Table 4-7: Extreme Precipitation Statistics Across Durations and Return Periods (mm)

Duration (days)	Return Period (years)										
	2	5	10	25	50	100	200	500	1,000	2,000	10,000
24-hour ⁽¹⁾	43.6	57.6	66.9	78.7	87.4	96.0	104.6	116.0	124.6	133.2	153.1
1	38.6	51.0	59.2	69.6	77.3	85.0	92.6	102.7	110.3	117.9	135.5
2	46.5	59.8	68.6	79.8	88.0	96.2	104.4	115.2	123.4	131.5	150.5
3	51.1	65.3	74.8	86.7	95.5	104.3	113.0	124.5	133.2	141.9	162.1
4	56.1	72.8	83.9	97.9	108.3	118.6	128.8	142.4	152.6	162.8	186.6
5	61.0	78.5	90.1	104.7	115.5	126.3	137.0	151.2	161.9	172.6	197.4
6	65.4	82.7	94.1	108.6	119.3	129.9	140.5	154.5	165.1	175.7	200.2
7	69.1	87.4	99.5	114.9	126.3	137.6	148.8	163.7	174.9	186.1	212.2
10	80.1	99.8	112.8	129.3	141.5	153.7	165.8	181.7	193.8	205.9	233.9
20	112.4	140.6	159.2	182.7	200.1	217.4	234.7	257.5	274.7	291.9	331.8
30	141.9	175.6	197.9	226.1	247.0	267.7	288.4	315.6	336.3	356.9	404.7
50	192.2	240.0	271.6	311.5	341.2	370.6	399.9	438.6	467.8	497.0	564.9
75	252.2	313.5	354.1	405.3	443.4	481.1	518.7	568.3	605.8	643.3	730.4
90	287.7	356.9	402.8	460.7	503.6	546.3	588.8	644.8	687.2	729.6	827.9
120	353.0	437.2	492.9	563.4	615.6	667.5	719.2	787.4	838.9	890.4	1010.0

Note:

1 Factor of 1.13 applied to 1-day duration to estimate 24-hour extreme precipitation following WMO (2009b).

Table 4-8: Extreme Combined Rainfall and Snowmelt Statistics Across Durations and Return Periods (mm)

Duration (days)	Return Period (years)										
	2	5	10	25	50	100	200	500	1,000	2,000	10,000
1	19.1	25.1	29.1	34.1	37.8	41.4	45.1	49.9	53.6	57.3	65.7
2	31.0	40.2	46.4	54.2	59.9	65.6	71.3	78.8	84.5	90.2	103.4
3	40.9	54.0	62.7	73.6	81.7	89.8	97.8	108.4	116.4	124.4	143.0
4	49.4	65.7	76.5	90.1	100.3	110.3	120.3	133.5	143.5	153.5	176.7
5	57.0	75.9	88.3	104.1	115.8	127.4	139.0	154.3	165.8	177.4	204.1
6	63.3	84.5	98.5	116.3	129.4	142.5	155.5	172.6	185.6	198.6	228.7
7	68.3	91.6	106.9	126.3	140.7	155.0	169.3	188.1	202.3	216.5	249.4
10	81.2	111.5	131.7	157.1	176.0	194.7	213.3	238.0	256.6	275.2	318.3
20	104.5	142.6	167.8	199.7	223.3	246.8	270.2	301.1	324.4	347.7	401.8
30	118.4	162.9	192.4	229.7	257.4	284.8	312.2	348.3	375.6	402.8	466.1
50	133.1	183.2	216.3	258.1	289.2	320.0	350.7	391.2	421.9	452.5	523.5
75	138.0	188.6	222.0	264.4	295.7	326.9	358.0	398.9	429.9	460.8	532.6
90	139.0	190.3	224.2	267.1	298.9	330.5	362.0	403.5	434.9	466.3	539.1
120	140.7	191.3	224.9	267.3	298.8	330.0	361.1	402.2	433.2	464.2	536.2

Table 4-9: Climate Input for use in PMF Development (mm)

Event Duration	Spring PMP (mm)	100-Year Snowmelt (mm)	Spring Water Input (mm)	Annual Water Input (mm)
1-Day	238.6	33.2	271.8	319.2
2-Day	265.2	59.5	324.6	319.6
3-Day	297.5	81.4	378.9	342.2

Table 4-10: Annual and Monthly Total Potential Evapotranspiration (mm)

Month	Mean	Minimum	Maximum
January	0	0	0
February	0	0	0
March	0	0	0
April	0	0	0
May	107.9	84.0	130.8
June	131.9	106.9	157.5
July	140.5	115.9	165.6
August	112.1	87.3	137.5
September	63.0	50.4	77.2
October	29.3	19.7	46.9
November	0	0	0
December	0	0	0
Annual	584.7	464.2	715.5

Table 4-11: Extreme Hourly Mean Wind Speed Frequency Analysis in the Project Region (m/s)

Cardinal Direction	Return Period (years)					
	2	5	10	20	50	100
N	6.7	7.3	7.7	8	8.5	8.8
NNE	6.6	7.4	8	8.5	9.2	9.8
NE	6.9	7.7	8.3	8.8	9.5	10
ENE	6.6	7.3	7.7	8.1	8.7	9.1
E	5.6	6.2	6.6	7	7.4	7.8
ESE	5.9	6.7	7.3	7.8	8.6	9.1
SE	5	5.7	6.2	6.6	7.2	7.6
SSE	5	5.6	6	6.3	6.8	7.2
S	5.5	6.2	6.6	7.1	7.7	8.2
SSW	7.4	8.6	9.5	10.4	11.5	12.4
SW	8	8.9	9.4	9.9	10.6	11.1
WSW	8.6	9.3	9.8	10.3	11	11.4
W	8.4	9.2	9.7	10.2	10.8	11.3
WNW	7.2	7.8	8.2	8.6	9.1	9.5
NW	6.7	7.3	7.7	8	8.5	8.8
NNW	6.6	7.4	8	8.5	9.2	9.8

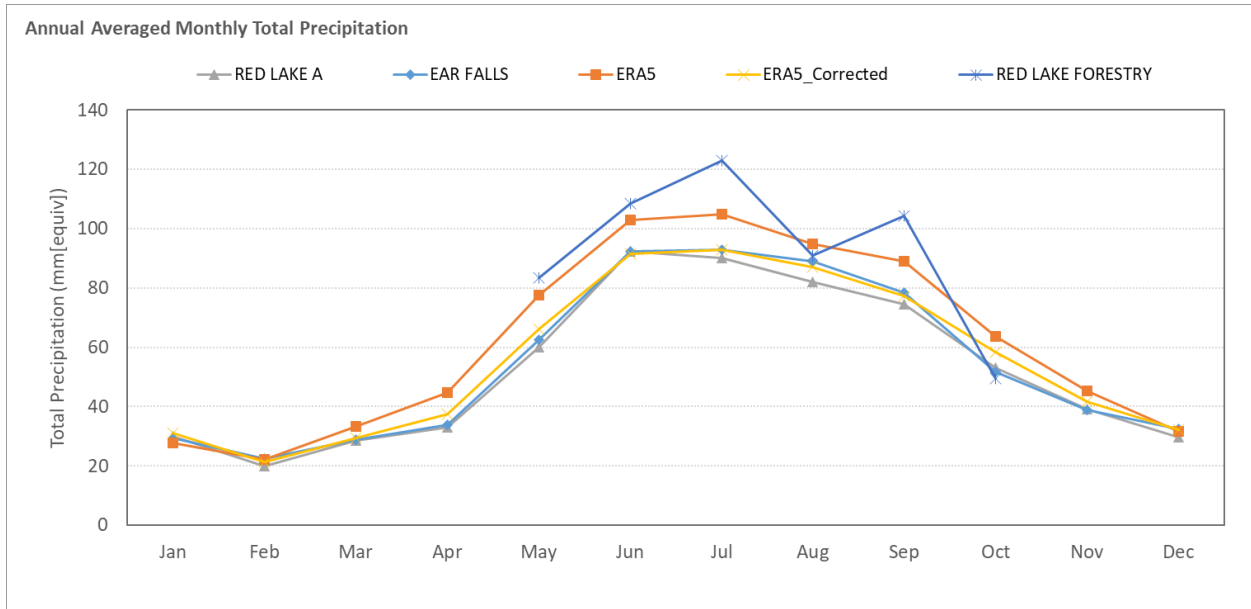


Figure 4-1: Average Monthly Total Precipitation Across Regional Climate Stations

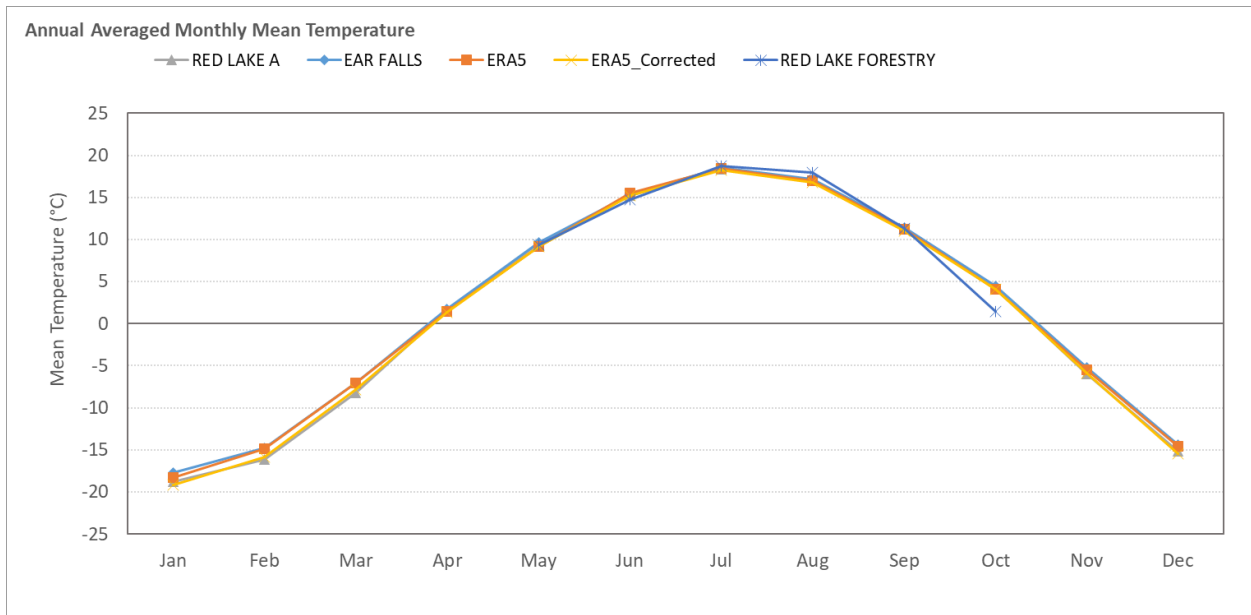


Figure 4-2: Average Monthly Mean Temperature Across Regional Climate Stations

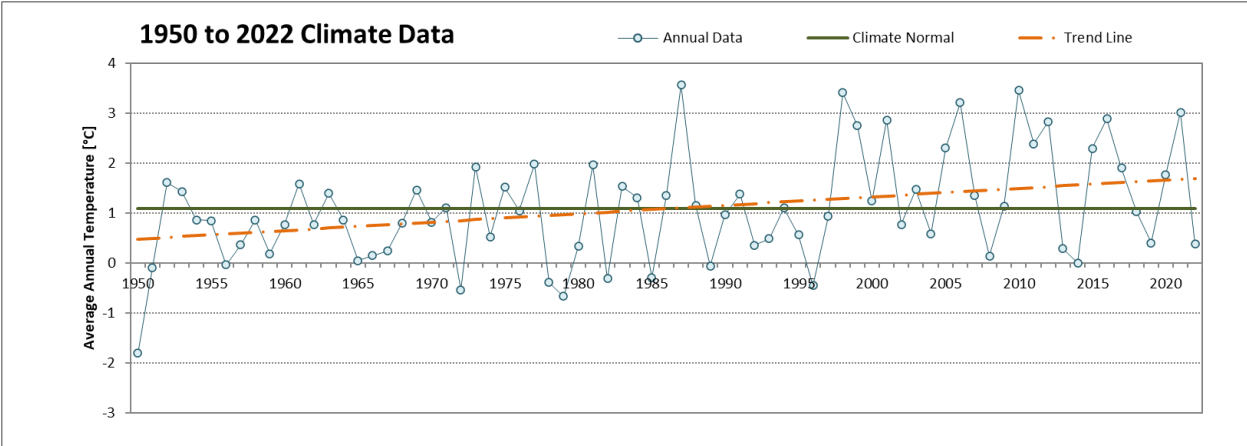


Figure 4-3: Current Climate Average Annual Temperature Analysis for Project

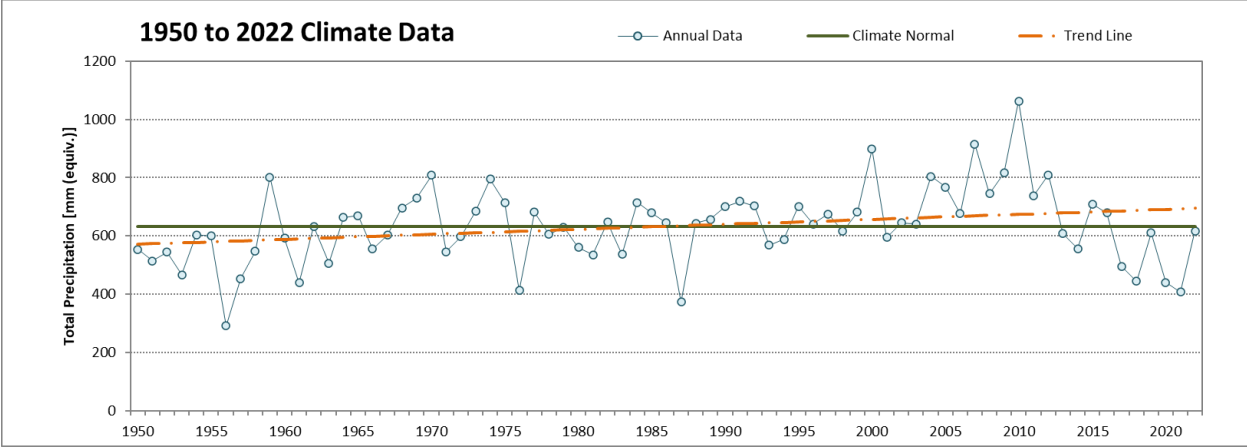


Figure 4-4: Current Climate Total Annual Precipitation Analysis for Project

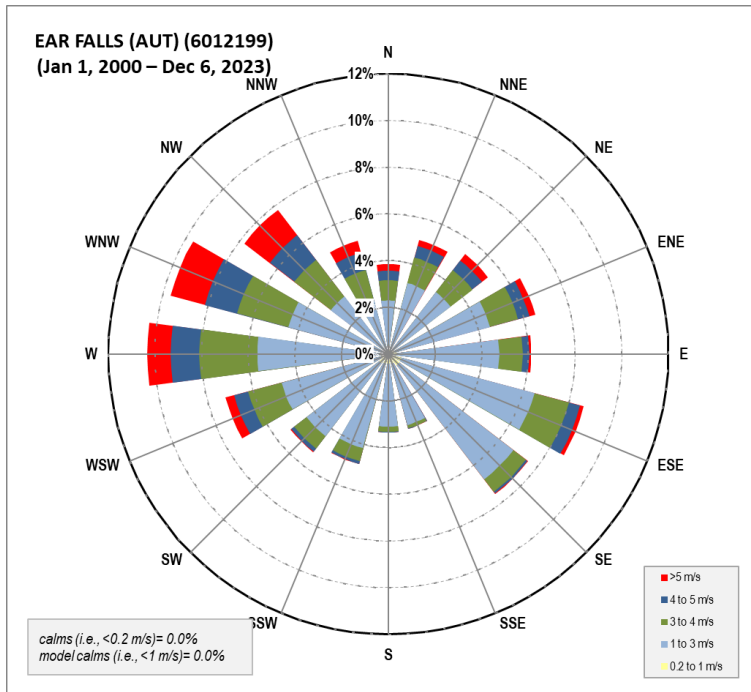


Figure 4-5: Magnitude and Frequency of Hourly Wind Speed and Direction in the Project Region

5 FUTURE CLIMATE

The future projected changes in climate statistics developed in this section are intended to be applied to the baseline climate statistics provided in Section 4. Projected changes are provided in terms of percentiles across the multi model ensemble; therefore, it is important to consider the percentile level used for a given application. More details about selecting percentiles to represent changes in climate variables are given in Section 2.

5.1 FUTURE TEMPERATURE AND PRECIPITATION

Statistically downscaled projections of daily total precipitation and mean temperature variables are used to estimate the change in monthly mean, minimum, and maximum statistics from the model baseline to the 2050s and 2080s future periods. Changes in precipitation are provided as percentage changes from the current climate baseline, while changes in temperature are provided as absolute values in degree Celsius. This is typically done to facilitate the application of projected changes to the baseline values (Anandhi et al. 2011).

Annual average temperature is projected to change by 2.5°C in the 2050s and 3.4°C in the 2080s at the 50th percentile, indicating an increasing trend due to changing climate (Table 5-1 and Table 5-2). In the 2050s and 2080s, projected changes in mean monthly temperature range from 2.0°C to 3.4°C and 3.0°C to 5.0°C, respectively with the greatest changes occurring in the winter months at the 50th percentile. All months have a projected increase in mean temperature across the distribution of the multi model ensemble. Therefore, it is very likely that temperature will become warmer at the Project site in the future. Higher temperatures have the potential to increase evapotranspiration rates (see Section 5.8). This, combined with greater projected precipitation amounts could lead to changes in the frequency and magnitude of both drought and flooding events.

As presented in Section 4.2, the current average annual temperature has been trending upwards at a statistically significant rate of 0.2°C per decade. A greater increase is projected in time periods further into the future based on the projected increases in temperature.

Annual total precipitation is projected to increase by 4% in the 2050s and 6% in the 2080s, indicating an upward trend in precipitation on the annual scale at the 50th percentile (Table 5-3 and Table 5-4). In the 2050s, monthly total precipitation at the 50th percentile is projected to increase for almost all months, except for the months of July and August. The high percentage changes in the precipitation during the winter months may lead to more snowfall and snowpack, however this also be impacted by changing temperatures. It should be noted that there is a large range of uncertainty for precipitation projections across the multi model ensemble, as all months show both increasing and decreasing total precipitation amounts for the minimum and maximum projected changes in both the 2050s and 2080s.

As presented in Section 4.2, the current annual total precipitation has statistically significant upward trends for the months of May, September, and October, using future climate projections increases are projected with greater changes further into the future, especially in the early fall months.

5.2 FUTURE WET AND DRY YEAR STATISTICS

Projected changes in wet and dry year statistics highlight changes in the magnitude and frequency of wet and dry conditions at Project site. At the 50th percentile, both wet and dry year precipitation amounts were estimated to range from approximately 3% to 4% in the 2050s and 6% to 8% in the 2080s (Table 5-5). Projected changes in total precipitation are similar for both wet and dry years, with consistent changes across return periods. This suggests that at an annual scale, an overall increase in total precipitation amounts is projected, with only small changes to the frequency of wet and dry years relative to the baseline period.

5.3 FUTURE WMO EXTREME INDICES

The change in WMO climate indices from the model baseline to the 2050s and 2080s future time periods provides an indication of how climate extremes may change under future climate conditions.

The distribution of changes to each of the 27 climate indices for the 2050s and 2080s is provided in Table 5-6 and Table 5-7, respectively. The projected changes are shown as absolute values to preserve the different units being used for the indices, as some are shown as days, mm, mm/day, and °C. The calculation of various WMO indices was performed considering different time periods within the year (e.g., growing season); therefore, monthly values cannot be provided as the focus is on the projected change of the aggregated indices on an annual time step.

In the 2050s at the 50th percentile the annual amount of precipitation on wet days, and annual maximum precipitation amounts are projected to increase (Table 5-6). The number of heavy and very heavy wet days suggest that precipitation intensity may increase. In the 2080s the same pattern is present, with slightly higher annual total wet day precipitation and maximum 1- and 5-day precipitation amounts (Table 5-7). These projections align with the current climate baseline, where statistically significant upward trends were found for annual total wet day precipitation and very heavy wet days. A trend analysis has not been conducted for the ensemble of future climate projections, however the projected changes presented here may indicate a shift in precipitation patterns for the Project site in the future at the 50th percentile of the ensemble climate projections. There is a considerable level of uncertainty in the projected changes to precipitation-based indices, since the range of projections across the multi model ensemble indicate both an increase and decrease for each of the indices.

For the temperature-based indices, fewer frost and ice days, more summer days and greater temperature extremes (lowest minimum and maximum temperature, highest minimum and maximum temperature) are indicated for the 2050s at the 50th percentile (Table 5-6). In the 2080s, the same patterns are present but amplified due to higher projected changes in temperature (Table 5-7). The direction of projected changes at the 50th percentile generally agree with the statistically significant trends found for the current climate baseline in Section 4.2. Wetter conditions along with greater temperature extremes may lead to higher variability in drought and flooding conditions at the site.

5.4 FUTURE PROBABLE MAXIMUM PRECIPITATION

With increasing temperatures due to climate change, atmospheric moisture holding capacity is anticipated to increase, thereby leading to greater magnitudes of probable maximum precipitation. Here the percentage change in PMP is estimated between the model baseline and future periods. In the 2050s at the 50th percentile, the 1-day, 2-day, and 3-day PMP are projected to increase by 19%, 16%, and 15%, respectively (Table 5-8). In the 2080s an increase of 23%, 21%, and 23% is projected for the 1-day, 2-day, and 3-day PMP events, respectively (Table 5-9).

Greater projected temperatures in the 2080s can be associated with greater atmospheric moisture holding capacity (Kunkel 2013; CSA 2019), which is anticipated to result in greater PMP projected further into the future. There is a considerable amount of uncertainty in PMP across the multi model ensemble as in both time periods there is a potential for increase and decrease across the range of projections. Therefore, a percentile should be selected to account for the level of risk associated with the application of these values (see Section 2).

5.5 FUTURE EXTREME PRECIPITATION STATISTICS

Projected changes in extreme precipitation statistics are provided across a set of durations and return periods for the 2050s and 2080s future periods at the 50th percentile. In the 2050s, the range of projected changes is 1% to 16% with a change of 15% for the 1-day, 100-year event (Table 5-10). In the 2080s, a

range of projected changes of 0% to 20% is estimated, with a change of 18% for the 1-day, 100-year event (Table 5-11).

Lower duration events at higher return periods generally show greater projected changes than longer durations events above 7 days. This may be due to increased temperatures leading to more atmospheric moisture holding capacity playing a larger role in shorter durations and longer return periods where rainfall intensity is higher (CSA 2019). For longer duration events, moisture limitations may not be present, and the annual maximum values may be dependent on the occurrence of multiple rainfall events.

Overall, increasing rainfall amounts at the 50th percentile agree with the climate extremes findings of Section 5.3 (more precipitation with little change to heavy and very heavy precipitation days). The results shown here for the 50th percentile may be used for screening purposes; however, for design of critical infrastructure a higher percentile could be considered to reduce potential risk (see Appendix C).

5.6 FUTURE EXTREME COMBINED RAINFALL AND SNOWMELT STATISTICS

Through separating precipitation into rain and snow, and simulating snow accumulation and melt, projected changes in extreme combined rainfall and snowmelt are estimated for the 2050s and 2080s relative to the modelled baseline period. Projected changes in combined rainfall and snowmelt across durations and return periods range from -4% to 12% for the 2050s, and from -2% to 17% for the 2080s at the 50th percentile (Table 5-12 and Table 5-13). Projected changes for the 1-day, 100-year event are estimated as 11% and 14% for the 2050s and 2080s, respectively.

For shorter durations from 1 to 3 days, projected changes are highest as the combined amounts would mainly consist of extreme rainfall. As the duration increases, projected decreases in combined rainfall and snowmelt are found. This is likely due to less accumulated snow due reduced snowfall and earlier melt (less accumulation) due to increasing projected temperatures. Compared to estimates of extreme precipitation, projected changes in extreme combined rainfall and snowmelt are slightly lower for shorter durations, and much lower for long durations. This may also be due to the decreasing extreme snowmelt with greater temperatures and increasing projected extreme precipitation amounts.

5.7 FUTURE CLIMATE INPUTS FOR PROBABLE MAXIMUM FLOOD ESTIMATION

For the modelled baseline and each future period, the climate inputs to PMF estimation are represented as the combined amount of rainfall generated from the spring PMP event and extreme snowmelt statistics generated for the same duration, while annually the projected changes in the climate inputs to PMF are assumed to be equivalent to PMP (Section 5.4). Annually, projected changes range from 11% to 16% for the 2050s and 17% to 22% for the 2080s at the 50th percentile (Table 5-14). Projected changes for the annual period may be slightly higher than the spring period due to greater influence of changes in extreme precipitation and decreasing amounts of extreme snowmelt. This was also found in comparing projected changes of extreme precipitation and combined rainfall and snowmelt (Section 5.6).

5.8 FUTURE POTENTIAL EVAPOTRANSPIRATION

Under future climate conditions, annual and monthly potential evapotranspiration rates are projected to increase for all months across the multi model ensemble at the 50th percentile, with an annual total increase of 10% and 13% for the 2050s and 2080s, respectively (Table 5-15 and Table 5-16). In the 2050s, monthly projected changes range from 6% in June to 46% in January. In the 2080s, monthly projected changes range from 9% in June and July, to 74% in January. Overall, the greatest percentage

increases are found in the winter months where potential evapotranspiration is smallest. The absolute change in potential evapotranspiration during the winter is very little because of this, while in the summer months lower percentage changes would result in a greater absolute change (Table 5-17 and Table 5-18).

5.9 FUTURE WIND SPEED

Jeong and Sushama (2019) projected changes in annual mean and 50-year return period maximum wind speeds using a meteorological model driven by two climate models and RCP scenarios for the period of 2071 to 2100 relative to 1981 to 2010 across Canada and the United States. It was found that in the region surrounding the Project site, annual mean wind speeds were projected to change between 0% to 4%, while 50-year return period maximum wind speed were projected to change between -12% to 8%. The IPCC interactive atlas contains an online interface for examining projected changes in surface winds. Using this tool, annual average surface wind speeds are projected to decrease by approximately -3% for the 2041-2060 period and -5% for the 2081-2100 period relative to a 1994-2014 baseline under a high emission scenario (IPCC 2021). It should be noted that like precipitation, wind speed can have a high degree of uncertainty across models and is indicated as low model agreement over the location of Project site.

Table 5-1: Projected Changes in Annual and Monthly Mean Temperature for the 2050s

Month	Min.	5%	10%	25%	50%	75%	90%	95%	Max.	Mean	Std. Dev.
Jan	0.5	1.2	1.6	2.3	3.1	4.0	5.1	6.1	6.9	3.3	1.4
Feb	-0.3	0.6	1.0	1.7	2.6	3.3	4.3	5.1	6.7	2.6	1.4
Mar	0.3	0.8	1.0	1.5	2.2	2.7	3.4	3.9	5.4	2.2	1.0
Apr	0.0	0.7	0.9	1.7	2.3	2.8	3.3	3.5	4.9	2.3	0.9
May	0.4	0.8	1.0	1.6	2.4	2.8	3.2	3.7	4.6	2.3	0.9
Jun	-0.1	0.9	1.0	1.4	2.0	2.8	3.6	4.5	5.5	2.2	1.1
Jul	0.1	0.8	1.3	1.8	2.4	3.2	4.2	4.7	6.2	2.6	1.2
Aug	0.7	1.0	1.3	1.9	2.6	3.4	4.2	4.7	6.8	2.7	1.2
Sep	0.2	0.6	1.1	1.7	2.5	3.3	4.6	5.0	7.8	2.6	1.4
Oct	0.6	1.0	1.2	1.7	2.4	3.1	3.9	4.2	6.8	2.5	1.1
Nov	0.6	0.9	1.3	1.8	2.7	3.4	4.4	4.8	7.0	2.7	1.3
Dec	0.1	1.4	1.7	2.6	3.4	4.4	6.2	6.5	9.3	3.6	1.6
Annual	0.8	1.4	1.5	1.9	2.5	3.1	3.8	4.8	6.0	2.6	1.0

Table 5-2: Projected Changes in Annual and Monthly Mean Temperature for the 2080s

Month	Min.	5%	10%	25%	50%	75%	90%	95%	Max.	Mean	Std. Dev.
Jan	-0.1	1.2	1.5	2.9	4.9	6.9	8.5	10.2	13.2	5.1	2.9
Feb	-0.4	0.8	1.1	2.1	3.5	5.5	7.6	8.8	10.4	4.0	2.5
Mar	-0.4	0.8	1.1	1.7	3.0	4.9	6.5	6.9	8.9	3.4	2.1
Apr	0.3	1.0	1.3	2.0	3.1	4.5	6.3	6.5	9.2	3.4	1.9
May	0.5	1.1	1.3	1.9	3.1	4.3	5.8	6.4	8.3	3.3	1.7
Jun	-0.2	0.9	1.0	1.9	3.1	4.3	6.2	7.2	9.2	3.4	2.0
Jul	0.2	0.7	1.3	2.1	3.4	5.0	7.0	8.2	10.3	3.8	2.3
Aug	0.0	0.9	1.3	2.4	3.7	5.6	7.1	8.8	11.2	4.1	2.4

Month	Min.	5%	10%	25%	50%	75%	90%	95%	Max.	Mean	Std. Dev.
Sep	0.2	1.1	1.4	2.2	3.5	5.8	6.8	9.2	11.2	4.1	2.4
Oct	0.2	1.1	1.3	1.8	3.2	4.8	6.7	8.2	10.0	3.7	2.2
Nov	-0.2	1.2	1.5	2.3	3.8	5.2	6.7	7.9	11.2	4.0	2.2
Dec	1.2	1.7	2.0	3.1	5.0	7.3	9.6	10.5	15.1	5.4	2.9
Annual	0.5	1.2	1.5	2.3	3.4	5.4	6.5	8.1	10.6	4.0	2.2

Table 5-3: Projected Changes in Annual and Monthly Total Precipitation for the 2050s

Month	Min.	5%	10%	25%	50%	75%	90%	95%	Max.	Mean	Std. Dev.
Jan	-18%	-5%	-3%	2%	10%	18%	25%	30%	35%	10%	12%
Feb	-17%	-11%	-8%	-3%	9%	20%	33%	38%	48%	10%	15%
Mar	-18%	-7%	-5%	3%	14%	26%	36%	40%	58%	15%	16%
Apr	-23%	-16%	-14%	-1%	6%	22%	29%	36%	51%	9%	16%
May	-11%	-6%	-3%	3%	11%	18%	26%	34%	49%	11%	12%
Jun	-27%	-20%	-16%	-7%	2%	10%	18%	25%	32%	2%	13%
Jul	-40%	-30%	-23%	-17%	-5%	5%	13%	16%	26%	-6%	15%
Aug	-34%	-26%	-20%	-14%	-8%	6%	13%	17%	49%	-5%	14%
Sep	-28%	-21%	-17%	-8%	2%	13%	21%	23%	36%	2%	14%
Oct	-25%	-17%	-15%	-1%	7%	17%	25%	31%	64%	7%	16%
Nov	-20%	-8%	-3%	2%	10%	23%	34%	44%	49%	13%	16%
Dec	-15%	-8%	-3%	4%	11%	22%	30%	36%	51%	13%	14%
Annual	-8%	-5%	-4%	-1%	4%	10%	11%	13%	18%	4%	6%

Table 5-4: Projected Changes in Annual and Monthly Total Precipitation for the 2080s

Month	Min.	5%	10%	25%	50%	75%	90%	95%	Max.	Mean	Std. Dev.
Jan	-14%	-8%	0%	8%	20%	30%	41%	51%	63%	19%	17%
Feb	-14%	-8%	-3%	5%	12%	29%	37%	44%	81%	17%	18%
Mar	-11%	-4%	1%	9%	21%	31%	45%	50%	82%	22%	19%
Apr	-23%	-13%	-7%	0%	17%	29%	40%	57%	81%	16%	21%
May	-17%	-4%	0%	7%	15%	27%	43%	47%	65%	18%	17%
Jun	-41%	-31%	-17%	-5%	3%	13%	24%	33%	42%	3%	18%
Jul	-49%	-37%	-33%	-20%	-7%	5%	15%	20%	26%	-8%	18%
Aug	-53%	-35%	-30%	-16%	-6%	4%	15%	19%	32%	-7%	18%
Sep	-39%	-23%	-17%	-7%	3%	8%	17%	32%	38%	1%	16%
Oct	-20%	-12%	-11%	2%	13%	25%	32%	47%	69%	14%	18%
Nov	-17%	-7%	-5%	3%	14%	33%	53%	59%	68%	19%	21%
Dec	-10%	-4%	-1%	7%	17%	30%	43%	49%	67%	20%	17%
Annual	-9%	-4%	-1%	3%	6%	10%	16%	22%	28%	7%	7%

Table 5-5: Projected Changes in Wet and Dry Year Statistics at the 50th Percentile

Return Period (years)	2050s		2080s	
	Dry Year	Wet Year	Dry Year	Wet Year
5	3%	4%	6%	7%
10	4%	4%	7%	7%
20	4%	4%	7%	8%
50	4%	3%	7%	8%
100	3%	4%	8%	8%

Table 5-6: Projected Changes in WMO Extreme Climate Indices for the 2050s

WMO Indices	Min.	5%	10%	25%	50%	75%	90%	95%	Max.	Mean	Std. Dev.
Consecutive dry days (days)	-4.6	-2.8	-2.5	-1.1	-0.1	0.3	1.7	2.2	3.5	-0.3	1.6
Cold spell duration indicator (days)	-2.7	-1.6	-1.5	-0.4	0.3	0.9	1.8	2.0	4.0	0.2	1.2
Consecutive wet days (days)	-0.9	-0.6	-0.5	-0.2	0.1	0.3	0.5	0.7	1.1	0.0	0.4
Diurnal temperature range (°C)	-1.0	-0.9	-0.7	-0.4	-0.2	0.0	0.3	0.4	0.5	-0.2	0.4
Frost days (days)	-52.1	-34.2	-30.2	-24.0	-20.1	-15.3	-11.7	-10.7	-6.2	-20.5	8.2
Growing season length (days)	5.4	7.7	11.0	13.5	18.2	21.7	25.3	29.2	40.1	18.4	6.5
Ice days (days)	-38.0	-28.3	-24.9	-18.1	-13.9	-10.1	-6.7	-5.5	-1.2	-14.9	7.3
Annual total wet-day precipitation (mm)	-52.4	-34.9	-28.9	-2.6	24.6	61.8	71.8	82.6	112.4	25.8	38.0
Heavy precipitation days (days)	-2.9	-1.8	-0.7	0.2	1.3	2.3	3.1	3.9	4.3	1.2	1.6
Very heavy precipitation days (days)	-1.3	-0.9	-0.7	-0.2	0.4	1.0	1.4	1.5	1.9	0.4	0.8
Very wet days (mm)	-1.2	-0.6	-0.4	-0.2	0.3	0.7	1.0	1.2	1.6	0.3	0.6
Extremely wet days (mm)	-25.3	-17.0	-12.6	-0.3	15.1	27.3	37.8	42.7	47.1	13.7	18.7
Days above 25 mm (days)	-16.0	-5.6	-4.7	-0.3	5.4	11.3	16.0	18.0	23.9	5.5	8.0
Max 1-day precipitation (mm)	-7.6	-3.8	-2.1	0.7	2.2	4.9	6.6	7.3	10.0	2.4	3.5
Max 5-day precipitation (mm)	-10.7	-4.9	-3.4	0.5	3.3	7.0	10.9	12.0	14.7	3.5	5.2
Simple daily intensity index (mm/day)	-0.3	-0.3	-0.1	0.0	0.2	0.4	0.5	0.5	0.7	0.2	0.2
Summer days (days)	2.7	9.1	10.3	18.7	24.9	34.6	42.7	47.7	63.7	26.6	12.2
Cool nights (% of days)	-0.2	-0.2	-0.1	-0.1	0.0	0.1	0.2	0.2	0.3	0.0	0.1
Warm nights (% of days)	-0.3	-0.2	-0.2	-0.1	0.0	0.1	0.1	0.2	0.2	0.0	0.1
Min Tmin (°C)	0.4	1.5	1.9	2.9	3.8	5.6	6.9	7.7	10.0	4.3	2.0
Max Tmin (°C)	0.5	0.8	1.1	1.8	2.4	2.9	4.1	4.5	5.9	2.5	1.1
Tropical nights (days)	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.9	3.8	0.2	0.5
Cool days (% of days)	-0.2	-0.2	-0.1	-0.1	0.0	0.1	0.2	0.2	0.2	0.0	0.1
Warm days (% of days)	-0.3	-0.2	-0.1	-0.1	0.0	0.0	0.1	0.2	0.3	0.0	0.1
Min Tmax (°C)	0.2	1.0	1.4	2.8	4.0	5.4	6.7	7.4	9.2	4.1	1.9
Max Tmax (°C)	-0.5	0.4	1.0	1.8	2.7	3.8	4.9	5.4	7.3	2.9	1.6
Warm spell duration indicator (days)	-3.2	-2.2	-1.7	-0.7	0.4	1.4	2.5	2.8	3.8	0.3	1.6

Table 5-7: Projected Changes in WMO Extreme Climate Indices for the 2080s

WMO Indices	Min.	5%	10%	25%	50%	75%	90%	95%	Max.	Mean	Std. Dev.
Consecutive dry days (days)	-4.1	-3.1	-2.7	-1.4	-0.3	0.7	1.3	1.6	6.8	-0.4	1.7
Cold spell duration indicator (days)	-2.5	-1.6	-1.1	-0.6	0.1	1.3	2.4	2.9	3.7	0.4	1.4
Consecutive wet days (days)	-1.1	-0.7	-0.5	-0.3	0.1	0.4	0.7	0.8	1.0	0.1	0.5
Diurnal temperature range (°C)	-1.6	-1.4	-1.2	-0.6	-0.3	-0.1	0.2	0.4	0.5	-0.4	0.5
Frost days (days)	-102.5	-64.1	-54.3	-40.3	-27.2	-18.5	-13.1	-8.6	-4.7	-30.6	17.9
Growing season length (days)	3.2	6.3	10.8	16.2	23.1	35.3	46.2	49.8	63.3	26.0	13.6
Ice days (days)	-82.4	-48.3	-42.4	-32.7	-19.2	-11.2	-6.7	-5.2	-0.4	-23.4	15.6
Annual total wet-day precipitation (mm)	-56.1	-28.8	-9.6	14.8	40.8	65.7	100.6	139.2	180.4	43.3	46.9
Heavy precipitation days (days)	-1.5	-1.1	-0.7	0.7	1.9	3.0	4.1	5.2	5.8	1.8	1.8
Very heavy precipitation days (days)	-0.9	-0.6	-0.3	0.1	0.6	1.3	2.0	2.8	2.9	0.8	0.9
Very wet days (mm)	-0.9	-0.4	-0.2	0.0	0.4	0.8	1.3	1.5	2.7	0.5	0.6
Extremely wet days (mm)	-15.0	-6.8	0.1	6.9	22.1	30.9	45.2	66.0	87.9	22.1	20.6
Days above 25 mm (days)	-11.2	-3.0	-1.8	2.4	7.9	13.3	19.9	23.1	37.4	8.5	8.7
Max 1-day precipitation (mm)	-5.9	-2.7	-0.2	1.3	3.1	5.2	7.5	9.3	12.0	3.3	3.4
Max 5-day precipitation (mm)	-8.3	-2.3	-1.3	1.5	4.6	9.9	12.1	13.5	18.8	5.4	5.4
Simple daily intensity index (mm/day)	-0.1	-0.1	0.0	0.1	0.3	0.4	0.6	0.8	1.2	0.3	0.3
Summer days (days)	1.1	7.8	13.8	22.0	36.0	52.4	64.9	76.6	94.5	38.5	21.2
Cool nights (% of days)	-0.4	-0.2	-0.1	-0.1	0.0	0.1	0.2	0.2	0.3	0.0	0.1
Warm nights (% of days)	-0.3	-0.2	-0.2	-0.1	0.0	0.0	0.1	0.2	0.2	0.0	0.1
Min Tmin (°C)	0.2	1.5	2.1	3.7	6.1	9.4	11.6	15.4	18.7	6.8	4.2
Max Tmin (°C)	0.3	0.7	1.2	2.0	3.4	5.0	7.2	7.8	9.7	3.7	2.2
Tropical nights (days)	0.0	0.0	0.0	0.0	0.2	1.0	5.1	8.6	18.6	1.6	3.6
Cool days (% of days)	-0.3	-0.2	-0.2	0.0	0.0	0.1	0.1	0.2	0.3	0.0	0.1
Warm days (% of days)	-0.2	-0.2	-0.1	-0.1	0.0	0.1	0.1	0.2	0.3	0.0	0.1
Min Tmax (°C)	-0.1	1.4	2.0	3.6	6.3	9.1	10.8	13.1	16.9	6.4	3.8
Max Tmax (°C)	-0.6	0.9	1.1	2.4	4.1	6.1	7.8	8.6	12.0	4.3	2.7
Warm spell duration indicator (days)	-3.7	-1.8	-1.3	-0.6	0.3	1.4	2.4	3.2	4.4	0.4	1.6

Table 5-8: Projected Changes in PMP for the 2050s

Statistic	1-Day	2-Day	3-Day
Min.	-27%	-33%	-29%
5%	-20%	-22%	-21%
10%	-14%	-15%	-12%
25%	1%	-1%	0%
50%	19%	16%	15%
75%	41%	36%	33%
90%	57%	63%	50%
95%	65%	74%	60%
99%	75%	99%	86%
Max.	97%	118%	108%
Mean	21%	21%	17%
Std. Dev.	27%	30%	26%

Table 5-9: Projected Changes in PMP for the 2080s

Statistic	1-Day	2-Day	3-Day
Min.	-29%	-35%	-39%
5%	-18%	-18%	-25%
10%	-14%	-10%	-15%
25%	4%	2%	0%
50%	23%	21%	23%
75%	43%	39%	37%
90%	59%	67%	56%
95%	72%	80%	67%
99%	97%	94%	90%
Max.	105%	106%	129%
Mean	24%	23%	21%
Std. Dev.	29%	30%	29%

Table 5-10: Projected Changes in Extreme Precipitation Statistics at the 50th Percentile for the 2050s

Duration (days)	Return Period (years)										
	2	5	10	25	50	100	200	500	1000	2000	10000
1	7%	9%	13%	14%	15%	15%	15%	16%	16%	16%	16%
2	6%	8%	10%	11%	10%	11%	11%	11%	11%	12%	12%
3	7%	9%	8%	10%	10%	10%	10%	9%	9%	9%	10%
4	6%	8%	10%	10%	10%	11%	11%	11%	11%	11%	11%
5	6%	7%	8%	9%	9%	10%	10%	10%	11%	11%	12%
6	6%	7%	9%	11%	11%	10%	11%	12%	12%	11%	12%
7	5%	7%	9%	11%	11%	12%	12%	13%	13%	13%	14%
10	4%	6%	6%	7%	7%	7%	7%	7%	7%	7%	7%
20	3%	4%	3%	3%	2%	2%	3%	3%	3%	3%	3%
30	3%	3%	3%	3%	3%	4%	4%	4%	4%	4%	4%
50	1%	2%	2%	2%	2%	2%	3%	3%	3%	3%	3%
75	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	1%
90	2%	2%	2%	2%	2%	2%	1%	1%	1%	1%	1%
120	1%	2%	3%	3%	2%	2%	2%	2%	2%	2%	2%

Table 5-11: Projected Changes in Extreme Precipitation Statistics at the 50th Percentile for the 2080s

Duration (days)	Return Period (years)										
	2	5	10	25	50	100	200	500	1000	2000	10000
1	9%	12%	13%	16%	18%	18%	18%	18%	19%	19%	20%
2	9%	12%	14%	14%	15%	16%	16%	16%	16%	16%	17%
3	9%	11%	13%	14%	14%	15%	15%	16%	16%	16%	17%
4	9%	12%	13%	13%	14%	14%	14%	15%	15%	15%	16%
5	8%	11%	12%	13%	13%	14%	15%	15%	15%	16%	16%
6	7%	10%	11%	11%	12%	12%	13%	13%	13%	13%	14%

Duration (days)	Return Period (years)										
	2	5	10	25	50	100	200	500	1000	2000	10000
7	7%	9%	10%	11%	11%	12%	12%	12%	13%	13%	14%
10	6%	7%	8%	7%	7%	7%	7%	7%	7%	7%	7%
20	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	4%
30	4%	4%	3%	3%	3%	3%	3%	2%	2%	3%	3%
50	1%	3%	2%	2%	1%	1%	1%	2%	2%	2%	2%
75	1%	2%	3%	3%	3%	3%	3%	2%	2%	2%	2%
90	0%	2%	2%	2%	3%	3%	4%	4%	4%	4%	3%
120	1%	2%	3%	4%	4%	3%	3%	3%	3%	3%	3%

Table 5-12: Projected Changes in Extreme Combined Rainfall and Snowmelt Statistics at the 50th Percentile for the 2050s

Duration (days)	Return Period (years)										
	2	5	10	25	50	100	200	500	1000	2000	10000
1	6%	8%	9%	10%	10%	11%	11%	11%	11%	11%	12%
2	6%	6%	6%	7%	6%	6%	6%	7%	7%	8%	8%
3	4%	5%	4%	4%	4%	3%	3%	3%	3%	3%	2%
4	4%	3%	4%	4%	4%	4%	5%	4%	4%	5%	5%
5	2%	3%	2%	2%	2%	3%	3%	3%	4%	4%	4%
6	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
7	2%	1%	0%	0%	1%	1%	1%	1%	1%	1%	1%
10	-1%	-1%	-2%	-2%	-3%	-3%	-3%	-3%	-3%	-3%	-4%
20	-1%	0%	0%	0%	0%	0%	-1%	-1%	-1%	-1%	-1%
30	-1%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%
50	1%	0%	1%	0%	0%	0%	0%	0%	-1%	-1%	-2%
75	1%	2%	0%	-1%	-2%	-3%	-3%	-3%	-3%	-3%	-3%
90	1%	1%	1%	0%	0%	-1%	-1%	-1%	-1%	-1%	-1%
120	2%	2%	3%	3%	3%	2%	2%	3%	3%	3%	3%

Table 5-13: Projected Changes in Extreme Combined Rainfall and Snowmelt Statistics at the 50th Percentile for the 2080s

Duration (days)	Return Period (years)										
	2	5	10	25	50	100	200	500	1000	2000	10000
1	12%	13%	13%	13%	14%	14%	15%	15%	16%	16%	17%
2	8%	9%	9%	10%	10%	11%	11%	11%	11%	12%	13%
3	6%	6%	5%	6%	7%	7%	8%	8%	9%	9%	9%
4	4%	5%	4%	5%	5%	5%	5%	5%	6%	6%	7%
5	3%	2%	3%	3%	3%	3%	4%	4%	5%	5%	6%
6	2%	1%	1%	1%	0%	-1%	0%	0%	0%	1%	1%
7	2%	0%	0%	0%	0%	-1%	0%	-1%	-1%	-1%	-1%
10	0%	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-2%	-2%	-2%
20	0%	-1%	-1%	-1%	-1%	-1%	-1%	-2%	-2%	-1%	-1%
30	0%	0%	0%	0%	1%	0%	0%	1%	1%	1%	2%
50	2%	1%	0%	0%	0%	1%	1%	0%	0%	-1%	-1%
75	2%	1%	1%	0%	-1%	-1%	-1%	-1%	-2%	-2%	-2%
90	2%	1%	2%	1%	1%	0%	0%	0%	0%	-1%	-1%
120	3%	4%	4%	5%	4%	4%	4%	4%	4%	4%	4%

Table 5-14: Projected Changes in Annual Probable Maximum Flood

Statistic	2050s			2080s		
	1-Day	2-Day	3-Day	1-Day	2-Day	3-Day
Min.	-24%	-30%	-25%	-27%	-29%	-31%
5%	-18%	-18%	-17%	-16%	-15%	-17%
10%	-13%	-13%	-9%	-13%	-9%	-10%
25%	1%	-2%	0%	7%	4%	0%
50%	16%	12%	11%	22%	18%	17%
75%	35%	32%	27%	37%	31%	29%
90%	48%	51%	39%	49%	51%	43%
95%	55%	64%	43%	59%	65%	52%
99%	62%	78%	61%	80%	76%	69%
Max.	75%	92%	81%	92%	84%	96%
Mean	18%	16%	13%	21%	19%	17%
Std. Dev.	23%	25%	20%	24%	24%	22%

Table 5-15: Projected Changes (%) in Annual and Monthly Total Potential Evapotranspiration for the 2050s

Month	Min.	5%	10%	25%	50%	75%	90%	95%	Max. ⁽¹⁾	Mean	Std. Dev.
January	3%	11%	20%	32%	46%	65%	84%	97%	120%	49%	26%
February	-8%	2%	10%	20%	30%	43%	58%	62%	85%	32%	19%
March	-4%	4%	5%	10%	14%	21%	29%	34%	37%	16%	9%
April	1%	3%	5%	8%	11%	15%	19%	24%	27%	12%	6%
May	-3%	1%	2%	4%	9%	12%	14%	16%	23%	8%	5%
June	-4%	1%	2%	5%	6%	11%	15%	18%	21%	8%	5%
July	-4%	0%	2%	5%	8%	12%	16%	18%	24%	9%	5%
August	-1%	2%	3%	6%	9%	13%	17%	18%	26%	10%	6%
September	-2%	1%	3%	6%	10%	15%	18%	23%	34%	11%	7%
October	4%	5%	6%	9%	12%	16%	21%	23%	37%	13%	6%
November	1%	2%	7%	11%	17%	22%	28%	29%	46%	17%	8%
December	1%	8%	14%	24%	35%	43%	60%	67%	84%	36%	17%
Annual	0%	2%	5%	7%	10%	13%	16%	19%	25%	10%	5%

* Note: Maximum percentage change can appear high due to outlying scenarios where potential evapotranspiration is low.

Table 5-16: Projected Changes (%) in Annual and Monthly Total Potential Evapotranspiration for the 2080s

Month	Min.	5%	10%	25%	50%	75%	90%	95%	Max. ⁽¹⁾	Mean	Std. Dev.
January	-3%	14%	20%	43%	74%	115%	147%	162%	228%	80%	49%
February	-10%	5%	8%	25%	43%	72%	99%	112%	145%	49%	34%
March	-12%	5%	7%	12%	21%	32%	42%	55%	73%	24%	16%
April	-2%	3%	5%	11%	16%	24%	30%	34%	58%	18%	11%
May	-3%	2%	3%	6%	11%	15%	23%	27%	35%	12%	8%
June	-2%	1%	2%	4%	9%	15%	23%	27%	37%	11%	9%
July	-2%	0%	2%	7%	10%	18%	23%	28%	40%	12%	9%
August	0%	2%	4%	6%	13%	19%	28%	34%	43%	14%	10%
September	-2%	4%	5%	9%	14%	22%	31%	34%	48%	17%	11%
October	-1%	4%	6%	8%	16%	25%	32%	42%	52%	18%	12%
November	-3%	7%	8%	16%	24%	33%	42%	46%	69%	25%	14%
December	13%	16%	19%	28%	48%	73%	90%	104%	135%	53%	28%
Annual	1%	2%	5%	8%	13%	21%	26%	31%	42%	15%	9%

* Note: Maximum percentage change can appear high due to outlying scenarios where potential evapotranspiration is low.

Table 5-17: Projected Changes (mm) in Annual and Monthly Total Potential Evapotranspiration for the 2050s

Month	Min.	5%	10%	25%	50%	75%	90%	95%	Max.*	Mean	Std. Dev.
January	0.1	0.2	0.4	0.7	0.9	1.2	1.8	2.0	2.6	1.0	0.5
February	-0.5	0.1	0.6	1.1	1.9	2.4	3.4	3.8	5.4	1.9	1.1
March	-0.8	0.9	1.3	2.4	3.5	5.2	7.0	7.6	8.6	3.8	2.1
April	0.7	2.2	3.2	4.9	6.9	9.5	12.2	14.5	15.7	7.3	3.5
May	-3.0	1.3	2.5	4.7	9.2	13.0	16.2	18.4	26.3	9.3	5.7
June	-4.9	1.7	3.1	6.1	8.7	14.7	20.0	24.1	29.0	10.2	7.0
July	-5.3	0.6	2.9	7.4	11.8	16.9	24.1	25.4	36.1	12.5	7.9
August	-0.9	2.3	3.0	6.7	10.8	15.5	20.4	21.8	31.4	11.3	6.7
September	-1.5	0.5	2.1	4.2	6.9	9.4	12.4	14.9	22.7	7.1	4.4
October	1.2	1.7	1.8	2.6	3.8	5.1	6.4	7.0	11.5	4.0	1.9
November	0.1	0.2	0.6	1.0	1.6	2.0	2.5	2.7	4.1	1.6	0.8
December	0.0	0.2	0.4	0.7	1.0	1.3	1.7	1.8	2.4	1.0	0.5
Annual	-1.4	15.8	34.9	49.3	68.0	91.7	115.8	135.2	181.6	71.0	34.5

Table 5-18: Projected Changes (mm) in Annual and Monthly Total Potential Evapotranspiration for the 2080s

Month	Min.	5%	10%	25%	50%	75%	90%	95%	Max.*	Mean	Std. Dev.
January	-0.1	0.3	0.5	0.9	1.6	2.4	3.0	3.3	4.5	1.7	1.0
February	-0.5	0.3	0.5	1.4	2.4	4.1	5.7	6.8	7.3	2.9	2.0
March	-2.8	1.3	1.6	3.1	5.1	7.9	10.8	13.0	17.3	5.7	3.8
April	-1.5	1.8	3.1	6.8	10.5	14.7	18.9	21.5	34.1	11.0	6.5
May	-3.0	2.3	3.2	6.5	12.3	16.5	25.5	29.7	39.6	13.2	8.9
June	-2.5	2.0	2.7	5.1	12.6	20.3	31.9	37.8	49.8	15.0	11.7
July	-2.4	0.6	2.3	9.7	14.8	26.0	34.0	40.2	59.6	17.8	13.1
August	-0.1	2.4	4.2	7.4	14.7	22.4	32.2	39.3	51.3	16.5	11.4
September	-1.2	2.5	3.0	5.8	9.4	14.4	20.8	22.3	31.7	10.9	7.0
October	-0.4	1.3	1.8	2.6	5.0	7.5	10.1	13.0	16.1	5.6	3.6
November	-0.3	0.7	0.8	1.4	2.3	3.1	3.9	4.4	6.1	2.3	1.3
December	0.4	0.5	0.6	0.8	1.5	2.2	2.6	3.0	3.6	1.5	0.8
Annual	3.9	14.7	34.8	60.5	90.9	149.0	186.1	227.1	304.4	104.1	64.8

6 SUMMARY

The climate change dataset for the Project site was completed by first reviewing readily available climate change information from literature. Next, baseline climate conditions were established. Evaluation of available observed data sources resulted in the selection of climate stations surrounding the Project site to represent baseline climate conditions at the site. These stations along with bias corrected ERA5 reanalysis data were used to create a long continuous climate baseline from 1950 to 2022 (73 years).

Analysis of the baseline climate conditions revealed the following findings:

- The warmest month on average is the month of July with a mean temperature of 18.3°C, and the coldest is the month of January with a mean temperature of -19.2°C. The annual temperature was found to have a statistically significant upwards trend of 0.2°C per decade, significant at the 99th percentile with an average value of 1.1°C. On a monthly scale, statistically significant trends were found for the January, March, August, September, and December with magnitudes ranging from 0.2°C to 0.7°C per decade. Increasing temperatures in the winter months has the potential to affect minimum extreme temperatures. No statistically significant decreasing monthly average temperatures were found.
- Average annual total precipitation over the baseline period was calculated to be 633.0 mm with July being the wettest month (90.4 mm) and February being the driest (20.1 mm) on average. The annual total precipitation was found to have a statistically significant increasing trend of 17.1 mm per decade, significant at the 95th percentile. Statistically significant increasing trend were found for the months of May, September, and October, with magnitudes ranging from 3.7 to 5.1 mm per decade.
- The 5-year return period corresponds to an annual total precipitation value of 724.3 mm and 487.5 mm for the wet and dry years. For the 100-year return period annual total precipitation values for the wet and dry years of 1026.9 mm and 343.8 mm were found. In general, the increase of annual total precipitation with return period is greater for the smaller return periods. For example, in the wet years there is an increase of 78.9 mm from the 5-, to 10-year return periods and a 63.7 mm increase from the 50-, to 100-year return periods.
- The trends in temperature extremes at Project are consistent with that of a warming climate. Cool days and summer days show a decreasing and increasing trend, respectively. For precipitation extremes, the annual total wet -day precipitation was found to have a statistically significant trend of 13.9 mm per decade.
- PMP calculated with the Hershfield method, is estimated to range from 319.2 mm to 342.2 mm for 1- to 3-day durations.
- Extreme precipitation statistics are calculated from the annual maximum series of daily total precipitation by fitting a statistical distribution and extracting precipitation depths over a range of return periods. Over the current climate baseline, the 100-year event for a 1-day duration corresponds to a precipitation depth of 85 mm.
- Combined rainfall and snowmelt statistics for the 100-year event for a 1-day duration corresponds to a combined rainfall and snowmelt depth of 41.4 mm. For medium durations, snowmelt may make up a larger fraction of the combined rainfall and snowmelt amount, as values between 5 to 30 days are higher across return periods than those estimated for extreme precipitation.
- The estimated climate inputs for PMF estimation ranges 271.8 mm to 378.9 mm for 1- to 3-day durations in the spring and 319.2 mm to 342.2 mm for 1- to 3-day durations annually. Climate inputs for the 1-day duration in the spring is lower than the annual period but exceeds the annual climate inputs for 2- and 3-day durations. For the 2- and 3-day durations, the spring climate inputs to PMF estimation provides the most critical flood volumes. This could be due to substantial snowmelt contribution, causing the spring climate inputs to PMF estimation to surpass the annual period for longer durations.

- The annual average total potential evapotranspiration was estimated as 584.7 mm, which is slightly less than the annual average total precipitation of 633 mm. This indicates that Project site is likely in a state water balance equilibrium on average.
- The westerly wind direction is the most common, accounting for approximately 10% of the hourly wind speeds. Windspeeds falling under the west northwesterly direction are slightly less frequent (9.5% of hourly wind speeds) but contain the greatest frequency of windspeed in excess of 5 m/s (18 km/h).
- For lower return periods of 2 to 10 years, the greatest wind speeds are estimated for the west (W) to south southwest (SSW) directions, with magnitudes ranging from 9.4 m/s to 9.8 m/s. For the 100-year return period, the greatest wind speed is estimated for the south southwest (SSW) direction, with a magnitude of 12.4 m/s.

Future climate conditions were assessed for the Project site by calculating projected changes in the climate variables over a model baseline period and two future periods (2050s and 2080s) using a set of climate projection that make up a multi-model ensemble. The ensemble consisted of 26 statistically downscaled climate models from [Climatedata.ca](https://climatedata.ca) (2023), which includes three emission scenarios (SSP1-2.6, SSP2-4.5, and SSP5-8.5) for precipitation, minimum and maximum temperature. The distribution of projected changes was summarized across the multi-model ensemble in terms of either percentage or absolute changes.

- Annual average temperature is projected to change by 2.5°C in the 2050s and 3.4°C in the 2080s at the 50th percentile, indicating an increasing trend due to changing climate. In the 2050s and 2080s, projected changes in mean monthly temperature range from 2.0°C to 3.4°C and 3.0°C to 5.0°C, respectively with the greatest changes occurring in the winter months at the 50th percentile.
- Annual total precipitation is projected to increase by 4% in the 2050s and 6% in the 2080s, indicating an upward trend in precipitation on the annual scale at the 50th percentile. In the 2050s, monthly total precipitation at the 50th percentile is projected to increase for almost all months, except for the months of July and August. The high percentage changes in the precipitation during the winter months may lead to more snowfall and snowpack, however this also be impacted by changing temperatures.
- At the 50th percentile, both wet and dry year precipitation amounts were estimated to range from approximately 3% to 4% in the 2050s and 6% to 8% in the 2080s. Projected changes in total precipitation are similar for both wet and dry years, with consistent changes across return periods. This suggests that at an annual scale, an overall increase in total precipitation amounts is projected, with only small changes to the frequency of wet and dry years relative to the baseline period.
- For the temperature-based indices, fewer frost and ice days, more summer days and greater temperature extremes (lowest minimum and maximum temperature, highest minimum and maximum temperature) are indicated for the 2050s at the 50th percentile. In the 2080s, the same patterns are present but amplified due to higher projected changes in temperature. The direction of projected changes at the 50th percentile generally agree with the statistically significant trends found for the current climate baseline. Wetter conditions along with greater temperature extremes may lead to higher variability in drought and flooding conditions at the site.
- Extreme precipitation indices indicate that in the 2050s at the 50th percentile the annual amount of precipitation on wet days, and annual maximum precipitation amounts are projected to increase. The number of heavy and very heavy wet days suggest that precipitation intensity may increase. In the 2080s the same pattern is present, with slightly higher annual total wet day precipitation and maximum 1- and 5-day precipitation amounts.
- The percentage change in PMP is estimated between the model baseline and future periods. In the 2050s at the 50th percentile, the 1-day, 2-day, and 3-day PMP are projected to increase by 19%, 16%, and 15%, respectively. In the 2080s an increase of 23%, 21%, and 23% is projected for the 1-day, 2-day, and 3-day PMP events, respectively. Greater projected temperatures in the 2080s can be associated with greater atmospheric moisture holding capacity, which is anticipated to result in greater PMP projected further into the future.

- Projected changes in extreme precipitation statistics are provided across a set of durations and return periods for the 2050s and 2080s future periods at the 50th percentile. In the 2050s, the range of projected changes is 1% to 16% with a change of 15% for the 1-day, 100-year event. In the 2080s, a range of projected changes of 0% to 20% is estimated, with a change of 18% for the 1-day, 100-year event. Lower duration events at higher return periods generally show greater projected changes than longer durations events above 7 days. This may be due to increased temperatures leading to more atmospheric moisture holding capacity playing a larger role in shorter durations and longer return periods where rainfall intensity is higher.
- Projected changes in combined rainfall and snowmelt across durations and return periods range from -4% to 12% for the 2050s, and from -2% to 17% for the 2080s at the 50th percentile. Projected changes for the 1-day, 100-year event are estimated as 11% and 14% for the 2050s and 2080s, respectively. For shorter durations from 1 to 3 days, projected changes are highest as the combined amounts would mainly consist of extreme rainfall. As the duration increases, projected decreases in combined rainfall and snowmelt are found. This is likely due to less accumulated snow due reduced snowfall and earlier melt (less accumulation) due to increasing projected temperatures.
- Annually, projected changes in the climate inputs to PMF range from 11% to 16% for the 2050s and 17% to 22% for the 2080s at the 50th percentile. Projected changes for the annual period may be slightly higher than the spring period due to greater influence of changes in extreme precipitation and decreasing amounts of extreme snowmelt.
- Under future climate conditions, annual and monthly potential evapotranspiration rates are projected to increase for all months across the multi model ensemble at the 50th percentile, with an annual total increase of 10% and 13% for the 2050s and 2080s, respectively. In the 2050s, monthly projected changes range from 6% in June to 46% in January. In the 2080s, monthly projected changes range from 9% in June and July, to 74% in January.
- Based on a review of Jeong and Sushama (2019), it was found that in the region surrounding the Project site, annual mean wind speeds were projected to change between 0% to 4%, while 50-year return period maximum wind speed were projected to change between -12% to 8%. The IPCC interactive atlas contains an online interface for examining projected changes in surface winds. Using this tool, annual average surface wind speeds are projected to decrease by approximately -3% for the 2041-2060 period and -5% for the 2081-2100 period relative to a 1994-2014 baseline under a high emission scenario. It should be noted that like precipitation, wind speed can have a high degree of uncertainty across models and is indicated as low model agreement over the location of Project site.

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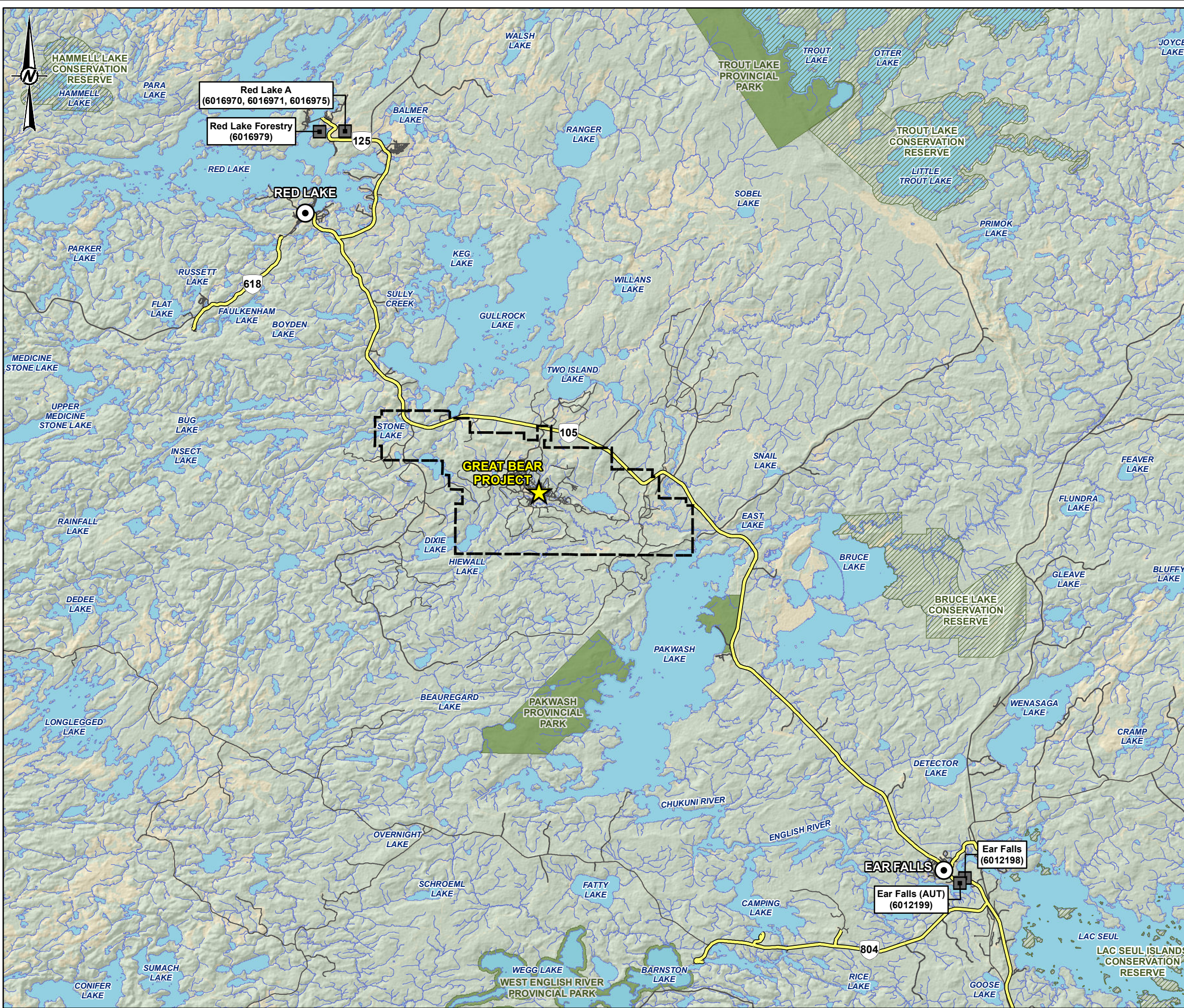
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Appendix A

Regional Climate Station Locations



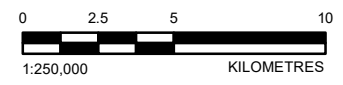


SCALE 1:30,000,000

LEGEND

- ★ GREAT BEAR PROJECT
- PROPERTY BOUNDARY
- ECCC CLIMATE STATION (LABELLED WITH STATION NAME AND ID)
- TOWN
- CONSERVATION RESERVE
- PROVINCIAL PARK
- HIGHWAY
- LOCAL ROAD
- RESOURCE/ RECREATION ROAD
- WATERCOURSE
- WATERBODY

STATION NAME	CLIMATE ID	COORDINATES	DISTANCE TO SITE (KM)	ELEVATION (M)	TIME PERIOD	DATA AVAILABILITY	
						MEAN TEMPERATURE	TOTAL PRECIPITATION
Great Bear Project	—	50.52°N, 93.38°W	—	405	—	—	—
Ear Falls	6012198	50.63°N, 93.22°W	39.9	361	1928-1999	76%	79%
Ear Falls (AUT)	6012199	50.63°N, 93.22°W	39.9	363	1999-2023	95%	92%
Red Lake A	6016970	51.07°N, 93.79°W	24.3	386	2012-2018	54%	3%
Red Lake A	6016971	51.07°N, 93.79°W	24.3	386	2018-2023	79%	0%
Red Lake A	6016975	51.07°N, 93.79°W	24.3	386	1930-2012	67%	74%
Red Lake Forestry	6016979	51.07°N, 93.82°W	25.3	375	1959-1960	37%	46%



NOTE(S)
1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)
1. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE - ONTARIO
2. WATERCOURSES AND WATERBODY ACQUIRED FROM LAND INFORMATION ONTARIO (MNR) AND MODIFIED TO MATCH AERIAL IMAGERY AND LIDAR.
3. ROADS INFORMATION PROVIDED BY GREAT BEAR RESOURCES, AUGUST 2022.
4. PROPERTY BOUNDARY PROVIDED BY GREAT BEAR RESOURCES, AUGUST 2024.
5. COORDINATE SYSTEM: NAD 1983 UTM ZONE 15N

CLIENT
GREAT BEAR RESOURCES

PROJECT
GREAT BEAR PROJECT

TITLE
LOCATION OF REGIONAL CLIMATE STATIONS

CONSULTANT
WSP

YYYY-MM-DD	2025-02-12
DESIGNED	---
PREPARED	MD
REVIEWED	PB
APPROVED	JK

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Appendix B

Detailed Methodology



APPENDIX B – DETAILED METHODOLOGY

1.0 BACKGROUND

WSP has developed a standardized approach for developing site-specific climate change data sets, described in the following sections. The purpose of this approach is to provide a description of the current climate conditions using the most representative local data for the site of interest, to provide a description of the future climate conditions using publicly available climate projections, and to provide a range of projections on how the current climate may change in the future.

2.0 CURRENT CLIMATE DATASET DEVELOPMENT

Understanding the current climate and current climate trends is important when evaluating current design parameters and developing the percentiles using the future climate projections. Where available, the climate baseline is grounded in observations from local observation stations. Based on missing observational data, the baseline will be established by using publicly available regional climate stations infilled with gridded or reanalysis data (to meet data completeness requirements and fill any missing gaps in observations). Before infilling, the gridded or reanalysis data will be compared and correlated to available regional climate stations.

2.1 Data Sources for Current Climate Baseline

The current climate baseline is based on available long term daily meteorological observations from climate stations near the project region. The climate station selection was based upon the following selection factors to identify the station that is most meteorologically representative of the Great Bear Project (Project) area:

- Length of monitoring data record (minimum 30 years of data);
- Availability of a continuous record;
- Proximity to the area of interest;
- Age of observations compared to the currently accepted normal period;
- Latitude;
- Elevation of station;
- Geographic siting; and
- Monthly data availability threshold of 3 and 5 rule for all years.

The 3 and 5 rule established by WMO (2017) allows for up to 5 days of missing observations per month and no more than 3 consecutive missing days. The available climate data from each station must be compared to, and pass, the selection criteria outlined above. Data from most climate stations is constrained by low numbers of observations or a limited life span for the station (data quantity), and varying data quality. Therefore, the station which matches the most selection criteria, with the first three criteria bearing the most weight, is selected.

Meeting the monthly data availability is often a challenge over the desired, long observation period. When available climate observations are representative of a site but fail to meet the required data completeness, either alternative climate stations as well as gridded or reanalysis data may be used to represent current climate or to infill the missing data. First, a climate sensitivity analysis is performed to assess regional climate variability and the potential for infilling from climate stations and gridded or reanalysis datasets. The datasets with similar climate attributes to the selected stations may be considered for infilling.

To infill the observations, first the climate stations and gridded or reanalysis datasets with similar climate attributes to the selected station are correlated with the observations from months with data availability above 90%. The correlation relationships are then applied to these datasets before infilling, providing a smooth transition between the local observations and the infilled data. In regions where varied topography may influence temperature and precipitation observations across regional climate stations, statistical

adjustments may be applied to improve the representation of the site. For precipitation, annual total precipitation amounts may be correlated to the elevation of regional climate stations. If a significant relationship exists, then linear adjustments may be applied to regional climate stations selected for infilling. Similarly, temperature observations may be adjusted based on the difference in elevation of the site, and regional climate stations using the dry adiabatic lapse rate (adapted from Sheridan et al. 2010).

For infilling at the project site, a gridded reanalysis dataset from the European Centre for Medium-Range Weather Forecasts (ECMWF) Re-Analysis (ERA5) is used (Hersbach et al. 2020). The dataset consists of a high-density network of observational stations gridded to a spacing of approximately 30 km. ERA5 is the fifth generation of atmospheric reanalysis datasets to be produced by the ECWMF and is based on a forecasting model which simulates interacting components of atmosphere, land, and ocean on a global grid. Data assimilation is used to bring together ground and satellite observations to reduce forecast uncertainty. Compare to previous generations ERA5 shows improved global hydrological and mass balance, reduced biases in precipitation, and refinement of the variability and trends of surface air temperature (Hersbach et al. 2020). However, for extreme value analyses (e.g., probable maximum precipitation and extreme precipitation statistics) only observations are included to avoid introducing potential biases that could impact estimations of low-frequency and high magnitude climate extremes.

2.2 Current Climate Temperature and Precipitation

The current climate temperature and precipitation condition will be used to calculate the annual and monthly current climate normals and trends using the definitions provided in Table 1.

Table 1: Definition of Current Climate Variables

Climate Indices	Definition	Units
Average Annual Temperature	Calculated as the average of all the observed daily mean temperatures during the selected annual period. Each annual value is averaged over the period of the climate normal.	°C
Monthly Temperature	Calculated as the average of all the observed mean temperatures during the selected month. Each annual value is averaged over the period of the climate normal.	°C
Total Precipitation	Calculated as the sum of all the observed total precipitation during the selected annual period. Each annual value is averaged over the period of the climate normal.	mm
Monthly Precipitation	Calculated as the sum of all the observed total precipitation during the selected month. Each annual value is averaged over the period of the climate normal.	mm

Note:

°C = degrees Celsius; mm = millimeters.

The reviewed data will be used to calculate these climate normals and trends using a method developed by the Finnish Meteorological Institute (Salmi et al. 2002) to assess climate changes from long-term climate observations. Both annual and seasonal climate normals and trends will be calculated for the mean temperature and total precipitation. The climate normal will be calculated as the average of a given climate parameter over the selected period, and the climate trend will be calculated as the average change in the climate parameter per decade (i.e., the decadal trend or change). Potential trends in temperature and precipitation will be evaluated by fitting a model to the data using the Sen's nonparametric model. The statistical significance of the observed trends will be measured using the Mann-Kendall test (Kamal and Pachauri 2018). The Mann-Kendall test is applicable to the detection of a monotonic trend of a time series with no seasonal cycle. The analysis uses a two-tail test to measure statistical significance at the 90th, 95th, 99th and 99.9th percentile levels.

2.3 Current Climate Wet and Dry Year Statistics

Return periods of 5-, 10-, 20-, 50- and 100-years are assigned to annual total precipitation for dry and wet years using the following approach. First, the annual total precipitation is obtained by summing the values from daily to annual intervals over the baseline period. The Log-Normal distribution is then fitted to the annual total precipitation values. Annual total precipitation values corresponding to 5-, 10-, 20-, 50- and 100-year return periods are obtained from the inverse cumulative Normal distribution for wet and dry years. If T is the return period, then the following equation is used to represent the lower-tail probability of the cumulative distribution (q) for which the corresponding annual total precipitation is obtained.

For wet years,

$$q = 1 - \frac{1}{T} \quad \text{Equation 1}$$

and for dry years,

$$q = \frac{1}{T} \quad \text{Equation 2}$$

Different equations are used for wet and dry periods due to the difference in the portion of the distribution used. For example, in the case of wet years the frequency of high values of precipitation are of interest, whereas the frequency of low values of precipitation are of interest for dry years. The value of q is used as input to the inverse cumulative probability distribution in order to obtain the corresponding annual total precipitation values.

2.4 Current Climate WMO Extreme Indices

In addition to the current climate indices discussed above, the climate extremes come from the World Meteorological Organization (WMO) Expert Team on Climate Change Detection and Indices (ETCCDI 2017; WMO 2009a) recommended 27 indices as a means of summarizing daily temperature and precipitation statistics, focusing primarily on aspects of climate extremes. They have been developed to allow comparison of climate conditions on an international basis. The detailed definitions for these 27 indices, quality control procedures and calculation software are provided by ETCCDI (2017). In addition to the climate normals and trends (calculated using the method described in Section 2.2), the minimum, maximum, mean, and median for each of the 27 indices will be calculated using the annual values provided for each index during the selected baseline range. Table 2 provides a summary of these indices and their definitions.

Table 2: List of WMO Recommended 27 Extreme Indices

ID	Indicator name	Definitions ⁽¹⁾	Units
CDD	Consecutive dry days	Maximum number of consecutive days with daily precipitation amount less than 1 mm (RR <1 mm)	Days
CSDI	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when daily minimum temperatures are less than the 10 th percentile (TN <10 th percentile)	Days
CWD	Consecutive wet days	Maximum number of consecutive days with daily precipitation amount greater than or equal to 1 mm (RR ≥ 1 mm)	Days
DTR	Diurnal temperature range	Monthly mean difference between the daily minimum temperature (TX) and the daily maximum temperature (TN)	°C
FD0	Frost days	Annual count when the daily minimum temperature is less than 0°C (TN < 0°C)	Days
GSL	Growing season Length	Annual (1st Jan to 31 st Dec in NH, 1 st July to 30 th June in SH) count between first span of at least 6 days with ground temperatures greater than 5°C (TG > 5°C) and first span after July 1 (January 1 in SH) of 6 days with ground temperatures less than 5°C (TG < 5°C)	Days

ID	Indicator name	Definitions ⁽¹⁾	Units
ID0	Ice days	Annual count when the daily maximum temperature is less than 0° (TX<0°C)	Days
PRCPTOT	Annual total wet-day precipitation	Annual total precipitation (PRCP) in wet days where the daily precipitation is greater than or equal to 1 mm (RR>=1 mm)	mm
R10	Number of heavy precipitation days	Annual count of days when precipitation is greater than or equal to 10 mm (PRCP>=10 mm)	Days
R20	Number of very heavy precipitation days	Annual count of days when precipitation is greater than or equal to 20 mm (PRCP>=20 mm)	Days
R95p	Very wet days	Annual total precipitation (PRCP) when the daily precipitation is greater than the 95 th percentile (RR>95 th percentile)	mm
R99p	Extremely wet days	Annual total precipitation (PRCP) when the daily precipitation is greater than the 99 th percentile (RR>99 th percentile)	mm
Rnn	Number of days above nn mm	Annual count of days when precipitation when precipitation is greater than or equal to a user defined threshold (PRCP>=nn mm, nn is user defined threshold)	Days
RX1day	Max 1-day precipitation amount	Monthly maximum 1-day precipitation	mm
Rx5day	Max 5-day precipitation amount	Monthly maximum consecutive 5-day precipitation	mm
SDII	Simple daily intensity index	Annual total precipitation divided by the number of wet days (defined as PRCP>=1.0 mm) in the year	mm/day
SU25	Summer days	Annual count when the daily maximum temperature is greater than 25°C (TX>25°C)	Days
TN10p	Cool nights	Percentage of days when the daily minimum temperature is less than the 10 th percentile (TN<10 th percentile)	% of Days
TN90p	Warm nights	Percentage of days when the daily minimum temperature is greater than the 90 th percentile (TN>90 th percentile)	% of Days
TNn	Min Tmin	Monthly minimum value of daily minimum temp	°C
TNx	Max Tmin	Monthly maximum value of daily minimum temp	°C
TR20	Tropical nights	Annual count when the daily minimum temperature is greater than 20°C (TN>20°C)	Days
TX10p	Cool days	Percentage of days when the daily maximum temperature is less than the 10 th percentile (TX<10 th percentile)	% of Days
TX90p	Warm days	Percentage of days when the daily maximum temperature is greater than the 90 th percentile (TX>90 th percentile)	% of Days
TXn	Min Tmax	Monthly minimum value of daily maximum temp	°C
TXx	Max Tmax	Monthly maximum value of daily maximum temp	°C
WSDI	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when the daily maximum temperature is greater than the 90 th percentile (TX>90 th percentile)	Days

Note:

1 The abbreviations for the variables used in the definitions are as follows: NH is northern hemisphere; SH is southern hemisphere; RR is the daily precipitation amount (mm); TX is the maximum temperature (°C); TN is the minimum temperature (°C); TG is the ground temperature (°C); and PRCP is the precipitation amount (mm); RR is the daily precipitation amount (mm).

Decadal trends and statistical significance are estimated for each of the climate indices using the same approach detailed in Section 2.2.

2.5 Current Climate Probable Maximum Precipitation

Probable Maximum Precipitation (PMP) is defined as “the greatest depth of precipitation for a given duration meteorologically possible for a design watershed or a given storm area at a particular location at a particular time of year, with no allowance made for long-term climatic trends” (WMO 2009b). The PMP is a theoretical value that represents the greatest amount of rain possible in a given area as opposed to a design storm that represents the greatest amount of rain observed in a given area. The WMO acknowledges that there is significant uncertainty regarding PMP calculations and recommends that a comparison of reported values is conducted.

There are two widely accepted approaches (meteorological and statistical) to estimate the PMP. The meteorological approach maximizes the moisture content or precipitable water of rainfall storm events while the statistical approach utilizes the historical annual maximum rainfall events to estimate the PMP.

The moisture maximization approach in a simple term can be estimated by:

$$PMP = P_s \times \frac{W_{max}}{W_{storm}} = P_s \times r \quad \text{Equation 3}$$

Where P_s is the observed precipitation of a large storm, W_{max} is the maximum precipitable water at the same time of year in the same location, W_{storm} is the precipitable water of the observed storm, and r is the moisture maximization ratio. Precipitable water is the amount of water from condensation of all water vapour in an atmospheric column.

The statistical approach following Hershfield Methods (WMO 2009b) is as follows:

$$PMP = X_n + KS_n \quad \text{Equation 4}$$

Where X_n and S_n are the mean and standard deviation (respectively) of the annual maximum precipitation, and K is a frequency factor that is a function of X_n and rainfall intervals. In computing PMP with Equation 4, various adjustments are made, including:

- Adjustment of X_n and S_n for the maximum observed events;
- Adjustment of X_n and S_n for sample size;
- Adjustment for fixed observational time intervals; and
- Adjustment for the area.

In this work the Hershfield method was used to estimate the current climate PMP, as the required calculation information was more readily available for the selected location compared to the meteorological method, which had missing information. It should be noted that the Hershfield method is empirically based using observations from a network of climate stations across North America. This estimate should therefore be used with caution and compared to other information previously used to estimate PMP for the site.

2.6 Current Extreme Precipitation Statistics

Daily and multi-day precipitation statistics are calculated by estimating the depth of precipitation over a given duration for a set of return periods. This process is accomplished by extracting the annual maximum rainfall amounts in each year of the current climate baseline for a set of durations (i.e., 1-day, 2-day). The annual maximum precipitation amounts for each duration are then fitted to a statistical distribution using the method of moments. To select an appropriate distribution for estimating extreme precipitation statistics, multiple distributions were assessed for goodness of fit including 3 Parameter Log-Normal, Extreme Value, Log-Pearson Type III, and Weibull distributions. The Anderson statistic, sum of squared error, and visual inspection are used to assess goodness of fit. Of these distributions, the Extreme Value (Type 1) of the Gumbel distribution had the best fit for many durations and provides

slightly more conservative values than the others for higher return periods. The rainfall amounts corresponding to the set of return periods are extracted from the inverse cumulative distribution function of the fitted statistical distribution.

2.7 Current Extreme Combined Rainfall and Snowmelt Statistics

The calculation of extreme combined rainfall and snowmelt statistics follows the methodology adopted by ECCC (Louie and Hogg 1980) to estimate runoff from snowmelt. The methodology first separates rainfall and snowmelt using mean daily temperature and uses a degree-day method to model the processes of snow accumulation and melt. The following steps are used in the procedure:

- The snowpack accumulation is estimated based on the daily mean temperature and the total rainfall. If temperature is $>0^{\circ}\text{C}$, precipitation falls as rain and no snowpack is accumulated; if temperature is $<0^{\circ}\text{C}$, precipitation falls as snow and is accumulated to the snowpack.
- The snowmelt amount (SM) is estimated based on the model presented in Equation 5 (Pysklywec et al. 1968) and is depleted from the snowpack.

$$SM = 1.008 (1.8 \cdot T_a + 4.4) \frac{mm}{day} \quad \text{Equation 5}$$

Where T_a is the mean daily air temperature in $^{\circ}\text{C}$.

- For combined rainfall and snowmelt, the calculated snowmelt is added to the rainfall amount, if any (rain + snowmelt).
- The process is repeated for all days in the data series are calculated.
- Finally, the daily maximums of rain, snow, snowfall, snowmelt, combined rainfall and snowmelt, and snowpack for each year (over the period of October through June) are calculated and a statistical distribution is fitted to estimate the required return periods.

A comparison of estimated snow depth using this method against ECCC snow survey measurements is provided in Appendix D: ECCC Snow Survey Comparison of *Detailed Climate Change Dataset*.

2.8 Current Climate Inputs for Probable Maximum Flood Estimation

The probable maximum flood (PMF) is defined as the largest flood resulting from a combination of the most severe meteorological and hydrologic conditions that could occur in a given area under idealized conditions. While this event is not defined by climate alone (i.e., dependant on hydrologic components such as flood routing/storage, and abstractions), climate inputs for estimation of PMF are provided assuming no losses by combining estimates of PMP (Section 2.5) and 100-year snowmelt (Section 2.7) for the spring period, and only PMP for the annual period for the same 1 through 3-day durations as provided for the PMP. These inputs may be used to drive a hydrologic model to simulate PMF flow rates and water volumes to be managed.

2.9 Current Potential Evapotranspiration

Evapotranspiration is the combined process of evaporation and transpiration over a vegetated surface. The principal weather parameters affecting evapotranspiration are air temperature, extraterrestrial radiation, humidity and wind speed, and vegetation parameters. Potential evapotranspiration represents the maximum actual evapotranspiration expected from a given area with no moisture limitations. As only the observed minimum temperature, maximum temperature and total precipitation are available from the daily current climate dataset (no infilled observations of radiation, humidity, and wind speed are produced), and an air temperature-based formula, namely the Hargreaves equation (Hargreaves and Samani 1985) will be used.

The Hargreaves equation was developed in 1982 as an alternative to the more complicated energy-balance approach of the Penman-Monteith equation (developed in 1948). The Penman-Monteith method required significant amounts of climate data including incoming solar radiation, wind speed, and humidity, which are often not available. By contrast, the Hargreaves equation requires only the daily minimum,

maximum, and mean temperatures. The Hargreaves equation builds into a more complete model by making assumptions about the solar radiation (based on latitude), accounting for humidity (based on the difference between daily minimum and maximum temperatures), and assuming that the effect of wind is not significant. The Food and Agriculture Organization has noted that for potential evapotranspiration (ET_o):

Temperatures methods remain empirical and require local calibration in order to achieve satisfactory results. A possible exception is the 1985 Hargreaves' method which has shown reasonable ET_o results with a global validity (Allen et al. 1998).

The Hargreaves estimate of daily potential evapotranspiration is arrived at by the following formula:

$$E = 0.0023(T_{\text{mean}} + 17.8)(T_{\text{max}} - T_{\text{min}})^{0.5}R_a \quad \text{Equation 6}$$

where T_{mean} is the average temperature, T_{max} and T_{min} are daily maximum and minimum temperatures, and R_a is the extraterrestrial radiation. The R_a is calculated as:

$$R_a = \frac{24(60)}{\pi} G_{sc} d_r [w_s \sin(\varphi) \sin(\delta) + \cos(\varphi) \cos(\delta) \sin(w_s)] \quad \text{Equation 7}$$

where G_{sc} is the solar constant: 0.0820 MJ/m²/min;

d_r is the inverse relative distance Earth-Sun: $d_r = 1 + 0.033 \cos\left(\frac{2\pi}{365} J\right)$;

w_s is the sunset hour angle: $w_s = \arccos[-\tan(\varphi)\tan(\delta)]$;

φ is the latitude of the site in radians;

δ is the solar declination in radians: $\delta = 0.409 \sin\left(\frac{2\pi}{365} J - 1.39\right)$; and

J is the Julian day.

Unlike other method to estimate potential evapotranspiration such as Thornthwaite, the Hargreaves equation has no lower bound to account for freezing temperatures in the winter months where evapotranspiration would be negligible. Movement of moisture to the atmosphere during these months would likely occur in the form of sublimation instead of potential evapotranspiration. Here it is assumed during the late fall to early spring months when temperatures are below freezing, that potential evapotranspiration amounts are negligible.

2.10 Current Climate Wind Speed

Hourly wind speed and direction under current climate conditions are obtained through the on-site South station. Wind speed direction data are rounded to the nearest 10 degrees. To avoid artificially binning the wind speeds through this rounding procedure, a randomization is applied to the wind direction by adding a uniformly distributed random variable spanning the range of -5 to 5 degrees. Wind speed and direction data can then be combined to develop wind roses, which divide the wind speed data using a number of cardinal directions. Each cardinal direction (e.g., north, northeast, east) is defined by a range of degrees for the wind direction. The windspeed data is binned using the wind direction data, in order to show the number of data points that correspond to each cardinal direction, forming a wind rose. The data that is binned into each cardinal direction can be divided further into ranges for the windspeed (such as 0 to 2 m/s, 2 to 3 m/s and 3 to 4 m/s) to show the relative frequency that different magnitudes of wind speeds occur in the cardinal directions.

Extreme value analysis is carried out by first estimating the annual maximum hourly wind speed corresponding to each cardinal direction. To select an appropriate distribution for estimating extreme precipitation statistics, multiple distributions were assessed for goodness of fit including 3 Parameter Log-Normal, Gumbel, Generalized Extreme Value, Log-Pearson Type III, and Weibull distributions. The Anderson statistic, sum of squared error, and visual inspection are used to assess goodness of fit. Of these distributions, the Generalized Extreme Value distribution had the best fit for many durations. The

annual maximum values are then fitted to the Generalized Extreme Value distribution for which values corresponding to a set of return periods are extracted from the cumulative distribution function.

3.0 FUTURE CLIMATE

Future climate projections are important for understanding how climate is projected to change from the climate baseline. The future climate projections come from publicly available statistical downscaled future climate projections on a daily scale. Recognizing the inherent uncertainty with projections, the results in this report have been derived by using multiple projections from multiple models and scenarios. Therefore, the future projections are provided in terms of percentiles across the multi-model ensemble.

3.1 Data Sources for Future Climate Projections

Future climate projections are important for understanding how climate is projected to change from the climate baseline. The future climate projections come from publicly available statistically downscaled future climate projections on a daily scale.

3.1.1 Global Climate Change Projections

The Intergovernmental Panel on Climate Change (IPCC) is generally considered to be the definitive source of information related to past and future climate change as well as climate science. As an international body, the IPCC provides a common source of information relating to emission scenarios, provides third party reviews of models, and recommends approaches to document future climate projections. Periodically, the IPCC issues assessment reports summarizing the most current state of climate science. The Sixth Assessment Report (AR6; IPCC 2021) represents the most current complete synthesis of information regarding climate change. The future climate projections come from publicly available statistically downscaled future climate projections based on the Sixth Assessment Report (AR6; IPCC 2021), on a daily scale.

Future climate is typically projected using global climate models (GCMs) that involve the mathematical representation of global land, sea, and atmosphere interactions over a long period of time. These GCMs have been developed by various government agencies, but they share a number of common elements described by the IPCC. The IPCC does not run the models but acts as a clearinghouse for the distribution and sharing of the model forecasts. Future climate projection data are available from about 33 GCMs and four representative concentration pathways (RCPs); RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5) in AR5. The pathways are named after the radiative forcing projected to occur by 2100. These RCPs are described more fully by van Vuuren et al. (2011) in their paper *The Representative Concentration Pathways: An Overview* and have been summarized in Table 3.

Table 3: Characterization of Representative Concentration Pathways

Name	Radiative Forcing in 2100	Characterization
RCP8.5	8.5 W/m ²	Increasing greenhouse gas emissions over time, with no stabilization, representative of scenarios leading to high greenhouse gas concentration levels; and comparable to the SRES A2/A1FI scenarios.
RCP6.0	6.0 W/m ²	Without additional efforts to constraint emissions (baseline scenarios); and comparable to SRES B2 scenario.
RCP4.5	4.5 W/m ²	Total radiative forcing is stabilized shortly after 2100, without overshoot. This is achieved through a reduction in greenhouse gases over time through climate policy; and comparable to SRES B1 scenario.
RCP2.6	2.6 W/m ²	Peak and decline scenario where the radiative forcing first reaches 3.1 W/m ² by mid-century and returns to 2.6 W/m ² by 2100. This is achieved through a substantial reduction in greenhouse gases over time through stringent climate policy.

Note:
W/m² = watts per square metre.

Compared to IPCC Fifth Assessment Report (AR5), a wider range of scenarios are provided in AR6, covering an updated set of pathways for future climate to unfold which are summarized in Table 4. Where possible, the analogous pathway of the Representative Concentration Pathways (RCP) from the IPCC Fifth Assessment Report (AR5) are noted for each SSP from O’Neil et al. (2014).

Table 4: Characterization of Shared Socioeconomic Pathways (SSPs) in IPCC Sixth Assessment Report

SSP	Radiative Forcing in 2100	Characterization
SSP1	1.9 W/m ² 2.6 W/m ²	Sustainable development proceeds at a reasonably high pace.
SSP2	4.5 W/m ²	An intermediate case analogous to RCP 4.5 scenario.
SSP3	7.0 W/m ²	Unmitigated emissions are high due to moderate economic growth.
SSP4	3.4 W/m ² 6.0 W/m ²	A mixed world, with relatively rapid technological development in low carbon energy sources in key emitting regions, leading to relatively large mitigative capacity in places where it mattered most to global emissions.
SSP5	8.5 W/m ²	In the absence of climate policies, energy demand is high and most of this demand is met with carbon-based fuels. Analogous to RCP 8.5 scenario.

Source: O’Neil et al. 2014.

This climate change projections provided in this report are based on AR6 (IPCC 2021), instead of AR5 (IPCC 2013). AR6 includes new and better representations of physical, chemical, and biological processes, along with higher resolution, compared to previous IPCC assessment reports, including AR5. Additionally, AR6 projections have a wider range of sensitivity to greenhouse gas emissions compared to models used in AR5, which gives a larger ensemble for capturing uncertainty in future climate projections (IPCC 2021).

The model projections can be summarized for magnitude of change from the climate regime baseline for different time horizons. The time horizons applied to this study include the following:

- 1991 to 2020 (model baseline);
- 2041 to 2070 (2050s or mid-century); and
- 2071 to 2100 (2080s or end-of-century).

3.1.2 Regional Climate Change Projections

GCMs resolution is generally too coarse for direct use as it does not resolve weather and extreme weather patterns or climatology at local scales. Outside of using the GCM output directly, there are different options to analyze climate projections at a regional scale. Most downscaled climate datasets include minimum temperature, maximum temperature, and precipitation. The focus is on statistical or dynamically downscaled datasets which have a higher temporal and spatial resolution of the data; however, they may have limited variables available. The availability of daily downscaled data allows for better characterization of climate extremes, especially for precipitation. The availability of high spatial resolution (25 km instead of hundreds of km in global climate models or GCMs) provides better data to represent site-specific information for the study.

The data used in this report is obtained from Climatedata.ca (2023). The data is comprised of GCM outputs, which are statistically downscaled using Bias Correction/Constructed Analogues with Quantile mapping reordering (BCCAQ) version 2 provided by the Pacific Climate Impacts Consortium to correct for systematic biases in temperature (systematic over or underestimation) and precipitation (frequent drizzle and underestimation of extremes). The IPCC describes future emission scenarios using Shared Socioeconomic Pathways (SSPs); however, this report focuses on the three SSPs (SSP1-2.6, SSP2-4.5

and SSP5-8.5) currently available from [Climatedata.ca](https://climatedata.ca), capturing the lower to upper range of emission scenarios.

The statistically downscaled models provide daily global climate scenarios, at a gridded resolution of approximately 10 km for the simulated period of 1950-2100 ([Climatedata.ca](https://climatedata.ca) 2023). The climate variables available from this dataset include minimum temperature, maximum temperature, and precipitation. The selection statistically downscaled climate scenarios for this project are based on the available temporal and spatial resolution of the data. The availability of daily downscaled data allows for better characterization of the climate extremes, especially for precipitation. The availability of high spatial resolution (10 km instead of hundreds of kilometres in GCMs) provides better representation for site-specific studies like this project.

Since no one model or climate scenario can be viewed as completely accurate, the IPCC recommends that climate change assessments use as many models and climate scenarios as possible, or a multi-model ensemble (IPCC 2021, p.221). For this reason, the multi-model ensemble approach was used to delineate the probable range of results and better capture the actual outcome (an inherent unknown).

The downscaled data has a daily temporal resolution (GCMs typically have monthly temporal resolution), which will allow for the characterization of future climate extremes. In addition, the improved horizontal resolution of 25 km in the downscaled data could better improve the representation of the Project, given the complex terrain in the Project Area.

3.2 Future Temperature and Precipitation

Minimum and maximum daily temperature from the multi-model ensemble of climate projections is first averaged into the mean temperature for all calendar months across all years in the model baseline and future time periods. In the case of mean temperature, annual mean values are calculated and averaged across years, while monthly averages are taken and averaged across calendar months. For precipitation annual and monthly totals are used. The percentage change for the annual and monthly values between the model baseline and future time periods is calculated for each member of the multi-model ensemble. The distribution of percentage changes across the multi-model ensemble is then provided using a set of percentiles.

3.3 Future Wet and Dry Year Statistics

Following the same approach applied current climate in Section 2.3, projected changes in wet and dry year statistics are estimated by applying this approach separately for modelled baseline and a future period(s). Projected changes between the modelled baseline and future period(s) are estimated for each climate model and emissions scenario. Using the ensemble approach the distribution of projected changes are summarized using percentiles.

3.4 Future WMO Extreme Indices

Future climate extremes are projected using the 27 WMO extreme indices described in Section 2.4 using the temperature and precipitation projections from the available downscaled climate scenarios described in 3.1.2. The future climate extremes are described in terms of an anomaly or change from the baseline. As each model has a unique baseline, the calculations are first completed for each model and then statistics are provided to describe the range of projections over the multi-model ensemble.

The 27 WMO indices are calculated for each of the 81 multi-model ensemble members for each year of the baseline and each year of the two desired future periods (2050s and 2080s). This creates the unique baseline and future projections for each model that will be used as a basis to calculate the anomaly. Before calculating the anomaly, for each ensemble member, each index is averaged over all the annual values contained in each period considered (baseline and two future periods) creating three values for each index for each model (i.e., mean value for the baseline, the 2050s and the 2080s). Finally, the anomalies are calculated as the difference between each future period and the baseline for each index (e.g., mean 2050s less mean baseline and mean 2080s less mean baseline) and each ensemble member. This provides an anomaly per index per ensemble member for each future period. This information is summarized using statistics to describe the range in projected anomalies across the ensemble members (min, max, mean, median, and percentiles).

3.5 Future Probable Maximum Precipitation

Consistent with all future projections, the ensemble approach will be used. The same methodology for current climate in Section 2.5 is applied to the modelled baseline and future periods. The percentage change in PMP is then estimated, while the distribution of percentage changes across the multi-model ensemble is then provided using a set of percentiles.

3.6 Future Extreme Precipitation Statistics

Consistent with all future projections, the ensemble approach will be used to describe the distribution of projected changes in extreme precipitation statistics. Methodology relating to projections of future extreme precipitation are provided in the subsections below.

The Quantile Distribution Mapping (QDM) method is used to calculate projected changes in precipitation statistics in the form of Intensity-Duration-Frequency (IDF) curves. The method is based on the Equidistant Quantile Matching algorithm (Li and Wood 2010; Piani et al. 2010; Hassanzadeh et al., 2014; Srivastav et al., 2014; Cannon et al. 2015; Schardong et al. 2018). First, the model baseline, and modelled future annual maximum precipitation datasets are fitted to a statistical distribution for each event duration of interest. Next, rainfall depth quantiles for a set of return periods are extracted from the distributions using the inverse cumulative distribution function. Projected changes in climate (Δ_m) are calculated between the quantiles of the model baseline ($IDF_{baseline}$) and future (IDF_{future}) distributions for each duration and return period of the IDF curve. This is done using the following equation for a given duration i ,

$$\Delta_{mi} = \frac{IDF_{futurei}}{IDF_{baselinei}} - 1 \quad \text{Equation 8}$$

3.7 Future Extreme Combined Rainfall and Snowmelt

Projected changes in extreme combined rainfall and snowmelt are estimated by first calculating these climate variables using the statistically downscaled precipitation, minimum temperature, and maximum temperature from the multi-model ensemble (same approach as Section 2.7). The QDM method is then used to calculate projected changes in extreme snow statistics in the form of IDF curves following the same methodology for extreme precipitation in Section 3.6.

3.8 Future Climate Inputs for Probable Maximum Flood Estimation

For the spring period, projected changes in the climate inputs for PMF estimation are assessed by combining projected absolute values of PMP and 100-year extreme snowmelt for the baseline and future periods. For the baseline and future periods climate inputs for PMF estimation are calculated as percentage changes. For the annual period, the projected change in climate inputs is equivalent to that of PMP.

3.9 Future Potential Evapotranspiration

Projected changes in potential evapotranspiration are estimated by first calculating potential evapotranspiration using the statistically downscaled minimum and maximum temperature projections from the multi-model ensemble (same approach as Section 2.8). Annual totals are calculated and average across years, while monthly totals are taken and averaged across calendar months. The percentage change for the annual and monthly values between the model baseline and future time periods is calculated for each member of the multi-model ensemble. The distribution of percentage changes across the multi-model ensemble is then provided using a set of percentiles.

3.10 Future Wind Speed

Qualitative assessment of future projected changes of wind speed is provided using published scientific literature. A high degree of uncertainty is assigned to these assessments as site specific information is not available.

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Appendix C

Additional Future Climate Statistics



Appendix C - Additional Climate Projection Statistics

Great Bear Mine Site: Detailed Climate Dataset (2023)

The nature of the work undertaken is stochastic with substantial inherent uncertainty around any given data points. The user acknowledges that the uncertainty associated with any projections or forecasts is increased with how far into the future the projected period extends and is subject to future developments or intervening acts which may manifest in the interim period.

See Report Section 3.0 for guidance on how to use the data provided in this Appendix

Variable	Projected Changes in Monthly and Annual Total Precipitation
Units	%
Area	Nearest Grid Cell to Great Bear Mine
Baseline	Projected Changes Calculated from Modelled Baseline Period (1991-2020)

Projected Changes in Monthly and Annual Total Precipitation

Period	Month	Minimum	1%	5%	10%	25%	50%	75%	90%	95%	99%	Maximum	Mean	Standard Deviation
2050s	1	-17.9%	-14.9%	-5.4%	-3.2%	1.7%	10.1%	18.0%	25.0%	29.9%	35.1%	35.4%	10.4%	11.5%
	2	-16.6%	-14.0%	-10.9%	-8.4%	-2.9%	8.8%	20.5%	33.2%	38.0%	43.3%	48.2%	9.8%	15.2%
	3	-17.6%	-16.9%	-7.2%	-5.5%	3.5%	14.4%	26.3%	36.3%	40.5%	55.6%	58.4%	15.5%	16.5%
	4	-22.5%	-21.3%	-16.5%	-13.5%	-1.3%	6.5%	21.9%	28.8%	36.5%	46.2%	51.4%	9.4%	16.2%
	5	-10.8%	-8.7%	-5.7%	-3.5%	2.7%	10.6%	18.4%	25.8%	34.3%	41.0%	49.4%	11.4%	11.9%
	6	-26.8%	-26.3%	-20.4%	-15.8%	-7.1%	2.2%	9.6%	17.7%	25.3%	28.6%	32.1%	1.8%	13.2%
	7	-39.8%	-36.7%	-30.5%	-23.3%	-16.8%	-5.0%	5.3%	13.4%	16.0%	24.8%	26.5%	-5.6%	14.7%
	8	-33.7%	-29.4%	-25.7%	-20.1%	-13.8%	-7.7%	5.7%	12.8%	17.3%	30.4%	49.4%	-4.8%	14.4%
	9	-27.8%	-26.9%	-20.8%	-16.5%	-7.6%	2.2%	12.7%	20.9%	23.4%	34.3%	36.1%	2.1%	14.3%
	10	-24.8%	-24.2%	-17.3%	-15.3%	-1.2%	6.6%	17.1%	25.2%	30.8%	42.3%	63.7%	7.0%	15.6%
	11	-20.3%	-17.7%	-7.7%	-3.4%	1.5%	10.0%	22.8%	34.4%	44.4%	45.9%	48.7%	12.7%	15.5%
	12	-15.3%	-11.4%	-8.1%	-3.3%	3.5%	11.0%	22.0%	29.6%	36.0%	50.3%	50.9%	13.4%	13.7%
	Annual	-8.2%	-6.4%	-5.3%	-4.3%	-0.7%	3.9%	9.7%	11.1%	13.1%	14.7%	17.9%	4.1%	5.9%
2080s	1	-14.4%	-12.3%	-7.6%	0.4%	7.7%	20.4%	30.4%	41.1%	51.0%	59.1%	62.6%	19.5%	17.0%
	2	-13.9%	-13.4%	-8.2%	-2.8%	5.4%	12.5%	29.0%	37.3%	44.2%	73.2%	81.5%	16.6%	18.0%
	3	-10.6%	-8.6%	-4.3%	1.2%	8.6%	20.9%	31.4%	45.1%	50.1%	75.1%	82.5%	22.0%	18.5%
	4	-22.6%	-20.6%	-13.5%	-7.3%	-0.2%	16.8%	28.9%	40.3%	56.9%	69.3%	80.7%	16.4%	21.3%
	5	-17.4%	-10.9%	-3.9%	-0.2%	7.0%	15.4%	27.5%	43.4%	47.4%	65.0%	65.5%	18.1%	16.8%
	6	-41.3%	-41.0%	-31.3%	-16.9%	-5.5%	3.4%	13.2%	23.9%	32.7%	39.8%	41.8%	3.3%	17.9%
	7	-48.8%	-45.0%	-37.3%	-32.7%	-19.7%	-7.3%	4.6%	15.3%	20.4%	25.0%	25.8%	-8.3%	17.6%
	8	-53.0%	-50.5%	-35.5%	-30.4%	-15.8%	-6.3%	4.1%	14.8%	18.7%	28.4%	32.5%	-7.0%	17.6%
	9	-38.7%	-35.2%	-22.8%	-17.4%	-6.9%	2.5%	8.0%	16.9%	32.1%	35.4%	37.6%	0.9%	15.6%
	10	-20.1%	-17.1%	-12.3%	-10.7%	1.6%	13.2%	25.2%	32.4%	47.4%	58.7%	68.8%	13.6%	18.1%
	11	-16.5%	-13.4%	-6.7%	-4.8%	3.2%	13.8%	32.8%	52.8%	59.1%	67.7%	68.0%	18.6%	20.8%
	12	-10.3%	-7.6%	-4.2%	-1.5%	7.3%	17.1%	30.4%	43.1%	49.0%	59.1%	66.6%	19.5%	17.0%
	Annual	-8.7%	-7.6%	-4.3%	-1.3%	2.5%	6.4%	10.2%	15.7%	21.6%	25.6%	27.6%	6.8%	7.4%

Variable	Projected Changes in Monthly and Annual Mean Temperature
Units	°C
Area	Nearest Grid Cell to Great Bear Mine
Baseline	Projected Changes Calculated from Modelled Baseline Period (1991-2020)

Projected Changes in Monthly and Annual Total Precipitation

Period	Month	Minimum	1%	5%	10%	25%	50%	75%	90%	95%	99%	Maximum	Mean	Standard Deviation
2050s	1	0.5	0.8	1.2	1.6	2.3	3.1	4.0	5.1	6.1	6.6	6.9	3.3	1.4
	2	-0.3	-0.2	0.6	1.0	1.7	2.6	3.3	4.3	5.1	6.3	6.7	2.6	1.4
	3	0.3	0.4	0.8	1.0	1.5	2.2	2.7	3.4	3.9	4.9	5.4	2.2	1.0
	4	0.0	0.2	0.7	0.9	1.7	2.3	2.8	3.3	3.5	4.5	4.9	2.3	0.9
	5	0.4	0.5	0.8	1.0	1.6	2.4	2.8	3.2	3.7	4.6	4.6	2.3	0.9
	6	-0.1	0.1	0.9	1.0	1.4	2.0	2.8	3.6	4.5	5.1	5.5	2.2	1.1
	7	0.1	0.2	0.8	1.3	1.8	2.4	3.2	4.2	4.7	5.3	6.2	2.6	1.2
	8	0.7	0.7	1.0	1.3	1.9	2.6	3.4	4.2	4.7	6.1	6.8	2.7	1.2
	9	0.2	0.3	0.6	1.1	1.7	2.5	3.3	4.6	5.0	5.9	7.8	2.6	1.4
	10	0.6	0.7	1.0	1.2	1.7	2.4	3.1	3.9	4.2	5.7	6.8	2.5	1.1
	11	0.6	0.7	0.9	1.3	1.8	2.7	3.4	4.4	4.8	6.6	7.0	2.7	1.3
	12	0.1	0.7	1.4	1.7	2.6	3.4	4.4	6.2	6.5	7.5	9.3	3.6	1.6
	Annual	0.8	1.0	1.4	1.5	1.9	2.5	3.1	3.8	4.8	5.2	6.0	2.6	1.0
2080s	1	-0.1	0.2	1.2	1.5	2.9	4.9	6.9	8.5	10.2	12.8	13.2	5.1	2.9
	2	-0.4	-0.4	0.8	1.1	2.1	3.5	5.5	7.6	8.8	9.8	10.4	4.0	2.5
	3	-0.4	0.1	0.8	1.1	1.7	3.0	4.9	6.5	6.9	8.4	8.9	3.4	2.1
	4	0.3	0.3	1.0	1.3	2.0	3.1	4.5	6.3	6.5	8.2	9.2	3.4	1.9
	5	0.5	0.6	1.1	1.3	1.9	3.1	4.3	5.8	6.4	7.5	8.3	3.3	1.7
	6	-0.2	0.4	0.9	1.0	1.9	3.1	4.3	6.2	7.2	8.7	9.2	3.4	2.0
	7	0.2	0.4	0.7	1.3	2.1	3.4	5.0	7.0	8.2	9.7	10.3	3.8	2.3
	8	0.0	0.6	0.9	1.3	2.4	3.7	5.6	7.1	8.8	10.1	11.2	4.1	2.4
	9	0.2	0.4	1.1	1.4	2.2	3.5	5.8	6.8	9.2	10.3	11.2	4.1	2.4
	10	0.2	0.4	1.1	1.3	1.8	3.2	4.8	6.7	8.2	9.6	10.0	3.7	2.2
	11	-0.2	0.5	1.2	1.5	2.3	3.8	5.2	6.7	7.9	10.8	11.2	4.0	2.2
	12	1.2	1.4	1.7	2.0	3.1	5.0	7.3	9.6	10.5	12.9	15.1	5.4	2.9
	Annual	0.5	0.9	1.2	1.5	2.3	3.4	5.4	6.5	8.1	9.5	10.6	4.0	2.2

Variable	Projected Changes in Monthly and Annual Potential Evapotranspiration
Units	%
Area	Nearest Grid Cell to Great Bear Mine
Baseline	Projected Changes Calculated from Modelled Baseline Period (1991-2020)

Projected Changes in Monthly and Annual Total Precipitation

Period	Month	Minimum	1%	5%	10%	25%	50%	75%	90%	95%	99%	Maximum	Mean	Standard Deviation
2050s	1	2.8%	4.2%	10.9%	20.3%	31.9%	46.2%	64.7%	83.8%	97.1%	116.6%	119.6%	48.9%	25.7%
	2	-7.5%	-6.5%	2.1%	10.4%	19.6%	29.9%	42.7%	58.4%	61.8%	80.3%	85.4%	31.9%	19.1%
	3	-3.6%	0.9%	3.6%	5.5%	9.7%	14.5%	21.0%	29.2%	33.5%	35.6%	36.9%	15.9%	8.8%
	4	1.0%	1.4%	3.5%	5.1%	7.7%	11.2%	15.2%	19.0%	23.9%	25.8%	26.6%	11.8%	5.8%
	5	-2.7%	-1.0%	1.2%	2.2%	4.3%	8.6%	11.9%	14.3%	16.1%	20.0%	23.3%	8.4%	5.1%
	6	-3.6%	-1.4%	1.3%	2.3%	4.5%	6.3%	10.8%	14.8%	18.0%	20.5%	21.0%	7.5%	5.1%
	7	-3.6%	-3.1%	0.4%	2.0%	5.2%	8.2%	11.8%	16.1%	17.6%	20.5%	24.3%	8.6%	5.4%
	8	-0.7%	0.6%	2.0%	2.6%	5.7%	9.4%	13.3%	17.3%	18.1%	25.3%	26.1%	9.8%	5.7%
	9	-2.3%	-1.3%	0.8%	3.2%	6.4%	10.5%	14.5%	18.5%	23.1%	28.0%	34.1%	10.9%	6.6%
	10	4.1%	4.2%	5.3%	5.9%	8.6%	12.5%	16.1%	20.9%	23.1%	29.8%	37.3%	13.0%	6.1%
	11	1.3%	1.3%	2.5%	6.8%	11.4%	17.0%	21.7%	27.6%	29.1%	39.1%	45.8%	16.9%	8.4%
	12	0.9%	3.2%	7.8%	14.5%	24.3%	35.1%	43.1%	60.0%	66.8%	78.2%	83.5%	35.8%	17.3%
	Annual	-0.2%	1.3%	2.3%	4.9%	6.9%	9.7%	12.9%	15.9%	19.1%	21.4%	25.1%	10.0%	4.8%
2080s	1	-3.1%	0.7%	13.7%	20.2%	43.4%	74.5%	115.5%	146.7%	162.1%	198.7%	227.8%	80.4%	49.1%
	2	-10.3%	-9.6%	4.7%	7.8%	24.7%	43.0%	72.3%	99.2%	112.1%	124.8%	144.9%	49.3%	34.3%
	3	-12.1%	-6.9%	5.4%	6.5%	12.5%	20.6%	32.5%	41.7%	54.6%	64.6%	73.0%	23.8%	15.8%
	4	-2.4%	-0.7%	3.0%	4.9%	10.9%	16.4%	23.9%	29.9%	33.6%	47.9%	57.8%	17.6%	10.5%
	5	-2.7%	-0.5%	2.1%	2.9%	5.7%	11.3%	15.3%	23.3%	26.7%	33.3%	35.1%	11.9%	7.9%
	6	-1.8%	-1.0%	1.5%	2.0%	3.9%	9.3%	15.1%	23.5%	27.4%	36.4%	36.6%	11.1%	8.6%
	7	-1.6%	-1.5%	0.4%	1.6%	6.8%	10.3%	18.1%	22.6%	27.7%	39.2%	40.3%	12.3%	9.0%
	8	-0.1%	0.6%	2.1%	3.7%	6.4%	12.8%	18.8%	27.9%	34.3%	42.6%	42.6%	14.1%	9.7%
	9	-1.7%	1.1%	3.8%	4.7%	8.9%	14.3%	21.7%	30.9%	34.1%	46.1%	47.6%	16.5%	10.5%
	10	-1.2%	0.1%	4.2%	5.8%	8.4%	16.4%	24.9%	31.9%	41.8%	48.1%	52.3%	18.0%	11.5%
	11	-2.9%	0.3%	6.9%	8.4%	15.8%	24.2%	33.1%	42.1%	46.4%	56.2%	68.7%	25.2%	13.6%
	12	12.6%	14.7%	16.5%	18.6%	28.4%	47.9%	73.2%	90.3%	104.0%	118.3%	135.0%	52.9%	28.3%
	Annual	0.5%	1.1%	2.1%	5.0%	8.4%	12.7%	20.9%	25.7%	31.3%	40.0%	42.1%	14.6%	9.0%

Variable	Probable Maximum Precipitation
Units	%
Area	Nearest Grid Cell to Mine site
Baseline	Projected changes calculated from model baseline (1991 - 2020)

Probable Maximum Precipitation for Select Durations

Period	Duration (days)	Minimum	1%	5%	10%	25%	50%	75%	90%	95%	99%	Maximum	Mean	Standard Deviation
2050s	1	-27.3%	-26.2%	-20.4%	-13.7%	1.1%	19.0%	40.7%	56.6%	64.9%	75.2%	96.7%	20.8%	26.7%
	2	-33.1%	-27.2%	-22.0%	-14.7%	-1.0%	15.7%	36.2%	63.1%	73.9%	98.6%	118.5%	20.5%	30.4%
	3	-29.1%	-29.1%	-21.2%	-11.8%	0.3%	14.7%	32.7%	50.1%	59.8%	85.9%	107.5%	16.8%	26.3%
2080s	1	-29.0%	-27.8%	-17.6%	-14.5%	4.4%	23.4%	42.8%	58.6%	72.4%	96.6%	104.9%	24.2%	28.7%
	2	-35.4%	-33.7%	-18.0%	-10.4%	2.1%	21.2%	38.6%	67.2%	80.1%	94.1%	106.1%	23.3%	29.9%
	3	-39.1%	-32.5%	-24.9%	-14.8%	-0.3%	22.8%	37.1%	55.9%	67.1%	90.5%	128.8%	20.9%	28.7%

Variable	Extreme Precipitation Statistics
Units	%
Area	Nearest Grid Cell to Mine site
Baseline	Projected changes calculated from model baseline (1991 - 2020)

Extreme Rainfall Statistics for Selected Return Periods and Durations

Period	Return Period (years)	Duration (days)	Minimum	1%	5%	10%	25%	50%	75%	90%	95%	99%	Maximum	Mean	Standard Deviation
2050s	2	1	-21.8%	-15.8%	-9.9%	-6.4%	2.2%	7.0%	13.9%	20.3%	25.0%	34.1%	34.1%	7.4%	10.7%
2050s	2	2	-18.8%	-11.9%	-7.2%	-4.2%	2.6%	6.2%	11.8%	19.6%	22.2%	29.2%	29.6%	7.3%	9.4%
2050s	2	3	-16.7%	-11.8%	-8.3%	-4.8%	1.9%	7.1%	12.5%	18.1%	23.5%	29.4%	30.8%	7.6%	9.4%
2050s	2	4	-18.5%	-11.1%	-7.5%	-5.4%	1.3%	6.1%	12.5%	17.8%	21.8%	27.7%	30.6%	6.6%	9.1%
2050s	2	5	-17.4%	-12.8%	-8.3%	-5.2%	0.2%	5.7%	11.7%	17.2%	20.0%	26.0%	29.1%	5.9%	8.9%
2050s	2	6	-19.1%	-12.6%	-8.7%	-5.3%	-0.3%	6.0%	10.7%	16.3%	19.8%	25.4%	26.9%	5.6%	8.6%
2050s	2	7	-20.4%	-13.4%	-9.9%	-4.5%	-0.2%	5.5%	10.8%	16.7%	20.6%	24.7%	27.9%	5.4%	8.8%
2050s	2	10	-20.4%	-15.6%	-8.0%	-5.4%	-1.3%	4.3%	10.6%	15.7%	17.8%	21.5%	22.3%	4.5%	8.4%
2050s	2	20	-17.7%	-15.4%	-10.3%	-8.5%	-4.2%	3.3%	9.9%	12.9%	15.6%	19.7%	22.4%	2.8%	8.6%
2050s	2	30	-18.9%	-17.6%	-10.7%	-7.9%	-4.2%	3.1%	9.5%	11.9%	13.5%	18.7%	20.5%	2.4%	8.5%
2050s	2	50	-18.0%	-15.2%	-11.6%	-9.9%	-5.6%	1.3%	8.9%	11.6%	13.9%	17.4%	18.5%	1.4%	8.3%
2050s	2	75	-17.0%	-16.1%	-12.9%	-10.3%	-5.5%	2.2%	6.7%	10.3%	12.0%	14.9%	16.1%	0.6%	7.9%
2050s	2	90	-16.4%	-16.2%	-12.9%	-10.2%	-5.8%	1.7%	6.8%	11.1%	12.7%	16.5%	16.9%	0.5%	8.1%
2050s	2	120	-15.8%	-13.4%	-11.2%	-10.6%	-5.6%	0.6%	7.3%	12.0%	12.3%	15.8%	15.8%	0.6%	8.1%
2050s	5	1	-20.7%	-16.6%	-13.1%	-8.3%	3.2%	9.4%	18.0%	25.2%	27.3%	37.2%	44.0%	9.9%	12.7%
2050s	5	2	-16.0%	-15.6%	-8.9%	-3.6%	2.5%	8.4%	17.1%	24.1%	29.8%	34.7%	35.5%	9.3%	11.3%
2050s	5	3	-16.0%	-14.1%	-7.8%	-6.3%	3.2%	8.5%	15.2%	22.8%	27.0%	31.9%	35.1%	8.9%	10.9%
2050s	5	4	-17.1%	-12.5%	-7.8%	-5.6%	1.9%	7.9%	16.0%	22.1%	24.8%	30.8%	33.5%	8.3%	10.5%
2050s	5	5	-16.3%	-11.4%	-6.4%	-5.7%	1.1%	7.3%	15.8%	20.2%	26.1%	29.1%	29.8%	7.7%	10.2%
2050s	5	6	-18.4%	-12.1%	-7.4%	-5.7%	-0.4%	7.0%	15.0%	18.7%	25.2%	28.0%	28.6%	7.2%	10.0%
2050s	5	7	-18.7%	-12.3%	-7.8%	-6.4%	-1.6%	7.2%	13.4%	19.9%	23.5%	27.7%	28.2%	6.9%	10.1%
2050s	5	10	-19.3%	-16.1%	-10.4%	-5.8%	-1.6%	5.6%	10.8%	17.9%	20.5%	24.1%	25.7%	5.2%	9.4%
2050s	5	20	-19.2%	-17.4%	-11.8%	-8.1%	-3.9%	3.5%	10.9%	17.1%	19.5%	23.2%	24.2%	3.3%	9.8%
2050s	5	30	-18.4%	-17.7%	-11.6%	-9.4%	-3.4%	2.8%	10.0%	13.8%	17.3%	20.5%	20.8%	2.8%	9.0%
2050s	5	50	-17.2%	-16.5%	-12.0%	-10.0%	-3.5%	1.9%	8.2%	12.8%	14.4%	17.0%	18.6%	1.7%	8.4%
2050s	5	75	-16.4%	-16.3%	-12.6%	-10.4%	-4.9%	2.2%	7.6%	11.2%	14.1%	16.5%	19.8%	1.2%	8.3%
2050s	5	90	-17.5%	-15.7%	-12.5%	-10.1%	-5.8%	2.2%	7.0%	9.8%	14.7%	17.2%	19.6%	1.0%	8.3%
2050s	5	120	-15.2%	-15.1%	-11.3%	-10.2%	-5.2%	2.4%	6.6%	10.9%	15.0%	17.9%	17.9%	1.1%	8.4%
2050s	10	1	-20.2%	-17.9%	-15.0%	-8.1%	2.6%	12.8%	19.9%	27.7%	30.9%	42.7%	51.5%	11.2%	14.2%
2050s	10	2	-18.7%	-15.0%	-11.3%	-5.0%	1.6%	9.5%	17.5%	25.2%	33.9%	40.3%	43.3%	10.4%	13.0%
2050s	10	3	-15.7%	-15.5%	-10.9%	-6.9%	2.6%	8.4%	16.6%	26.4%	28.6%	36.7%	41.6%	9.6%	12.2%
2050s	10	4	-16.4%	-14.3%	-9.0%	-6.7%	0.8%	9.6%	16.7%	24.5%	28.4%	34.7%	39.0%	9.1%	11.7%
2050s	10	5	-15.8%	-12.8%	-7.4%	-6.0%	0.0%	8.3%	16.5%	23.6%	26.7%	33.4%	34.5%	8.7%	11.4%
2050s	10	6	-18.1%	-14.8%	-8.8%	-7.2%	-1.3%	8.6%	16.1%	22.4%	25.9%	31.7%	33.0%	8.0%	11.2%
2050s	10	7	-17.9%	-14.8%	-8.9%	-7.0%	-0.3%	9.0%	14.1%	22.1%	26.5%	30.4%	31.9%	7.7%	11.2%
2050s	10	10	-18.7%	-16.3%	-13.1%	-7.4%	-1.6%	6.3%	11.7%	18.8%	22.1%	27.6%	29.3%	5.5%	10.3%
2050s	10	20	-21.2%	-17.7%	-13.7%	-8.6%	-4.4%	3.4%	11.3%	16.7%	22.5%	26.8%	28.5%	3.5%	10.8%
2050s	10	30	-18.1%	-17.8%	-11.7%	-8.9%	-3.9%	3.0%	10.9%	14.0%	19.7%	22.3%	22.5%	3.1%	9.6%
2050s	10	50	-18.5%	-16.1%	-13.1%	-9.5%	-4.1%	2.2%	7.6%	13.6%	17.1%	18.8%	19.4%	1.9%	8.8%
2050s	10	75	-17.1%	-16.7%	-12.8%	-10.7%	-4.6%	2.2%	7.8%	12.4%	16.8%	19.6%	21.8%	1.6%	8.9%
2050s	10	90	-18.2%	-16.3%	-12.6%	-10.0%	-5.0%	2.4%	6.8%	10.3%	16.5%	21.0%	21.0%	1.4%	8.8%
2050s	10	120	-17.3%	-16.6%	-11.4%	-10.1%	-5.1%	2.8%	6.7%	12.3%	18.4%	20.8%	22.7%	1.5%	8.9%
2050s	25	1	-19.7%	-19.3%	-16.5%	-7.4%	1.9%	14.3%	22.5%	31.4%	34.2%	49.4%	58.9%	12.4%	15.8%
2050s	25	2	-21.2%	-16.3%	-12.4%	-6.1%	1.0%	10.6%	19.5%	30.3%	38.1%	45.9%	51.0%	11.4%	14.8%
2050s	25	3	-17.1%	-16.1%	-14.1%	-7.1%	2.3%	9.6%	17.8%	29.2%	33.7%	41.4%	48.1%	10.3%	13.7%
2050s	25	4	-16.1%	-15.8%	-11.7%	-8.0%	1.4%	9.6%	17.4%	27.9%	31.2%	39.2%	44.4%	9.9%	13.1%
2050s	25	5	-15.2%	-15.0%	-9.1%	-6.1%	0.0%	8.9%	19.5%	25.9%	30.2%	37.7%	39.1%	9.6%	12.8%
2050s	25	6	-17.8%	-17.3%	-11.0%	-7.5%	-1.0%	10.7%	16.9%	24.2%	28.7%	35.8%	37.2%	8.8%	12.6%

Extreme Rainfall Statistics for Selected Return Periods and Durations

Period	Return Period (years)	Duration (days)	Minimum	1%	5%	10%	25%	50%	75%	90%	95%	99%	Maximum	Mean	Standard Deviation
2050s	25	7	-17.2%	-17.0%	-11.2%	-7.7%	-1.4%	10.7%	15.2%	25.1%	29.3%	35.3%	35.6%	8.5%	12.5%
2050s	25	10	-18.2%	-17.5%	-14.7%	-9.3%	-1.2%	7.0%	11.5%	19.3%	24.6%	32.6%	32.8%	5.9%	11.3%
2050s	25	20	-23.2%	-20.1%	-15.8%	-9.6%	-5.1%	2.6%	12.2%	18.3%	26.3%	30.5%	32.7%	3.8%	11.9%
2050s	25	30	-17.9%	-17.8%	-13.0%	-8.9%	-4.0%	3.2%	10.6%	16.2%	22.0%	24.5%	26.3%	3.4%	10.4%
2050s	25	50	-19.9%	-17.8%	-14.1%	-9.6%	-4.4%	2.2%	7.6%	15.0%	18.7%	20.7%	22.1%	2.1%	9.5%
2050s	25	75	-17.8%	-17.1%	-14.2%	-10.8%	-3.6%	1.8%	8.7%	15.2%	18.6%	23.0%	24.0%	2.0%	9.7%
2050s	25	90	-18.8%	-18.3%	-14.4%	-10.0%	-4.4%	1.7%	7.3%	11.3%	19.4%	24.9%	26.1%	1.7%	9.6%
2050s	25	120	-19.3%	-18.0%	-13.0%	-10.1%	-5.1%	2.6%	6.9%	13.9%	19.9%	24.1%	27.8%	1.8%	9.7%
2050s	50	1	-20.2%	-20.0%	-17.4%	-7.2%	1.5%	14.6%	23.7%	32.0%	36.9%	53.6%	63.2%	13.1%	16.9%
2050s	50	2	-22.7%	-17.4%	-12.7%	-7.0%	0.5%	10.4%	20.8%	31.7%	40.9%	49.3%	55.7%	12.0%	16.0%
2050s	50	3	-18.0%	-17.7%	-15.3%	-7.6%	2.1%	9.5%	18.7%	31.0%	35.3%	44.2%	52.0%	10.7%	14.7%
2050s	50	4	-17.5%	-15.9%	-12.9%	-8.7%	1.0%	10.3%	17.6%	29.7%	33.6%	41.9%	47.6%	10.4%	14.0%
2050s	50	5	-16.6%	-15.3%	-10.2%	-6.5%	-0.2%	9.3%	20.6%	27.9%	32.8%	40.2%	41.9%	10.2%	13.7%
2050s	50	6	-19.0%	-18.0%	-12.0%	-7.5%	-1.1%	10.7%	17.6%	26.0%	31.6%	38.3%	39.8%	9.3%	13.5%
2050s	50	7	-18.7%	-17.5%	-12.3%	-8.3%	-1.9%	11.4%	16.0%	26.5%	31.4%	38.0%	38.7%	9.0%	13.4%
2050s	50	10	-19.1%	-18.2%	-15.1%	-10.5%	-1.1%	7.0%	12.4%	19.9%	26.5%	35.2%	35.8%	6.1%	11.9%
2050s	50	20	-24.3%	-21.4%	-16.0%	-10.8%	-4.8%	1.8%	12.7%	19.9%	28.4%	32.9%	35.2%	4.0%	12.7%
2050s	50	30	-17.9%	-17.8%	-13.9%	-9.2%	-4.1%	3.2%	10.9%	17.3%	23.3%	26.7%	28.7%	3.6%	10.9%
2050s	50	50	-20.7%	-18.8%	-14.0%	-9.6%	-4.1%	1.7%	8.4%	15.9%	19.4%	22.2%	24.3%	2.2%	10.0%
2050s	50	75	-18.2%	-18.1%	-15.7%	-10.6%	-4.3%	1.9%	9.0%	16.5%	20.6%	25.2%	25.4%	2.2%	10.3%
2050s	50	90	-19.7%	-19.3%	-15.7%	-10.0%	-5.1%	1.6%	7.8%	12.2%	21.2%	27.8%	29.3%	2.0%	10.1%
2050s	50	120	-20.6%	-18.8%	-13.2%	-10.4%	-4.8%	2.3%	7.5%	14.9%	20.7%	26.8%	31.1%	2.0%	10.3%
2050s	100	1	-21.1%	-21.1%	-17.8%	-7.5%	1.9%	15.2%	26.0%	33.5%	39.1%	57.1%	66.9%	13.7%	17.8%
2050s	100	2	-23.8%	-18.3%	-14.2%	-8.4%	0.4%	10.7%	21.9%	33.9%	43.2%	52.1%	59.7%	12.5%	17.0%
2050s	100	3	-19.5%	-19.0%	-15.4%	-7.8%	1.8%	9.8%	19.8%	32.5%	36.9%	46.6%	55.2%	11.0%	15.5%
2050s	100	4	-18.6%	-15.9%	-13.7%	-9.1%	1.1%	10.7%	18.3%	31.2%	35.0%	44.1%	50.2%	10.8%	14.7%
2050s	100	5	-18.0%	-15.4%	-11.1%	-7.0%	-0.2%	9.6%	21.5%	28.7%	34.4%	42.3%	44.2%	10.7%	14.6%
2050s	100	6	-20.6%	-18.2%	-12.6%	-7.8%	-1.6%	10.4%	18.4%	26.7%	34.1%	40.3%	41.9%	9.7%	14.2%
2050s	100	7	-20.1%	-19.0%	-13.0%	-9.1%	-1.4%	11.9%	16.6%	27.3%	33.0%	40.1%	41.7%	9.4%	14.2%
2050s	100	10	-20.6%	-18.3%	-15.4%	-11.3%	-1.2%	7.1%	13.1%	20.6%	28.1%	37.2%	38.5%	6.3%	12.5%
2050s	100	20	-25.2%	-22.5%	-15.9%	-11.9%	-4.6%	1.9%	13.1%	21.2%	30.2%	34.9%	37.4%	4.2%	13.3%
2050s	100	30	-18.7%	-18.4%	-14.6%	-9.8%	-4.2%	3.6%	11.4%	18.7%	24.3%	28.6%	30.8%	3.8%	11.4%
2050s	100	50	-21.4%	-19.6%	-13.7%	-10.2%	-4.5%	2.2%	9.0%	16.7%	20.2%	23.8%	26.3%	2.4%	10.4%
2050s	100	75	-19.0%	-18.7%	-16.7%	-10.4%	-4.2%	2.2%	9.3%	17.7%	22.4%	26.7%	27.2%	2.5%	10.8%
2050s	100	90	-20.9%	-19.8%	-16.1%	-10.0%	-4.1%	1.6%	8.3%	13.3%	22.7%	30.5%	32.1%	2.2%	10.7%
2050s	100	120	-21.7%	-19.5%	-13.4%	-10.6%	-4.5%	2.2%	7.6%	15.7%	21.4%	29.4%	34.1%	2.3%	10.8%
2050s	200	1	-22.0%	-21.9%	-18.2%	-7.6%	1.7%	15.3%	27.5%	35.3%	41.0%	60.1%	70.0%	14.2%	18.6%
2050s	200	2	-24.8%	-19.0%	-15.4%	-9.3%	0.2%	10.6%	23.5%	35.8%	45.2%	54.5%	63.1%	13.0%	17.9%
2050s	200	3	-21.1%	-19.8%	-15.5%	-8.6%	1.5%	10.1%	20.8%	33.8%	38.1%	48.5%	58.0%	11.3%	16.3%
2050s	200	4	-19.5%	-17.1%	-14.4%	-9.4%	1.7%	10.8%	19.6%	32.2%	36.0%	45.9%	52.5%	11.1%	15.4%
2050s	200	5	-19.1%	-15.5%	-11.7%	-7.8%	-0.3%	9.9%	22.2%	30.0%	35.7%	44.0%	46.1%	11.1%	15.3%
2050s	200	6	-21.9%	-18.4%	-13.1%	-8.2%	-2.1%	10.9%	19.5%	27.6%	36.2%	42.1%	43.7%	10.1%	14.9%
2050s	200	7	-21.3%	-20.3%	-13.6%	-9.9%	-1.2%	12.1%	17.3%	27.8%	34.4%	41.9%	44.2%	9.7%	14.8%
2050s	200	10	-21.8%	-18.7%	-15.6%	-11.9%	-1.1%	7.1%	13.5%	21.1%	29.5%	38.9%	40.9%	6.5%	13.0%
2050s	200	20	-26.0%	-23.5%	-15.8%	-12.8%	-4.5%	2.8%	13.8%	22.3%	31.7%	36.6%	39.3%	4.4%	13.9%
2050s	200	30	-19.5%	-19.2%	-15.2%	-10.3%	-4.4%	3.7%	11.9%	19.9%	25.0%	30.2%	32.6%	3.9%	11.9%
2050s	200	50	-21.9%	-20.3%	-14.1%	-11.2%	-4.2%	2.9%	9.3%	17.3%	21.0%	25.1%	28.0%	2.5%	10.9%
2050s	200	75	-19.8%	-19.1%	-17.3%	-10.2%	-4.0%	2.1%	9.4%	19.1%	23.9%	28.5%	29.1%	2.7%	11.3%
2050s	200	90	-22.0%	-20.3%	-16.4%	-10.0%	-4.5%	1.4%	8.9%	14.3%	24.1%	32.9%	34.7%	2.4%	11.2%
2050s	200	120	-22.6%	-20.1%	-13.5%	-10.6%	-4.4%	1.9%	8.2%	16.5%	22.0%	31.8%	36.8%	2.4%	11.3%
2050s	500	1	-23.0%	-22.8%	-18.5%	-8.5%	1.4%	15.6%	29.1%	37.2%	43.2%	63.4%	73.5%	14.8%	19.5%
2050s	500	2	-25.9%	-19.9%	-16.7%	-9.3%	0.0%	10.6%	25.0%	38.2%	47.5%	57.3%	67.0%	13.5%	18.9%
2050s	500	3	-22.8%	-20.8%	-15.5%	-9.5%	1.1%	9.5%	21.9%	35.3%	39.3%	50.8%	61.1%	11.7%	17.1%
2050s	500	4	-20.5%	-18.4%	-14.6%	-9.5%	1.6%	10.9%	21.0%	33.6%	38.0%	48.4%	55.0%	11.6%	16.2%
2050s	500	5	-20.4%	-16.8%	-12.4%	-8.7%	-0.5%	10.3%	23.1%	31.5%	37.5%	46.4%	48.3%	11.6%	16.1%

Extreme Rainfall Statistics for Selected Return Periods and Durations

Period	Return Period (years)	Duration (days)	Minimum	1%	5%	10%	25%	50%	75%	90%	95%	99%	Maximum	Mean	Standard Deviation
2050s	500	6	-23.3%	-19.4%	-13.6%	-8.9%	-2.7%	11.6%	19.9%	29.2%	38.6%	44.0%	45.8%	10.5%	15.7%
2050s	500	7	-22.6%	-21.7%	-14.3%	-10.7%	-1.4%	12.9%	18.2%	29.3%	35.9%	43.9%	47.1%	10.1%	15.6%
2050s	500	10	-23.2%	-19.6%	-15.8%	-12.6%	-1.3%	7.2%	13.8%	22.0%	30.9%	40.9%	43.6%	6.7%	13.6%
2050s	500	20	-26.8%	-24.5%	-15.7%	-13.4%	-5.3%	3.2%	14.7%	23.3%	33.4%	38.7%	41.3%	4.5%	14.6%
2050s	500	30	-20.3%	-20.1%	-15.8%	-10.8%	-4.5%	4.0%	12.1%	21.3%	25.8%	32.1%	34.7%	4.1%	12.4%
2050s	500	50	-22.6%	-21.1%	-15.2%	-11.8%	-4.6%	3.3%	9.7%	17.9%	21.9%	26.7%	30.1%	2.6%	11.4%
2050s	500	75	-20.6%	-19.7%	-17.6%	-10.5%	-4.0%	1.9%	9.7%	20.5%	25.6%	30.7%	31.2%	2.9%	11.9%
2050s	500	90	-23.3%	-21.1%	-16.7%	-11.0%	-4.4%	1.4%	10.0%	15.4%	25.6%	35.7%	37.6%	2.6%	11.8%
2050s	500	120	-23.6%	-20.8%	-13.6%	-10.6%	-4.2%	1.5%	8.9%	17.3%	23.2%	34.5%	39.9%	2.7%	11.9%
2050s	1000	1	-23.7%	-23.3%	-18.7%	-9.0%	1.2%	15.8%	30.3%	38.4%	44.6%	65.5%	75.8%	15.2%	20.1%
2050s	1000	2	-26.6%	-20.5%	-17.2%	-9.6%	0.0%	11.1%	26.0%	39.7%	48.8%	59.1%	69.5%	13.8%	19.6%
2050s	1000	3	-23.9%	-21.4%	-15.6%	-9.9%	0.8%	9.2%	22.7%	36.2%	40.3%	52.2%	63.1%	11.9%	17.7%
2050s	1000	4	-21.2%	-19.2%	-14.6%	-9.9%	1.3%	10.9%	21.9%	34.8%	39.3%	50.2%	56.6%	11.8%	16.7%
2050s	1000	5	-21.1%	-17.6%	-12.9%	-9.2%	-0.7%	10.6%	23.4%	32.6%	38.8%	48.3%	49.8%	11.9%	16.7%
2050s	1000	6	-24.2%	-20.2%	-14.0%	-9.3%	-3.3%	11.5%	20.1%	30.2%	40.2%	45.3%	47.1%	10.8%	16.2%
2050s	1000	7	-23.4%	-22.6%	-14.6%	-11.1%	-1.6%	12.7%	19.1%	30.8%	36.9%	45.3%	48.9%	10.4%	16.1%
2050s	1000	10	-24.1%	-20.3%	-16.0%	-13.0%	-1.2%	7.2%	14.3%	22.9%	31.7%	42.2%	45.4%	6.8%	14.0%
2050s	1000	20	-27.4%	-25.1%	-15.7%	-14.0%	-5.2%	3.3%	14.9%	23.9%	34.5%	40.0%	42.7%	4.7%	15.0%
2050s	1000	30	-20.9%	-20.7%	-16.2%	-10.9%	-4.4%	4.1%	12.2%	22.2%	26.5%	33.4%	36.1%	4.2%	12.8%
2050s	1000	50	-23.0%	-21.6%	-16.4%	-12.1%	-4.7%	3.3%	9.8%	18.4%	22.5%	27.8%	31.5%	2.7%	11.7%
2050s	1000	75	-21.2%	-20.4%	-17.7%	-11.2%	-3.9%	1.8%	9.8%	21.4%	26.6%	32.2%	32.7%	3.1%	12.3%
2050s	1000	90	-24.1%	-21.7%	-16.9%	-11.4%	-4.2%	1.3%	10.6%	16.2%	26.6%	37.6%	39.6%	2.8%	12.2%
2050s	1000	120	-24.3%	-21.2%	-13.8%	-10.8%	-4.4%	1.9%	9.2%	18.2%	24.2%	36.3%	42.1%	2.8%	12.4%
2050s	2000	1	-24.3%	-23.8%	-18.9%	-9.5%	1.0%	16.0%	30.9%	39.3%	45.8%	67.4%	77.8%	15.5%	20.6%
2050s	2000	2	-27.2%	-20.9%	-17.6%	-10.1%	0.0%	11.7%	26.9%	41.1%	49.9%	60.7%	71.8%	14.1%	20.2%
2050s	2000	3	-24.8%	-22.1%	-15.6%	-10.3%	0.6%	9.3%	23.4%	37.0%	41.1%	53.5%	64.9%	12.1%	18.2%
2050s	2000	4	-21.7%	-20.0%	-14.9%	-10.3%	1.3%	11.0%	22.6%	35.9%	40.5%	51.9%	58.1%	12.0%	17.2%
2050s	2000	5	-21.8%	-18.4%	-13.3%	-9.6%	-0.9%	11.0%	23.7%	33.7%	40.0%	50.0%	51.0%	12.2%	17.2%
2050s	2000	6	-25.0%	-21.0%	-14.3%	-9.6%	-3.6%	11.5%	20.6%	31.1%	41.7%	46.4%	48.3%	11.0%	16.7%
2050s	2000	7	-24.1%	-23.3%	-14.8%	-11.5%	-1.8%	13.0%	19.9%	32.1%	38.3%	46.4%	50.6%	10.6%	16.6%
2050s	2000	10	-24.8%	-20.8%	-16.1%	-13.3%	-1.2%	7.3%	14.9%	23.7%	32.5%	43.3%	47.0%	6.9%	14.4%
2050s	2000	20	-27.9%	-25.7%	-16.0%	-14.3%	-5.1%	3.2%	14.8%	24.4%	35.5%	41.2%	43.9%	4.8%	15.4%
2050s	2000	30	-21.3%	-21.2%	-16.6%	-11.3%	-4.3%	4.2%	12.2%	22.9%	27.2%	34.5%	37.3%	4.4%	13.1%
2050s	2000	50	-23.4%	-22.0%	-17.2%	-12.1%	-4.9%	2.9%	9.9%	18.9%	23.0%	28.7%	32.7%	2.8%	12.0%
2050s	2000	75	-21.6%	-21.0%	-17.9%	-12.0%	-4.2%	1.5%	10.1%	22.3%	27.6%	33.5%	34.0%	3.2%	12.7%
2050s	2000	90	-24.8%	-22.2%	-17.0%	-11.4%	-4.1%	1.2%	11.0%	16.9%	27.2%	39.3%	41.4%	2.9%	12.6%
2050s	2000	120	-24.8%	-21.6%	-14.2%	-11.5%	-4.3%	1.8%	9.8%	18.9%	25.1%	38.0%	44.0%	3.0%	12.8%
2050s	10000	1	-25.4%	-24.7%	-19.4%	-10.4%	0.6%	16.3%	32.7%	40.8%	48.1%	71.0%	81.7%	16.1%	21.7%
2050s	10000	2	-28.3%	-22.1%	-18.3%	-11.0%	0.0%	12.2%	28.6%	43.7%	53.2%	63.7%	76.1%	14.7%	21.3%
2050s	10000	3	-26.6%	-23.6%	-15.6%	-10.8%	0.1%	9.9%	24.6%	38.6%	42.7%	56.0%	68.4%	12.5%	19.1%
2050s	10000	4	-22.8%	-21.4%	-15.5%	-11.1%	1.4%	11.1%	23.4%	37.6%	42.7%	55.1%	60.9%	12.5%	18.1%
2050s	10000	5	-23.1%	-19.7%	-13.6%	-10.1%	-1.1%	11.6%	24.4%	35.9%	42.2%	53.3%	53.4%	12.7%	18.1%
2050s	10000	6	-26.4%	-22.4%	-15.3%	-10.2%	-4.0%	12.1%	21.0%	33.0%	44.4%	48.6%	50.6%	11.5%	17.6%
2050s	10000	7	-25.4%	-24.7%	-15.3%	-12.2%	-2.3%	13.5%	21.4%	34.5%	41.0%	48.7%	53.8%	11.1%	17.5%
2050s	10000	10	-26.2%	-21.8%	-17.1%	-13.9%	-1.1%	7.4%	15.1%	25.2%	34.0%	45.5%	50.1%	7.2%	15.1%
2050s	10000	20	-28.8%	-26.7%	-17.2%	-14.7%	-4.9%	3.1%	14.6%	25.8%	37.5%	43.6%	46.3%	5.0%	16.2%
2050s	10000	30	-22.2%	-22.2%	-17.1%	-12.1%	-4.3%	4.3%	12.4%	24.0%	29.3%	36.8%	39.8%	4.6%	13.7%
2050s	10000	50	-24.1%	-22.9%	-18.1%	-11.8%	-5.7%	2.5%	10.3%	19.9%	24.2%	30.6%	35.2%	3.0%	12.7%
2050s	10000	75	-22.5%	-22.1%	-18.1%	-12.4%	-4.0%	1.3%	10.7%	23.9%	29.4%	36.2%	36.7%	3.6%	13.5%
2050s	10000	90	-26.1%	-23.2%	-17.2%	-11.3%	-4.2%	1.4%	12.0%	18.3%	28.4%	42.8%	45.1%	3.2%	13.3%
2050s	10000	120	-26.0%	-22.3%	-14.9%	-12.1%	-4.6%	1.7%	10.1%	20.3%	26.9%	41.4%	48.0%	3.3%	13.6%
2080s	2	1	-16.7%	-10.9%	-7.3%	-1.6%	3.2%	9.0%	15.0%	22.1%	29.2%	37.6%	40.5%	10.0%	10.6%
2080s	2	2	-10.6%	-8.5%	-2.7%	0.4%	4.3%	9.5%	16.1%	21.6%	24.2%	33.4%	36.4%	10.4%	9.1%
2080s	2	3	-11.8%	-7.4%	-2.6%	0.2%	3.3%	9.3%	15.8%	22.3%	23.8%	28.2%	34.7%	10.1%	8.8%
2080s	2	4	-11.8%	-7.7%	-2.6%	-0.7%	2.7%	8.6%	15.8%	21.8%	24.5%	26.9%	31.0%	9.7%	9.0%

Extreme Rainfall Statistics for Selected Return Periods and Durations

Period	Return Period (years)	Duration (days)	Minimum	1%	5%	10%	25%	50%	75%	90%	95%	99%	Maximum	Mean	Standard Deviation
2080s	2	5	-13.0%	-8.6%	-3.9%	-1.9%	2.8%	8.0%	15.9%	20.4%	22.2%	30.6%	31.5%	8.9%	9.0%
2080s	2	6	-11.2%	-8.0%	-4.9%	-3.9%	3.1%	7.1%	15.2%	19.8%	22.7%	28.6%	29.5%	8.4%	8.8%
2080s	2	7	-11.5%	-9.0%	-5.8%	-3.4%	2.9%	7.5%	14.6%	20.3%	22.1%	27.2%	30.4%	8.3%	8.9%
2080s	2	10	-12.6%	-10.4%	-6.0%	-2.8%	0.1%	6.1%	12.8%	18.4%	22.6%	25.6%	31.6%	7.1%	8.7%
2080s	2	20	-17.0%	-13.5%	-9.6%	-4.8%	-2.6%	4.9%	9.8%	16.9%	19.2%	24.9%	32.8%	4.8%	9.0%
2080s	2	30	-15.5%	-13.2%	-9.9%	-9.0%	-2.2%	3.8%	9.7%	15.7%	18.6%	24.9%	30.3%	4.1%	9.1%
2080s	2	50	-16.3%	-15.0%	-13.3%	-8.2%	-2.6%	1.2%	7.7%	15.4%	18.1%	23.4%	30.5%	2.5%	9.1%
2080s	2	75	-16.7%	-16.1%	-12.2%	-8.8%	-3.1%	1.4%	6.6%	13.1%	16.3%	19.7%	26.2%	1.8%	8.5%
2080s	2	90	-15.9%	-15.3%	-13.0%	-10.2%	-3.5%	0.2%	7.1%	13.0%	15.3%	20.8%	27.3%	1.6%	8.8%
2080s	2	120	-17.3%	-17.0%	-13.2%	-10.5%	-4.3%	0.7%	7.6%	13.5%	16.6%	21.2%	29.7%	1.6%	9.3%
2080s	5	1	-15.8%	-14.5%	-9.6%	-3.6%	6.4%	11.9%	22.1%	30.1%	33.4%	34.9%	36.8%	12.7%	12.4%
2080s	5	2	-13.7%	-11.0%	-5.0%	-1.7%	3.8%	12.4%	20.4%	28.2%	32.2%	35.5%	37.7%	12.5%	11.7%
2080s	5	3	-11.2%	-10.8%	-8.6%	-2.7%	4.1%	11.0%	20.4%	26.0%	28.9%	34.7%	35.3%	11.9%	11.3%
2080s	5	4	-12.1%	-11.4%	-6.9%	-4.8%	3.7%	12.0%	20.8%	25.7%	27.1%	31.8%	36.7%	11.5%	11.1%
2080s	5	5	-13.9%	-10.2%	-6.6%	-5.4%	4.1%	10.6%	19.7%	24.8%	28.9%	34.3%	36.0%	10.9%	11.2%
2080s	5	6	-11.5%	-11.5%	-8.5%	-6.3%	3.3%	10.3%	18.5%	24.9%	30.3%	32.8%	36.2%	10.2%	11.2%
2080s	5	7	-12.2%	-11.5%	-8.6%	-4.8%	1.7%	9.4%	18.5%	23.2%	27.8%	34.6%	35.2%	10.1%	11.1%
2080s	5	10	-12.3%	-12.2%	-8.1%	-5.7%	0.2%	7.3%	15.3%	20.2%	23.1%	33.5%	37.8%	7.9%	10.6%
2080s	5	20	-19.2%	-15.8%	-10.9%	-7.4%	-3.2%	5.2%	12.3%	19.7%	24.0%	36.0%	41.4%	5.3%	11.1%
2080s	5	30	-18.8%	-15.7%	-10.9%	-6.7%	-3.4%	3.7%	11.4%	17.9%	22.7%	35.3%	42.1%	4.8%	11.0%
2080s	5	50	-19.7%	-18.3%	-12.3%	-9.9%	-4.1%	2.5%	8.9%	13.7%	20.9%	30.4%	39.4%	2.7%	10.2%
2080s	5	75	-21.0%	-16.7%	-12.7%	-10.5%	-4.0%	2.4%	6.5%	13.5%	19.6%	28.3%	34.1%	2.0%	9.8%
2080s	5	90	-19.2%	-16.4%	-13.1%	-11.7%	-5.1%	1.7%	7.8%	13.8%	19.2%	27.8%	33.4%	1.6%	10.1%
2080s	5	120	-16.9%	-16.7%	-14.9%	-12.7%	-6.4%	2.3%	7.8%	12.7%	18.0%	27.5%	37.6%	1.5%	10.4%
2080s	10	1	-16.2%	-15.6%	-11.7%	-5.3%	6.0%	13.5%	24.9%	32.4%	37.0%	41.3%	41.7%	14.0%	14.0%
2080s	10	2	-16.4%	-14.5%	-6.2%	-3.4%	3.7%	14.0%	21.8%	33.1%	35.2%	41.6%	43.2%	13.6%	13.4%
2080s	10	3	-14.2%	-13.6%	-10.0%	-4.8%	3.5%	12.6%	22.0%	28.3%	33.7%	39.6%	40.4%	12.8%	12.9%
2080s	10	4	-13.9%	-12.6%	-10.4%	-6.4%	5.2%	12.9%	20.8%	27.2%	33.4%	41.4%	42.5%	12.4%	12.8%
2080s	10	5	-14.4%	-11.9%	-9.9%	-7.0%	4.7%	12.0%	19.5%	28.9%	35.3%	40.3%	42.0%	11.8%	13.0%
2080s	10	6	-16.3%	-14.8%	-11.5%	-7.4%	3.1%	10.5%	19.4%	28.5%	34.4%	37.5%	42.9%	11.1%	13.0%
2080s	10	7	-16.8%	-14.1%	-11.2%	-6.2%	2.6%	10.1%	19.2%	27.3%	32.8%	37.4%	41.1%	11.1%	12.8%
2080s	10	10	-13.6%	-13.6%	-11.4%	-6.3%	-0.2%	7.6%	17.8%	22.6%	26.6%	37.8%	40.7%	8.4%	11.9%
2080s	10	20	-20.2%	-16.8%	-11.8%	-9.5%	-2.9%	4.8%	11.7%	20.5%	28.4%	41.8%	45.7%	5.7%	12.6%
2080s	10	30	-20.3%	-18.5%	-11.7%	-7.3%	-3.7%	3.3%	12.1%	18.8%	25.4%	40.7%	48.0%	5.2%	12.5%
2080s	10	50	-21.2%	-19.9%	-13.0%	-9.8%	-4.4%	2.3%	9.3%	16.5%	24.2%	34.9%	43.9%	2.8%	11.2%
2080s	10	75	-22.9%	-17.8%	-13.9%	-11.8%	-4.8%	2.5%	8.3%	13.9%	21.7%	32.9%	38.2%	2.2%	10.9%
2080s	10	90	-21.1%	-17.7%	-15.0%	-13.1%	-6.2%	2.0%	7.8%	14.0%	21.9%	31.5%	36.6%	1.7%	11.1%
2080s	10	120	-18.4%	-18.3%	-15.2%	-13.7%	-6.5%	3.3%	7.9%	13.1%	20.2%	30.8%	41.8%	1.6%	11.4%
2080s	25	1	-18.3%	-15.8%	-12.9%	-6.9%	6.8%	15.7%	23.9%	37.7%	39.4%	48.1%	49.0%	15.3%	15.8%
2080s	25	2	-19.1%	-17.8%	-6.6%	-4.8%	3.7%	14.2%	24.0%	37.1%	40.0%	47.6%	48.6%	14.6%	15.3%
2080s	25	3	-18.4%	-16.6%	-11.1%	-6.7%	2.7%	13.8%	23.2%	31.5%	41.0%	44.5%	45.5%	13.7%	14.8%
2080s	25	4	-16.5%	-16.5%	-12.1%	-7.9%	5.3%	13.1%	23.2%	29.8%	38.0%	49.1%	51.8%	13.3%	14.7%
2080s	25	5	-15.8%	-15.5%	-11.5%	-9.3%	4.8%	12.9%	19.9%	32.3%	38.1%	48.9%	51.5%	12.9%	15.0%
2080s	25	6	-20.7%	-18.1%	-12.3%	-8.9%	4.6%	11.5%	21.1%	32.0%	38.5%	46.6%	49.6%	12.0%	15.0%
2080s	25	7	-21.0%	-17.0%	-13.3%	-6.7%	3.5%	10.6%	20.8%	30.2%	38.3%	43.4%	47.0%	12.0%	14.7%
2080s	25	10	-18.4%	-16.2%	-12.3%	-8.0%	-0.7%	7.1%	19.6%	25.9%	30.0%	42.1%	43.7%	8.9%	13.5%
2080s	25	20	-21.1%	-17.8%	-14.2%	-10.4%	-3.8%	5.3%	12.3%	23.6%	32.7%	47.8%	50.0%	6.1%	14.3%
2080s	25	30	-21.9%	-21.3%	-12.6%	-8.9%	-4.1%	3.0%	12.6%	21.1%	28.7%	46.2%	53.8%	5.7%	14.1%
2080s	25	50	-22.6%	-21.5%	-15.2%	-10.4%	-4.6%	1.6%	9.2%	16.8%	27.0%	39.6%	48.4%	3.0%	12.4%
2080s	25	75	-24.7%	-19.0%	-16.4%	-13.2%	-5.5%	2.7%	9.6%	15.1%	23.8%	37.8%	42.4%	2.4%	12.2%
2080s	25	90	-22.9%	-19.3%	-16.7%	-13.2%	-8.2%	2.4%	8.3%	15.8%	24.7%	35.4%	39.9%	1.9%	12.3%
2080s	25	120	-21.5%	-20.2%	-16.7%	-15.0%	-7.8%	3.7%	8.8%	13.1%	22.5%	34.4%	46.3%	1.7%	12.6%
2080s	50	1	-19.4%	-17.1%	-13.9%	-7.9%	7.0%	17.6%	25.3%	38.3%	42.7%	52.2%	53.5%	16.1%	17.0%
2080s	50	2	-20.6%	-19.7%	-7.4%	-5.5%	3.6%	15.0%	25.6%	40.1%	42.8%	51.2%	51.9%	15.3%	16.4%
2080s	50	3	-20.9%	-18.4%	-12.4%	-7.8%	2.3%	14.2%	23.4%	32.5%	45.3%	47.6%	48.5%	14.2%	15.9%

Extreme Rainfall Statistics for Selected Return Periods and Durations

Period	Return Period (years)	Duration (days)	Minimum	1%	5%	10%	25%	50%	75%	90%	95%	99%	Maximum	Mean	Standard Deviation
2080s	50	4	-19.0%	-18.2%	-13.6%	-8.8%	5.4%	13.6%	24.1%	31.7%	40.5%	53.3%	58.3%	13.8%	15.9%
2080s	50	5	-18.5%	-18.0%	-12.9%	-10.5%	4.0%	13.2%	20.9%	35.0%	41.6%	53.5%	58.7%	13.5%	16.3%
2080s	50	6	-23.1%	-20.3%	-13.4%	-9.7%	5.0%	12.3%	22.1%	33.7%	41.0%	52.1%	53.6%	12.6%	16.2%
2080s	50	7	-23.3%	-18.6%	-15.0%	-7.8%	3.6%	10.7%	22.1%	32.5%	39.7%	48.7%	50.7%	12.6%	15.9%
2080s	50	10	-21.2%	-18.0%	-12.5%	-8.9%	-0.8%	6.7%	21.3%	27.9%	32.1%	44.7%	45.5%	9.2%	14.4%
2080s	50	20	-21.7%	-19.2%	-15.8%	-11.4%	-4.0%	4.8%	13.8%	25.7%	35.7%	51.6%	52.6%	6.3%	15.4%
2080s	50	30	-22.9%	-22.8%	-13.1%	-9.3%	-4.4%	2.9%	13.4%	22.7%	31.1%	51.1%	57.4%	6.0%	15.2%
2080s	50	50	-23.5%	-22.4%	-16.4%	-11.9%	-5.1%	1.3%	9.2%	16.9%	28.6%	42.6%	51.2%	3.2%	13.3%
2080s	50	75	-25.7%	-20.2%	-17.6%	-13.4%	-5.9%	3.0%	10.0%	15.9%	25.2%	40.9%	45.1%	2.6%	13.1%
2080s	50	90	-23.9%	-20.9%	-17.9%	-13.4%	-8.9%	3.0%	9.3%	16.5%	26.5%	37.9%	42.0%	2.0%	13.1%
2080s	50	120	-23.3%	-21.3%	-17.6%	-15.8%	-8.5%	3.6%	9.5%	14.3%	24.0%	36.6%	49.2%	1.8%	13.4%
2080s	100	1	-20.4%	-18.4%	-14.6%	-9.1%	6.2%	18.3%	26.7%	39.5%	44.7%	55.6%	57.2%	16.7%	18.0%
2080s	100	2	-21.9%	-21.3%	-8.4%	-5.6%	3.4%	15.5%	26.4%	42.5%	45.2%	54.3%	54.7%	15.8%	17.4%
2080s	100	3	-23.0%	-19.9%	-13.7%	-8.6%	2.1%	14.7%	24.0%	34.3%	48.7%	51.2%	51.4%	14.6%	16.9%
2080s	100	4	-21.0%	-19.7%	-15.0%	-9.5%	5.5%	14.0%	25.2%	33.0%	42.6%	56.9%	63.7%	14.3%	16.9%
2080s	100	5	-20.8%	-20.0%	-14.1%	-11.5%	3.4%	14.1%	21.7%	37.2%	43.8%	57.4%	64.9%	14.0%	17.4%
2080s	100	6	-25.1%	-22.6%	-14.3%	-10.2%	4.4%	12.4%	23.2%	35.0%	44.2%	56.7%	57.0%	13.1%	17.3%
2080s	100	7	-25.1%	-20.0%	-16.1%	-8.4%	4.0%	11.8%	23.2%	34.8%	41.7%	53.2%	53.7%	13.1%	16.9%
2080s	100	10	-23.5%	-19.4%	-12.5%	-9.6%	-1.1%	6.8%	22.1%	29.7%	33.5%	46.9%	47.0%	9.5%	15.3%
2080s	100	20	-22.1%	-21.0%	-17.2%	-12.2%	-4.3%	4.8%	14.1%	27.4%	38.4%	54.9%	54.9%	6.5%	16.3%
2080s	100	30	-24.4%	-23.7%	-14.0%	-9.9%	-4.7%	2.8%	14.0%	24.1%	33.3%	55.6%	60.4%	6.3%	16.2%
2080s	100	50	-24.1%	-23.1%	-17.4%	-12.9%	-5.2%	1.3%	9.9%	18.1%	30.0%	45.1%	53.5%	3.3%	14.0%
2080s	100	75	-26.5%	-21.4%	-18.4%	-13.4%	-6.5%	3.0%	10.3%	16.6%	26.5%	43.6%	47.4%	2.7%	13.9%
2080s	100	90	-24.7%	-22.2%	-18.9%	-13.6%	-8.6%	3.1%	10.3%	16.8%	28.1%	40.1%	43.8%	2.1%	13.8%
2080s	100	120	-24.9%	-22.3%	-18.5%	-16.3%	-9.7%	3.4%	10.4%	16.1%	25.3%	38.6%	51.7%	1.8%	14.1%
2080s	200	1	-21.3%	-19.6%	-14.6%	-10.0%	5.5%	18.3%	27.9%	41.4%	47.1%	58.6%	60.5%	17.3%	18.9%
2080s	200	2	-23.0%	-22.7%	-9.2%	-6.2%	3.6%	15.6%	27.2%	44.5%	47.3%	57.0%	57.0%	16.2%	18.3%
2080s	200	3	-24.7%	-21.1%	-14.9%	-9.4%	1.9%	15.3%	24.9%	35.8%	51.7%	53.7%	54.8%	15.0%	17.7%
2080s	200	4	-22.7%	-20.9%	-16.2%	-10.0%	5.6%	14.3%	25.8%	34.4%	44.3%	60.0%	68.5%	14.7%	17.8%
2080s	200	5	-22.7%	-21.6%	-15.2%	-12.1%	2.8%	14.8%	22.9%	38.7%	45.5%	60.7%	70.2%	14.4%	18.4%
2080s	200	6	-26.7%	-24.5%	-15.0%	-10.6%	3.7%	12.6%	23.9%	36.1%	46.0%	60.2%	60.8%	13.5%	18.2%
2080s	200	7	-26.7%	-21.2%	-17.1%	-8.7%	4.1%	11.7%	24.3%	36.7%	43.5%	56.6%	57.2%	13.5%	17.8%
2080s	200	10	-25.4%	-20.7%	-12.8%	-10.2%	-1.2%	7.0%	22.6%	31.3%	34.8%	48.5%	48.9%	9.7%	16.0%
2080s	200	20	-22.5%	-22.4%	-17.9%	-12.8%	-4.4%	5.2%	14.8%	28.9%	40.7%	57.1%	58.0%	6.7%	17.1%
2080s	200	30	-25.6%	-24.5%	-15.3%	-10.6%	-4.9%	2.7%	14.5%	25.3%	35.1%	59.5%	63.0%	6.5%	17.0%
2080s	200	50	-24.7%	-23.8%	-18.3%	-13.0%	-5.4%	1.3%	10.5%	18.8%	31.2%	47.4%	55.6%	3.4%	14.7%
2080s	200	75	-27.2%	-22.5%	-18.9%	-14.1%	-7.0%	2.9%	10.7%	17.3%	27.5%	46.0%	49.5%	2.9%	14.6%
2080s	200	90	-25.5%	-23.2%	-19.8%	-14.7%	-8.4%	3.5%	10.5%	18.2%	29.4%	42.1%	45.4%	2.2%	14.4%
2080s	200	120	-26.2%	-23.1%	-19.2%	-16.8%	-9.7%	3.3%	10.4%	17.9%	26.5%	40.3%	53.9%	1.9%	14.8%
2080s	500	1	-22.2%	-20.8%	-14.7%	-11.0%	4.8%	18.5%	29.5%	43.5%	49.9%	61.9%	64.1%	17.9%	19.9%
2080s	500	2	-24.2%	-24.2%	-10.2%	-6.8%	3.8%	15.7%	28.6%	46.8%	49.7%	59.7%	60.0%	16.8%	19.3%
2080s	500	3	-26.6%	-22.5%	-16.1%	-10.0%	1.9%	15.8%	26.1%	37.3%	54.1%	56.5%	58.7%	15.4%	18.7%
2080s	500	4	-24.6%	-22.2%	-17.5%	-10.4%	5.6%	14.7%	26.0%	35.7%	46.3%	63.6%	73.8%	15.2%	18.8%
2080s	500	5	-24.8%	-23.4%	-15.8%	-12.7%	2.3%	14.9%	23.8%	39.9%	47.4%	64.6%	76.2%	15.0%	19.5%
2080s	500	6	-28.5%	-26.6%	-16.0%	-10.7%	2.9%	13.0%	25.3%	37.8%	47.9%	63.9%	65.7%	13.9%	19.2%
2080s	500	7	-28.3%	-22.9%	-18.1%	-9.0%	3.6%	12.3%	25.2%	38.9%	45.6%	60.0%	62.0%	14.0%	18.8%
2080s	500	10	-27.5%	-22.1%	-13.4%	-10.9%	-1.3%	7.1%	23.3%	33.2%	36.8%	50.1%	51.2%	10.0%	16.9%
2080s	500	20	-24.3%	-23.3%	-18.6%	-13.3%	-5.0%	5.0%	15.6%	30.7%	43.3%	59.6%	61.7%	7.0%	18.0%
2080s	500	30	-26.9%	-25.4%	-16.7%	-11.6%	-5.1%	2.3%	15.2%	26.7%	37.3%	64.2%	66.0%	6.8%	18.0%
2080s	500	50	-25.3%	-24.5%	-19.2%	-13.3%	-5.7%	1.7%	11.4%	20.0%	32.5%	50.0%	57.9%	3.6%	15.4%
2080s	500	75	-28.0%	-23.6%	-19.5%	-15.3%	-7.6%	2.4%	11.2%	18.7%	28.8%	48.9%	51.8%	3.0%	15.4%
2080s	500	90	-26.2%	-24.4%	-20.5%	-15.8%	-9.0%	3.8%	11.3%	19.8%	30.8%	44.3%	47.3%	2.4%	15.2%
2080s	500	120	-27.7%	-24.0%	-20.2%	-16.9%	-9.7%	3.2%	10.8%	19.3%	27.8%	42.3%	56.5%	2.0%	15.5%
2080s	1000	1	-22.7%	-21.6%	-15.0%	-11.7%	5.0%	18.6%	30.4%	45.1%	51.7%	64.0%	66.4%	18.3%	20.6%
2080s	1000	2	-25.3%	-25.1%	-10.9%	-7.2%	3.9%	15.9%	29.1%	48.2%	51.2%	61.5%	62.0%	17.1%	19.9%

Extreme Rainfall Statistics for Selected Return Periods and Durations

Period	Return Period (years)	Duration (days)	Minimum	1%	5%	10%	25%	50%	75%	90%	95%	99%	Maximum	Mean	Standard Deviation
2080s	1000	3	-27.9%	-23.4%	-16.9%	-10.1%	2.0%	16.2%	27.1%	38.3%	55.6%	58.4%	61.2%	15.7%	19.3%
2080s	1000	4	-25.8%	-23.1%	-18.3%	-10.6%	5.6%	15.0%	26.4%	36.6%	47.6%	65.9%	77.2%	15.5%	19.5%
2080s	1000	5	-26.1%	-24.5%	-16.0%	-13.1%	2.3%	15.4%	24.2%	40.9%	48.8%	67.1%	80.2%	15.3%	20.2%
2080s	1000	6	-29.6%	-27.9%	-16.7%	-10.8%	2.4%	13.1%	26.1%	38.9%	49.1%	66.3%	68.8%	14.3%	19.9%
2080s	1000	7	-29.4%	-24.1%	-18.7%	-9.1%	3.2%	12.7%	25.8%	40.3%	46.9%	62.3%	65.1%	14.4%	19.5%
2080s	1000	10	-28.8%	-22.9%	-13.7%	-11.3%	-1.4%	7.1%	23.8%	34.3%	38.4%	51.2%	52.7%	10.1%	17.4%
2080s	1000	20	-25.6%	-23.8%	-19.0%	-13.6%	-5.6%	4.8%	16.0%	31.9%	45.1%	61.3%	64.1%	7.2%	18.7%
2080s	1000	30	-27.7%	-25.9%	-17.7%	-12.5%	-5.2%	2.3%	15.6%	27.6%	38.7%	67.3%	67.9%	7.0%	18.7%
2080s	1000	50	-25.7%	-25.0%	-19.8%	-13.4%	-6.1%	1.9%	11.9%	20.8%	33.4%	51.8%	59.4%	3.7%	16.0%
2080s	1000	75	-28.5%	-24.3%	-19.9%	-15.8%	-8.0%	2.1%	11.6%	19.8%	29.7%	50.8%	53.4%	3.2%	15.9%
2080s	1000	90	-26.7%	-25.1%	-20.9%	-16.6%	-9.5%	3.8%	11.5%	20.8%	31.7%	45.8%	48.5%	2.4%	15.7%
2080s	1000	120	-28.7%	-24.6%	-21.6%	-17.0%	-9.9%	3.2%	11.0%	19.9%	28.8%	43.7%	58.3%	2.1%	16.1%
2080s	2000	1	-23.3%	-22.4%	-15.3%	-12.2%	5.2%	19.0%	31.1%	46.4%	53.3%	65.9%	68.5%	18.7%	21.2%
2080s	2000	2	-26.2%	-25.8%	-11.5%	-7.6%	4.0%	16.1%	29.5%	49.6%	52.5%	63.2%	63.8%	17.4%	20.5%
2080s	2000	3	-29.0%	-24.2%	-17.6%	-10.2%	2.0%	16.5%	28.2%	39.1%	57.0%	60.5%	63.4%	16.0%	19.9%
2080s	2000	4	-26.8%	-23.9%	-19.1%	-10.9%	5.6%	15.0%	27.0%	37.4%	48.8%	67.9%	80.3%	15.7%	20.1%
2080s	2000	5	-27.3%	-25.5%	-16.2%	-13.4%	2.3%	15.8%	24.7%	41.9%	50.1%	69.4%	83.7%	15.6%	20.9%
2080s	2000	6	-30.5%	-29.0%	-17.2%	-10.9%	2.0%	13.4%	26.8%	40.0%	50.2%	68.4%	71.6%	14.5%	20.5%
2080s	2000	7	-30.3%	-25.1%	-19.3%	-9.2%	2.7%	13.1%	26.3%	41.6%	48.1%	64.3%	67.9%	14.6%	20.1%
2080s	2000	10	-30.0%	-23.7%	-14.1%	-11.6%	-1.9%	7.1%	24.3%	35.3%	39.5%	52.2%	54.0%	10.3%	17.9%
2080s	2000	20	-26.7%	-24.2%	-19.2%	-13.9%	-6.1%	4.7%	16.5%	32.8%	46.6%	62.8%	66.3%	7.3%	19.2%
2080s	2000	30	-28.5%	-26.4%	-18.5%	-13.0%	-5.2%	2.6%	16.2%	28.4%	40.0%	69.8%	70.2%	7.2%	19.3%
2080s	2000	50	-26.1%	-25.4%	-20.3%	-13.5%	-6.3%	2.0%	12.4%	21.6%	34.3%	53.4%	60.8%	3.7%	16.4%
2080s	2000	75	-29.0%	-24.9%	-20.2%	-16.3%	-8.4%	2.4%	11.9%	21.0%	30.4%	52.5%	54.8%	3.3%	16.4%
2080s	2000	90	-27.2%	-25.8%	-21.3%	-17.3%	-9.9%	3.7%	11.9%	21.8%	32.6%	47.2%	49.6%	2.5%	16.1%
2080s	2000	120	-29.5%	-25.1%	-22.7%	-17.0%	-10.2%	3.3%	11.2%	20.4%	29.6%	44.9%	59.9%	2.2%	16.5%
2080s	10000	1	-24.2%	-23.7%	-15.8%	-13.3%	5.6%	19.9%	32.7%	48.8%	56.3%	69.5%	72.6%	19.3%	22.3%
2080s	10000	2	-28.0%	-27.2%	-12.7%	-8.2%	3.5%	16.6%	30.2%	52.1%	55.1%	67.3%	67.3%	18.0%	21.6%
2080s	10000	3	-31.1%	-25.7%	-18.9%	-10.4%	1.7%	17.1%	29.1%	40.6%	59.7%	64.6%	67.6%	16.4%	21.0%
2080s	10000	4	-28.8%	-25.3%	-20.5%	-11.3%	5.3%	15.6%	28.6%	38.9%	51.0%	71.9%	86.3%	16.2%	21.3%
2080s	10000	5	-29.5%	-27.3%	-17.1%	-14.3%	1.5%	16.1%	26.0%	44.0%	52.6%	73.8%	90.6%	16.2%	22.2%
2080s	10000	6	-32.3%	-31.2%	-18.3%	-11.1%	1.2%	13.7%	27.8%	42.0%	52.3%	72.6%	77.0%	15.1%	21.7%
2080s	10000	7	-31.9%	-27.0%	-20.3%	-9.6%	2.0%	13.7%	27.2%	43.5%	50.4%	68.2%	73.3%	15.2%	21.3%
2080s	10000	10	-32.2%	-25.1%	-14.6%	-11.7%	-2.2%	7.2%	25.1%	37.2%	41.7%	54.0%	56.6%	10.6%	18.9%
2080s	10000	20	-28.8%	-25.0%	-19.7%	-14.2%	-6.4%	4.5%	17.5%	34.4%	49.8%	65.7%	70.7%	7.6%	20.4%
2080s	10000	30	-29.8%	-27.3%	-19.3%	-13.8%	-5.3%	2.8%	17.5%	30.0%	42.6%	73.9%	76.6%	7.5%	20.4%
2080s	10000	50	-26.7%	-26.2%	-21.3%	-13.7%	-6.9%	2.0%	12.8%	23.1%	36.3%	56.5%	63.5%	3.9%	17.4%
2080s	10000	75	-29.8%	-26.0%	-20.8%	-16.8%	-9.1%	2.1%	12.5%	23.3%	32.0%	56.0%	57.6%	3.5%	17.5%
2080s	10000	90	-28.0%	-27.0%	-22.1%	-18.5%	-10.2%	3.5%	12.6%	23.7%	34.3%	50.0%	51.8%	2.7%	17.0%
2080s	10000	120	-31.2%	-26.5%	-24.2%	-17.6%	-10.8%	3.4%	11.8%	21.5%	31.4%	47.3%	63.0%	2.3%	17.5%

Variable	Extreme Combined Rainfall and Snowmelt Statistics
Units	%
Area	Nearest Grid Cell to Mine site
Baseline	Projected changes calculated from model baseline (1991 - 2020)

Extreme Rainfall Statistics for Selected Return Periods and Durations

Period	Return Period (years)	Duration (days)	Minimum	1%	5%	10%	25%	50%	75%	90%	95%	99%	Maximum	Mean	Standard Deviation
2050s	2	1	-10.6%	-8.2%	-4.2%	-0.6%	1.7%	6.2%	13.1%	20.8%	25.9%	31.6%	35.1%	8.2%	9.2%
2050s	2	2	-14.0%	-11.1%	-3.1%	-1.0%	2.2%	5.7%	9.4%	17.3%	22.2%	31.3%	35.0%	6.8%	8.4%
2050s	2	3	-11.7%	-11.4%	-8.0%	-3.2%	1.1%	3.8%	8.3%	14.4%	22.1%	24.3%	25.9%	5.2%	7.8%
2050s	2	4	-12.7%	-12.3%	-7.6%	-4.0%	-0.3%	3.6%	8.9%	14.0%	17.3%	21.5%	22.1%	4.1%	7.3%
2050s	2	5	-14.4%	-11.4%	-7.6%	-4.9%	-1.5%	2.5%	8.9%	12.9%	14.6%	18.5%	19.4%	3.4%	7.2%
2050s	2	6	-16.1%	-12.7%	-8.0%	-6.2%	-1.8%	1.7%	7.8%	12.3%	14.3%	16.8%	17.7%	2.5%	7.0%
2050s	2	7	-15.4%	-14.8%	-8.6%	-6.9%	-2.5%	1.8%	6.7%	11.4%	13.6%	17.3%	17.6%	1.8%	7.1%
2050s	2	10	-16.9%	-16.2%	-11.4%	-7.6%	-3.9%	-1.0%	4.5%	9.7%	13.0%	16.8%	19.7%	0.1%	7.3%
2050s	2	20	-22.6%	-20.3%	-12.2%	-10.0%	-5.3%	-1.3%	3.3%	7.9%	13.1%	16.6%	20.1%	-0.9%	7.8%
2050s	2	30	-20.3%	-18.6%	-12.9%	-9.8%	-4.7%	-1.3%	4.2%	8.1%	9.8%	20.6%	21.4%	-0.7%	7.9%
2050s	2	50	-17.8%	-14.8%	-11.8%	-7.3%	-3.9%	0.5%	4.9%	10.2%	11.9%	19.9%	22.1%	0.7%	7.4%
2050s	2	75	-17.3%	-14.8%	-10.6%	-7.9%	-4.5%	0.6%	4.3%	8.1%	11.2%	18.7%	21.2%	0.2%	7.0%
2050s	2	90	-17.9%	-15.1%	-11.4%	-8.3%	-3.8%	0.8%	4.2%	7.6%	10.7%	17.7%	20.7%	0.2%	7.0%
2050s	2	120	-18.1%	-14.8%	-9.2%	-6.3%	-2.4%	2.1%	5.1%	8.4%	13.2%	19.9%	20.4%	1.6%	6.7%
2050s	5	1	-14.8%	-11.0%	-7.2%	-3.8%	2.1%	7.7%	14.3%	27.9%	32.3%	39.6%	40.6%	9.6%	11.9%
2050s	5	2	-16.7%	-14.8%	-5.1%	-3.4%	0.0%	6.3%	12.6%	20.5%	22.7%	34.2%	39.1%	7.2%	10.3%
2050s	5	3	-16.5%	-13.2%	-7.8%	-5.5%	-0.7%	5.1%	11.5%	14.4%	25.2%	28.3%	31.1%	5.5%	9.5%
2050s	5	4	-16.6%	-15.3%	-9.2%	-7.0%	-0.8%	3.4%	10.3%	15.0%	20.1%	25.9%	26.9%	4.3%	9.0%
2050s	5	5	-16.3%	-15.2%	-9.6%	-6.4%	-2.0%	2.6%	9.1%	15.0%	16.5%	22.4%	24.9%	3.4%	8.6%
2050s	5	6	-18.5%	-14.6%	-11.0%	-7.1%	-3.3%	1.3%	8.6%	13.7%	16.5%	20.4%	24.7%	2.4%	8.6%
2050s	5	7	-18.1%	-15.7%	-10.0%	-7.4%	-5.1%	1.0%	7.7%	12.7%	15.2%	21.4%	26.3%	1.6%	8.6%
2050s	5	10	-18.2%	-16.8%	-12.4%	-8.9%	-5.2%	-1.4%	5.0%	9.6%	12.3%	23.3%	26.4%	-0.2%	8.3%
2050s	5	20	-23.1%	-21.4%	-15.2%	-11.1%	-6.2%	-0.2%	4.6%	8.3%	14.7%	20.7%	25.1%	-0.7%	9.0%
2050s	5	30	-23.4%	-21.6%	-14.1%	-12.0%	-5.6%	1.0%	5.6%	9.6%	11.5%	23.9%	27.8%	0.0%	9.3%
2050s	5	50	-21.3%	-19.9%	-13.1%	-10.8%	-5.6%	0.2%	6.4%	10.8%	13.8%	23.0%	23.4%	0.4%	9.0%
2050s	5	75	-23.8%	-19.1%	-12.9%	-10.6%	-5.4%	1.7%	4.0%	9.8%	13.1%	20.1%	21.0%	-0.4%	8.5%
2050s	5	90	-23.6%	-19.2%	-13.4%	-10.1%	-5.3%	1.1%	5.2%	10.2%	12.2%	20.8%	21.3%	0.3%	8.4%
2050s	5	120	-21.0%	-17.8%	-9.6%	-5.9%	-1.6%	2.5%	6.4%	9.1%	15.0%	18.1%	18.7%	2.1%	7.3%
2050s	10	1	-16.8%	-14.7%	-8.3%	-6.1%	0.7%	8.8%	14.9%	31.5%	35.3%	44.4%	46.6%	10.4%	13.6%
2050s	10	2	-17.9%	-16.5%	-7.5%	-5.4%	-1.4%	6.4%	14.6%	23.7%	25.2%	35.5%	41.0%	7.5%	11.8%
2050s	10	3	-18.7%	-14.0%	-9.3%	-6.0%	-2.4%	4.5%	13.4%	18.1%	27.6%	30.5%	33.7%	5.7%	10.8%
2050s	10	4	-18.6%	-16.6%	-11.4%	-7.6%	-2.7%	3.8%	11.8%	17.7%	22.4%	28.1%	29.2%	4.5%	10.3%
2050s	10	5	-17.1%	-17.0%	-11.7%	-8.1%	-2.3%	1.5%	9.7%	16.7%	20.9%	24.3%	27.7%	3.4%	9.8%
2050s	10	6	-19.6%	-16.8%	-11.8%	-9.8%	-4.8%	0.8%	10.2%	16.2%	19.9%	23.5%	28.2%	2.4%	9.9%
2050s	10	7	-19.3%	-17.4%	-11.6%	-9.0%	-5.4%	0.3%	8.0%	15.1%	17.1%	23.4%	30.7%	1.5%	9.8%
2050s	10	10	-18.8%	-17.3%	-13.8%	-11.2%	-6.4%	-2.3%	6.8%	10.0%	12.1%	26.4%	29.6%	-0.3%	9.2%
2050s	10	20	-23.3%	-22.1%	-18.3%	-12.3%	-6.8%	-0.2%	5.5%	10.4%	15.7%	23.5%	27.5%	-0.6%	10.0%
2050s	10	30	-24.8%	-23.1%	-15.0%	-12.8%	-5.9%	0.8%	6.3%	12.2%	14.0%	26.5%	31.1%	0.4%	10.4%
2050s	10	50	-22.9%	-22.2%	-14.5%	-12.0%	-6.3%	0.5%	7.0%	12.0%	17.8%	23.7%	25.6%	0.3%	10.2%
2050s	10	75	-26.7%	-21.1%	-14.5%	-12.3%	-6.8%	0.3%	4.5%	12.4%	13.6%	21.3%	22.7%	-0.7%	9.5%
2050s	10	90	-26.2%	-21.1%	-15.6%	-10.8%	-5.5%	0.8%	6.3%	12.1%	14.8%	22.1%	23.7%	0.4%	9.4%
2050s	10	120	-22.4%	-19.2%	-10.6%	-5.9%	-1.9%	2.9%	7.1%	10.4%	14.5%	20.5%	22.8%	2.4%	8.0%
2050s	25	1	-18.6%	-18.1%	-9.5%	-7.3%	-0.3%	9.9%	16.8%	34.2%	39.6%	49.5%	53.8%	11.1%	15.4%
2050s	25	2	-19.1%	-18.2%	-10.1%	-8.5%	-2.9%	6.7%	17.0%	26.4%	31.2%	36.9%	42.8%	7.7%	13.5%
2050s	25	3	-20.8%	-16.8%	-11.3%	-7.3%	-3.6%	4.2%	15.1%	21.8%	29.0%	32.7%	36.2%	5.9%	12.3%
2050s	25	4	-20.6%	-17.9%	-13.6%	-9.9%	-4.0%	4.1%	12.5%	20.6%	25.7%	31.4%	31.7%	4.6%	11.8%
2050s	25	5	-18.8%	-18.2%	-13.1%	-10.3%	-3.7%	2.3%	11.6%	18.5%	23.4%	27.6%	30.6%	3.5%	11.1%
2050s	25	6	-20.6%	-18.8%	-13.5%	-11.8%	-5.4%	0.9%	11.1%	18.6%	22.6%	26.6%	31.9%	2.4%	11.4%
2050s	25	7	-20.5%	-19.0%	-13.1%	-11.6%	-6.7%	0.3%	9.3%	16.9%	19.8%	26.1%	35.2%	1.5%	11.1%

Extreme Rainfall Statistics for Selected Return Periods and Durations

Period	Return Period (years)	Duration (days)	Minimum	1%	5%	10%	25%	50%	75%	90%	95%	99%	Maximum	Mean	Standard Deviation
2050s	25	10	-19.3%	-17.8%	-15.4%	-12.9%	-7.5%	-2.3%	7.5%	11.6%	15.3%	29.5%	32.9%	-0.3%	10.3%
2050s	25	20	-23.4%	-22.8%	-20.6%	-13.9%	-7.0%	-0.1%	7.0%	12.4%	16.5%	26.3%	30.0%	-0.4%	11.2%
2050s	25	30	-26.2%	-24.5%	-15.9%	-13.9%	-6.8%	0.5%	7.2%	15.8%	16.8%	29.2%	34.5%	0.9%	11.8%
2050s	25	50	-24.5%	-24.3%	-16.0%	-13.7%	-8.4%	0.2%	6.8%	15.5%	20.8%	24.5%	27.8%	0.3%	11.5%
2050s	25	75	-29.4%	-22.9%	-17.3%	-14.0%	-8.2%	-1.4%	5.6%	13.1%	16.6%	21.9%	25.6%	-0.9%	10.7%
2050s	25	90	-28.7%	-22.9%	-17.4%	-11.4%	-5.4%	0.5%	7.7%	12.7%	18.1%	23.1%	26.9%	0.5%	10.5%
2050s	25	120	-23.7%	-20.6%	-11.0%	-6.6%	-2.1%	3.0%	8.4%	12.8%	15.6%	23.4%	27.6%	2.7%	8.9%
2050s	50	1	-20.2%	-19.8%	-10.1%	-8.0%	-1.3%	10.3%	17.7%	36.2%	42.1%	52.6%	58.2%	11.5%	16.4%
2050s	50	2	-19.9%	-19.2%	-11.6%	-9.8%	-3.8%	6.4%	17.1%	28.3%	34.8%	38.2%	44.0%	7.9%	14.5%
2050s	50	3	-22.1%	-18.8%	-12.4%	-8.5%	-4.3%	3.7%	16.2%	24.6%	29.8%	34.1%	37.7%	6.1%	13.3%
2050s	50	4	-21.7%	-18.6%	-14.9%	-11.0%	-4.9%	3.8%	13.1%	22.6%	27.0%	33.2%	33.6%	4.8%	12.8%
2050s	50	5	-20.0%	-18.8%	-14.8%	-11.3%	-4.2%	2.4%	12.2%	20.0%	24.2%	30.8%	32.4%	3.6%	12.0%
2050s	50	6	-21.2%	-19.9%	-15.0%	-13.0%	-6.6%	1.0%	11.0%	20.0%	24.0%	28.6%	34.1%	2.5%	12.3%
2050s	50	7	-21.1%	-20.0%	-15.0%	-12.9%	-7.6%	0.6%	9.3%	17.9%	22.2%	28.0%	38.0%	1.5%	12.0%
2050s	50	10	-19.7%	-18.0%	-16.3%	-13.5%	-8.2%	-2.5%	7.7%	11.8%	18.2%	31.4%	34.8%	-0.3%	11.1%
2050s	50	20	-23.5%	-23.2%	-21.7%	-14.7%	-8.0%	-0.2%	6.8%	14.0%	17.2%	27.9%	31.5%	-0.3%	11.9%
2050s	50	30	-27.0%	-25.3%	-16.6%	-14.5%	-6.9%	0.1%	8.5%	17.4%	19.1%	30.9%	36.6%	1.1%	12.6%
2050s	50	50	-25.6%	-25.4%	-16.6%	-14.9%	-9.0%	-0.1%	7.1%	17.6%	23.1%	26.0%	29.1%	0.2%	12.4%
2050s	50	75	-31.0%	-24.0%	-19.4%	-15.0%	-8.8%	-2.3%	6.5%	14.7%	18.4%	23.0%	27.4%	-1.1%	11.4%
2050s	50	90	-30.1%	-23.9%	-18.4%	-12.7%	-5.4%	0.3%	8.7%	13.4%	20.2%	24.2%	28.9%	0.6%	11.3%
2050s	50	120	-24.5%	-21.4%	-11.0%	-7.0%	-2.6%	2.5%	8.8%	13.7%	16.4%	25.1%	30.5%	2.9%	9.5%
2050s	100	1	-22.0%	-21.0%	-11.0%	-8.9%	-2.1%	10.6%	19.0%	37.9%	44.1%	55.1%	61.8%	11.8%	17.4%
2050s	100	2	-20.5%	-20.0%	-12.8%	-11.4%	-4.5%	6.0%	17.7%	29.9%	36.4%	41.4%	44.9%	8.0%	15.4%
2050s	100	3	-23.2%	-20.5%	-13.3%	-10.0%	-4.5%	3.2%	17.0%	26.9%	30.7%	35.2%	38.9%	6.2%	14.1%
2050s	100	4	-22.7%	-19.3%	-16.0%	-11.8%	-5.8%	4.3%	13.6%	23.8%	28.2%	34.7%	35.5%	4.9%	13.7%
2050s	100	5	-20.9%	-19.4%	-16.3%	-12.0%	-4.9%	3.1%	12.8%	21.4%	24.8%	33.6%	33.9%	3.6%	12.8%
2050s	100	6	-21.7%	-20.9%	-16.3%	-13.6%	-7.5%	0.9%	11.0%	21.2%	25.1%	31.2%	36.0%	2.5%	13.1%
2050s	100	7	-21.7%	-20.7%	-15.9%	-13.9%	-8.4%	0.9%	9.3%	18.8%	23.8%	29.7%	40.4%	1.5%	12.7%
2050s	100	10	-19.9%	-18.2%	-17.1%	-14.6%	-8.7%	-3.0%	7.5%	12.5%	20.0%	33.0%	36.4%	-0.3%	11.7%
2050s	100	20	-24.2%	-23.8%	-22.1%	-15.7%	-8.7%	-0.4%	7.0%	15.1%	18.8%	29.2%	32.7%	-0.2%	12.5%
2050s	100	30	-27.6%	-25.9%	-17.6%	-15.3%	-7.1%	0.2%	9.7%	18.8%	21.0%	32.3%	38.5%	1.4%	13.4%
2050s	100	50	-26.6%	-26.2%	-18.0%	-15.8%	-9.8%	0.1%	7.5%	19.4%	24.0%	28.1%	30.3%	0.2%	13.1%
2050s	100	75	-32.3%	-24.9%	-21.0%	-15.8%	-8.9%	-2.9%	7.0%	16.2%	19.6%	25.1%	29.0%	-1.2%	12.1%
2050s	100	90	-31.3%	-25.0%	-19.0%	-13.7%	-5.5%	-0.5%	9.5%	13.8%	21.8%	26.1%	30.6%	0.6%	11.9%
2050s	100	120	-25.1%	-22.1%	-11.0%	-7.8%	-3.0%	2.3%	9.6%	14.6%	17.3%	26.6%	33.0%	3.1%	10.1%
2050s	200	1	-23.5%	-21.9%	-11.7%	-9.6%	-2.6%	10.9%	20.1%	39.4%	45.8%	57.3%	65.0%	12.1%	18.1%
2050s	200	2	-21.0%	-20.7%	-13.9%	-12.7%	-5.2%	6.5%	18.5%	31.4%	37.0%	44.1%	45.7%	8.2%	16.2%
2050s	200	3	-24.1%	-21.9%	-13.8%	-11.2%	-5.1%	2.9%	17.5%	28.6%	32.0%	36.2%	40.0%	6.3%	14.9%
2050s	200	4	-23.5%	-19.8%	-16.9%	-13.0%	-6.6%	4.6%	14.0%	24.8%	29.3%	36.4%	37.2%	4.9%	14.4%
2050s	200	5	-21.7%	-20.0%	-17.5%	-12.6%	-5.1%	3.4%	13.4%	22.3%	25.4%	35.5%	36.2%	3.7%	13.5%
2050s	200	6	-22.2%	-21.7%	-17.4%	-14.9%	-7.8%	0.9%	11.8%	22.0%	26.1%	33.4%	37.7%	2.5%	13.8%
2050s	200	7	-22.2%	-21.4%	-17.2%	-14.8%	-8.9%	0.7%	9.5%	20.2%	24.4%	31.1%	42.4%	1.5%	13.4%
2050s	200	10	-20.2%	-19.0%	-17.5%	-15.7%	-9.2%	-3.1%	7.4%	13.5%	21.5%	34.3%	37.8%	-0.3%	12.3%
2050s	200	20	-25.3%	-24.1%	-22.4%	-16.6%	-9.4%	-0.5%	7.7%	15.8%	20.2%	30.4%	33.8%	-0.1%	13.1%
2050s	200	30	-28.2%	-26.5%	-18.4%	-16.1%	-7.1%	-0.1%	10.7%	20.1%	22.6%	33.6%	40.1%	1.6%	14.0%
2050s	200	50	-27.5%	-26.9%	-19.1%	-16.8%	-10.7%	0.3%	8.1%	21.0%	24.2%	29.9%	31.3%	0.2%	13.8%
2050s	200	75	-33.4%	-25.7%	-22.4%	-16.4%	-9.1%	-3.0%	7.3%	17.5%	20.4%	26.9%	30.3%	-1.3%	12.6%
2050s	200	90	-32.3%	-26.2%	-19.7%	-14.3%	-5.6%	-0.9%	10.3%	14.8%	22.6%	27.8%	32.1%	0.7%	12.5%
2050s	200	120	-25.6%	-22.7%	-11.0%	-8.4%	-3.3%	2.3%	10.0%	15.5%	18.2%	27.9%	35.1%	3.2%	10.6%
2050s	500	1	-25.1%	-22.9%	-12.5%	-10.4%	-2.8%	11.2%	21.3%	41.0%	47.7%	59.7%	68.5%	12.5%	19.0%
2050s	500	2	-21.5%	-21.5%	-15.4%	-14.1%	-5.9%	7.1%	19.4%	33.4%	37.6%	46.7%	47.3%	8.3%	17.2%
2050s	500	3	-25.1%	-23.4%	-14.1%	-12.4%	-5.7%	2.9%	18.2%	30.5%	33.4%	37.3%	41.2%	6.4%	15.8%
2050s	500	4	-24.4%	-21.1%	-18.0%	-14.0%	-7.3%	4.4%	14.4%	26.4%	30.7%	39.2%	39.2%	5.1%	15.3%
2050s	500	5	-22.6%	-21.0%	-18.8%	-13.5%	-5.5%	3.4%	14.0%	23.2%	26.8%	37.4%	39.3%	3.7%	14.2%
2050s	500	6	-22.7%	-22.6%	-18.6%	-16.1%	-8.4%	1.0%	12.7%	23.0%	27.3%	35.9%	39.6%	2.6%	14.6%
2050s	500	7	-22.7%	-22.1%	-18.7%	-15.5%	-9.4%	0.9%	10.2%	21.8%	25.2%	32.8%	44.8%	1.5%	14.1%

Extreme Rainfall Statistics for Selected Return Periods and Durations

Period	Return Period (years)	Duration (days)	Minimum	1%	5%	10%	25%	50%	75%	90%	95%	99%	Maximum	Mean	Standard Deviation
2050s	500	10	-20.4%	-20.0%	-18.1%	-16.8%	-9.7%	-3.2%	7.6%	14.6%	22.9%	35.9%	39.4%	-0.3%	13.0%
2050s	500	20	-26.5%	-24.6%	-22.6%	-17.5%	-9.9%	-0.7%	8.6%	17.0%	21.8%	31.7%	35.0%	0.0%	13.8%
2050s	500	30	-28.8%	-27.1%	-19.4%	-16.4%	-7.2%	-0.1%	11.7%	21.6%	24.4%	35.0%	41.9%	1.8%	14.8%
2050s	500	50	-28.5%	-27.7%	-20.4%	-17.5%	-11.6%	-0.4%	8.9%	22.6%	25.2%	32.0%	32.5%	0.2%	14.5%
2050s	500	75	-34.6%	-26.6%	-23.7%	-17.1%	-9.5%	-3.0%	7.6%	18.9%	20.6%	28.9%	31.9%	-1.4%	13.3%
2050s	500	90	-33.4%	-27.5%	-20.7%	-15.2%	-6.1%	-0.9%	10.4%	15.9%	24.2%	29.7%	33.7%	0.8%	13.2%
2050s	500	120	-26.3%	-23.3%	-11.0%	-8.7%	-3.8%	2.9%	10.4%	16.5%	19.2%	29.4%	37.5%	3.4%	11.3%
2050s	1000	1	-26.2%	-23.6%	-13.0%	-10.8%	-3.0%	11.2%	22.1%	42.0%	48.9%	61.2%	70.8%	12.7%	19.6%
2050s	1000	2	-22.0%	-21.9%	-16.3%	-15.0%	-6.4%	7.4%	20.1%	34.6%	38.0%	47.8%	49.8%	8.4%	17.8%
2050s	1000	3	-25.7%	-24.4%	-14.2%	-13.0%	-6.3%	2.9%	18.6%	31.6%	35.0%	38.4%	42.0%	6.5%	16.3%
2050s	1000	4	-24.9%	-21.9%	-18.6%	-14.4%	-7.4%	4.4%	14.7%	27.6%	32.0%	40.6%	41.2%	5.1%	15.9%
2050s	1000	5	-23.1%	-21.6%	-19.6%	-14.3%	-5.9%	3.5%	14.0%	23.8%	28.2%	38.7%	41.4%	3.8%	14.7%
2050s	1000	6	-23.3%	-23.0%	-19.4%	-17.0%	-9.0%	1.1%	13.2%	24.1%	28.4%	37.6%	40.9%	2.6%	15.2%
2050s	1000	7	-23.0%	-22.6%	-19.7%	-15.7%	-9.7%	1.2%	10.6%	22.4%	26.2%	33.9%	46.3%	1.5%	14.6%
2050s	1000	10	-20.6%	-20.6%	-18.3%	-17.3%	-10.0%	-3.3%	7.7%	15.4%	24.3%	36.9%	40.4%	-0.3%	13.4%
2050s	1000	20	-27.2%	-25.2%	-22.7%	-18.1%	-10.3%	-0.8%	9.2%	17.8%	22.9%	32.5%	35.8%	0.0%	14.2%
2050s	1000	30	-29.1%	-27.5%	-20.0%	-16.6%	-7.5%	-0.1%	12.4%	22.7%	25.7%	36.0%	43.2%	2.0%	15.3%
2050s	1000	50	-29.1%	-28.1%	-21.2%	-17.8%	-12.2%	-0.8%	9.6%	23.7%	25.9%	33.3%	33.5%	0.2%	15.0%
2050s	1000	75	-35.4%	-27.5%	-24.3%	-17.5%	-9.8%	-2.9%	7.9%	19.9%	21.4%	30.2%	32.9%	-1.4%	13.7%
2050s	1000	90	-34.2%	-28.4%	-21.4%	-15.8%	-6.4%	-1.1%	10.8%	16.6%	25.3%	30.9%	34.9%	0.8%	13.6%
2050s	1000	120	-26.6%	-23.7%	-11.1%	-9.1%	-4.1%	3.2%	10.7%	17.3%	20.1%	30.8%	39.1%	3.5%	11.7%
2050s	2000	1	-27.1%	-24.2%	-13.3%	-11.2%	-3.2%	11.4%	22.8%	42.9%	50.0%	62.6%	72.8%	12.9%	20.1%
2050s	2000	2	-22.5%	-22.3%	-17.0%	-15.6%	-6.8%	7.8%	20.6%	35.6%	38.4%	48.6%	52.0%	8.5%	18.3%
2050s	2000	3	-26.3%	-25.3%	-14.7%	-13.5%	-6.7%	2.6%	19.0%	32.3%	36.4%	39.8%	42.7%	6.6%	16.8%
2050s	2000	4	-25.4%	-22.6%	-19.2%	-14.8%	-7.5%	4.7%	15.1%	28.6%	33.3%	41.9%	43.0%	5.2%	16.4%
2050s	2000	5	-23.6%	-22.2%	-20.2%	-15.0%	-6.2%	3.6%	13.9%	24.3%	29.4%	39.8%	43.2%	3.8%	15.2%
2050s	2000	6	-23.9%	-23.4%	-20.1%	-17.7%	-9.5%	1.2%	13.8%	24.7%	29.4%	39.1%	42.0%	2.7%	15.7%
2050s	2000	7	-23.3%	-23.1%	-20.5%	-16.1%	-10.0%	1.1%	10.9%	22.9%	27.1%	35.3%	47.7%	1.5%	15.0%
2050s	2000	10	-21.3%	-20.8%	-18.7%	-17.5%	-10.3%	-3.3%	8.0%	16.2%	25.5%	37.8%	41.3%	-0.3%	13.8%
2050s	2000	20	-27.9%	-25.7%	-22.8%	-18.6%	-10.7%	-0.7%	9.7%	18.6%	23.8%	33.2%	36.5%	0.1%	14.6%
2050s	2000	30	-29.5%	-27.8%	-20.5%	-16.8%	-7.7%	-0.1%	13.0%	23.9%	26.8%	36.8%	44.3%	2.1%	15.8%
2050s	2000	50	-29.6%	-28.6%	-21.8%	-18.2%	-12.8%	-1.3%	10.2%	24.4%	26.6%	34.1%	34.9%	0.2%	15.4%
2050s	2000	75	-36.0%	-28.3%	-24.7%	-17.9%	-10.1%	-2.9%	8.2%	20.5%	22.2%	31.4%	33.8%	-1.5%	14.1%
2050s	2000	90	-34.8%	-29.2%	-22.0%	-16.3%	-7.0%	-1.2%	11.1%	17.3%	26.3%	32.0%	35.9%	0.8%	14.0%
2050s	2000	120	-27.0%	-24.2%	-11.6%	-9.4%	-4.1%	3.2%	10.9%	18.0%	21.0%	32.2%	40.5%	3.6%	12.1%
2050s	10000	1	-28.8%	-25.3%	-14.0%	-12.0%	-3.5%	11.8%	24.2%	44.7%	52.5%	65.2%	76.8%	13.3%	21.1%
2050s	10000	2	-23.4%	-23.0%	-18.5%	-17.0%	-7.6%	8.1%	22.1%	37.3%	39.6%	52.2%	56.3%	8.7%	19.4%
2050s	10000	3	-27.4%	-27.0%	-15.9%	-14.3%	-7.2%	2.1%	20.0%	33.3%	38.9%	42.4%	44.1%	6.8%	17.9%
2050s	10000	4	-26.4%	-24.1%	-20.3%	-15.7%	-8.0%	5.1%	15.6%	30.6%	35.9%	44.5%	46.5%	5.4%	17.4%
2050s	10000	5	-24.6%	-23.3%	-20.8%	-15.9%	-6.8%	3.7%	14.3%	25.3%	30.6%	42.0%	46.9%	3.9%	16.1%
2050s	10000	6	-25.0%	-24.0%	-21.4%	-18.9%	-9.6%	1.3%	14.5%	25.9%	31.4%	42.1%	44.2%	2.7%	16.6%
2050s	10000	7	-24.0%	-23.9%	-22.1%	-17.1%	-10.5%	0.6%	11.4%	23.7%	28.9%	37.8%	50.5%	1.5%	15.8%
2050s	10000	10	-22.6%	-21.3%	-20.0%	-18.2%	-10.9%	-3.7%	8.2%	17.7%	27.4%	39.5%	43.1%	-0.3%	14.5%
2050s	10000	20	-29.1%	-26.6%	-23.6%	-19.6%	-11.4%	-0.9%	10.3%	20.0%	25.6%	34.6%	37.8%	0.2%	15.3%
2050s	10000	30	-30.1%	-28.4%	-20.9%	-17.8%	-8.2%	-0.1%	14.1%	25.9%	28.3%	38.5%	46.5%	2.4%	16.7%
2050s	10000	50	-30.6%	-29.4%	-22.9%	-18.7%	-13.2%	-1.9%	11.0%	25.8%	28.4%	35.8%	37.7%	0.2%	16.3%
2050s	10000	75	-37.3%	-30.0%	-25.4%	-18.6%	-11.1%	-2.8%	8.5%	20.9%	23.6%	33.8%	35.7%	-1.6%	14.9%
2050s	10000	90	-36.0%	-30.6%	-23.1%	-17.1%	-7.9%	-1.4%	11.9%	18.8%	28.4%	34.1%	37.8%	0.9%	14.8%
2050s	10000	120	-27.7%	-25.6%	-12.8%	-9.9%	-4.5%	3.2%	11.5%	19.6%	22.9%	34.9%	43.3%	3.8%	12.9%
2080s	2	1	-9.2%	-4.6%	-1.8%	-0.5%	4.5%	12.0%	18.3%	23.6%	27.5%	37.9%	57.1%	12.2%	10.3%
2080s	2	2	-9.0%	-9.0%	-2.9%	-0.2%	3.8%	8.4%	13.8%	18.6%	22.7%	40.1%	49.5%	9.4%	9.2%
2080s	2	3	-14.5%	-12.3%	-6.3%	-1.6%	1.3%	6.2%	10.7%	16.8%	19.0%	34.1%	40.7%	6.7%	8.7%
2080s	2	4	-16.1%	-12.6%	-6.5%	-4.7%	-0.2%	4.3%	9.0%	16.9%	18.4%	25.3%	31.7%	4.9%	8.3%
2080s	2	5	-17.1%	-13.6%	-9.8%	-7.5%	-1.6%	3.1%	7.8%	17.2%	18.1%	21.7%	24.9%	3.7%	8.6%
2080s	2	6	-19.5%	-15.1%	-12.2%	-8.2%	-3.9%	2.4%	7.5%	14.6%	16.4%	22.2%	23.0%	2.5%	8.7%
2080s	2	7	-21.3%	-20.6%	-13.5%	-9.9%	-3.6%	2.1%	7.1%	13.9%	16.5%	23.6%	24.4%	1.8%	9.3%

Extreme Rainfall Statistics for Selected Return Periods and Durations

Period	Return Period (years)	Duration (days)	Minimum	1%	5%	10%	25%	50%	75%	90%	95%	99%	Maximum	Mean	Standard Deviation
2080s	2	10	-22.7%	-22.6%	-15.6%	-11.1%	-4.7%	0.3%	5.0%	12.0%	13.8%	23.3%	25.1%	-0.1%	9.6%
2080s	2	20	-24.2%	-24.0%	-14.6%	-12.4%	-6.8%	-0.4%	5.3%	9.1%	12.4%	19.8%	25.1%	-0.9%	9.2%
2080s	2	30	-24.2%	-21.4%	-14.7%	-11.6%	-5.2%	-0.3%	5.6%	11.6%	13.2%	17.7%	21.7%	-0.2%	8.9%
2080s	2	50	-18.2%	-15.5%	-10.8%	-8.4%	-3.1%	2.0%	6.7%	14.4%	17.0%	19.9%	23.2%	2.4%	8.5%
2080s	2	75	-17.7%	-15.2%	-10.6%	-9.1%	-4.2%	1.9%	6.5%	13.8%	15.3%	19.7%	24.6%	1.7%	8.4%
2080s	2	90	-17.5%	-15.7%	-12.4%	-8.9%	-4.6%	1.8%	7.0%	13.0%	14.7%	20.5%	26.1%	1.5%	8.5%
2080s	2	120	-18.0%	-16.3%	-9.1%	-8.1%	-1.6%	3.3%	8.6%	13.8%	15.6%	22.9%	26.8%	3.2%	8.5%
2080s	5	1	-13.1%	-7.9%	-5.7%	-3.4%	4.0%	13.1%	21.6%	26.8%	32.7%	50.7%	68.6%	13.4%	13.4%
2080s	5	2	-8.8%	-7.9%	-5.5%	-2.7%	3.7%	8.5%	16.8%	24.6%	30.0%	43.4%	57.6%	10.5%	11.6%
2080s	5	3	-13.1%	-9.7%	-6.6%	-4.0%	0.4%	5.7%	13.3%	24.5%	26.8%	39.4%	45.6%	7.8%	11.0%
2080s	5	4	-13.4%	-12.1%	-6.8%	-5.5%	-0.8%	4.6%	10.9%	20.9%	25.2%	32.9%	35.1%	5.9%	10.1%
2080s	5	5	-12.9%	-11.5%	-8.1%	-5.8%	-1.7%	2.5%	9.6%	18.4%	22.7%	28.1%	33.5%	4.5%	9.8%
2080s	5	6	-15.3%	-13.2%	-10.3%	-8.2%	-3.9%	1.3%	9.2%	16.9%	21.0%	26.9%	28.5%	2.9%	9.8%
2080s	5	7	-17.7%	-17.3%	-12.6%	-9.7%	-5.7%	0.1%	7.9%	18.2%	20.9%	25.6%	27.1%	1.9%	10.3%
2080s	5	10	-21.1%	-20.9%	-14.6%	-12.8%	-7.7%	-0.6%	6.0%	16.0%	17.5%	24.0%	27.3%	-0.3%	10.7%
2080s	5	20	-25.9%	-24.2%	-15.8%	-14.4%	-7.9%	-0.8%	5.1%	10.8%	15.1%	21.2%	23.5%	-1.0%	10.2%
2080s	5	30	-23.4%	-23.0%	-18.8%	-11.8%	-7.5%	0.4%	6.8%	11.5%	14.5%	24.1%	25.8%	-0.1%	10.2%
2080s	5	50	-20.0%	-18.9%	-15.3%	-10.8%	-4.7%	0.9%	7.4%	14.1%	16.2%	22.2%	24.9%	1.4%	9.6%
2080s	5	75	-20.4%	-19.5%	-14.6%	-13.6%	-5.6%	0.8%	5.8%	11.4%	12.9%	21.5%	28.3%	0.2%	9.5%
2080s	5	90	-21.2%	-20.1%	-14.4%	-13.2%	-4.6%	1.5%	7.4%	11.0%	12.1%	20.7%	28.5%	0.7%	9.5%
2080s	5	120	-19.0%	-18.8%	-12.9%	-8.4%	-3.0%	3.6%	8.5%	12.7%	14.5%	25.3%	29.8%	2.9%	8.9%
2080s	10	1	-14.9%	-11.2%	-8.0%	-5.1%	2.0%	13.4%	23.7%	31.2%	33.5%	57.2%	74.1%	13.9%	15.3%
2080s	10	2	-12.8%	-10.9%	-5.8%	-3.7%	1.4%	9.1%	19.1%	26.0%	34.4%	45.4%	61.5%	11.1%	13.2%
2080s	10	3	-15.3%	-11.3%	-8.0%	-5.7%	0.5%	5.1%	14.0%	26.7%	31.1%	43.9%	48.0%	8.4%	12.6%
2080s	10	4	-14.8%	-13.1%	-8.4%	-6.4%	-2.1%	4.3%	12.7%	25.4%	28.8%	37.4%	39.5%	6.4%	11.6%
2080s	10	5	-13.1%	-12.5%	-8.5%	-7.0%	-2.0%	3.1%	11.5%	20.1%	26.2%	33.7%	41.4%	4.9%	11.0%
2080s	10	6	-13.3%	-12.9%	-11.2%	-8.6%	-4.5%	1.1%	11.6%	17.3%	22.2%	32.6%	35.0%	3.2%	10.8%
2080s	10	7	-16.0%	-15.8%	-12.4%	-10.5%	-6.6%	-0.2%	10.3%	18.2%	22.1%	30.5%	33.0%	2.0%	11.3%
2080s	10	10	-20.3%	-20.1%	-15.5%	-14.0%	-9.6%	-0.9%	5.5%	17.6%	19.7%	26.5%	30.5%	-0.3%	11.6%
2080s	10	20	-26.6%	-25.4%	-17.8%	-15.1%	-8.1%	-1.2%	6.7%	12.2%	15.3%	22.9%	26.1%	-1.0%	11.0%
2080s	10	30	-24.6%	-24.4%	-20.2%	-12.5%	-7.9%	0.5%	7.4%	11.9%	15.8%	27.9%	28.1%	0.0%	11.2%
2080s	10	50	-22.4%	-22.1%	-15.2%	-13.3%	-6.0%	0.2%	9.2%	14.8%	16.8%	23.8%	25.8%	0.9%	10.4%
2080s	10	75	-23.6%	-23.3%	-17.1%	-15.1%	-6.3%	0.9%	5.9%	11.8%	13.9%	22.4%	30.3%	-0.4%	10.3%
2080s	10	90	-24.1%	-23.2%	-16.5%	-13.8%	-5.8%	1.5%	7.6%	10.3%	12.6%	21.8%	29.7%	0.3%	10.2%
2080s	10	120	-20.6%	-20.6%	-13.8%	-8.4%	-2.2%	4.1%	9.0%	12.5%	14.6%	26.5%	31.3%	2.8%	9.3%
2080s	25	1	-16.6%	-14.6%	-9.5%	-7.0%	1.1%	13.4%	26.3%	33.5%	38.1%	63.7%	79.6%	14.5%	17.3%
2080s	25	2	-17.7%	-14.1%	-8.3%	-4.9%	1.0%	9.9%	20.9%	27.9%	39.7%	48.9%	65.3%	11.6%	14.9%
2080s	25	3	-17.5%	-14.3%	-9.6%	-7.3%	0.6%	6.1%	15.2%	30.8%	35.4%	49.4%	50.5%	9.0%	14.3%
2080s	25	4	-16.1%	-14.1%	-10.6%	-9.1%	-2.6%	4.6%	14.7%	29.2%	32.9%	40.5%	47.0%	6.9%	13.3%
2080s	25	5	-13.6%	-13.4%	-10.8%	-8.0%	-3.2%	3.2%	12.6%	22.1%	27.5%	39.4%	49.5%	5.4%	12.5%
2080s	25	6	-13.1%	-13.0%	-12.0%	-10.9%	-4.9%	0.8%	12.3%	19.7%	24.3%	38.5%	41.6%	3.5%	12.1%
2080s	25	7	-15.2%	-15.0%	-13.2%	-11.6%	-8.1%	-0.1%	11.6%	18.4%	24.2%	35.6%	39.0%	2.1%	12.4%
2080s	25	10	-19.7%	-19.6%	-16.9%	-15.7%	-11.1%	-1.0%	7.2%	19.1%	22.5%	30.2%	33.6%	-0.2%	12.8%
2080s	25	20	-27.3%	-26.4%	-19.0%	-16.3%	-9.8%	-1.2%	7.2%	12.5%	17.2%	25.1%	28.6%	-1.0%	11.9%
2080s	25	30	-25.8%	-25.7%	-21.3%	-14.3%	-8.8%	0.4%	8.0%	13.8%	17.0%	30.7%	32.8%	0.1%	12.3%
2080s	25	50	-25.1%	-24.8%	-18.0%	-13.7%	-5.9%	0.3%	8.5%	15.3%	17.6%	25.3%	26.7%	0.5%	11.4%
2080s	25	75	-27.6%	-26.2%	-20.0%	-16.5%	-7.1%	-0.2%	6.7%	11.4%	15.4%	23.3%	32.2%	-1.0%	11.2%
2080s	25	90	-26.8%	-26.1%	-19.1%	-14.7%	-6.3%	1.3%	8.2%	11.3%	14.6%	23.1%	30.9%	-0.1%	11.0%
2080s	25	120	-22.5%	-22.2%	-14.3%	-8.5%	-3.4%	4.6%	9.5%	13.4%	15.2%	27.7%	32.8%	2.7%	9.9%
2080s	50	1	-17.7%	-16.7%	-10.8%	-8.0%	0.3%	13.9%	27.3%	34.1%	39.8%	67.7%	83.0%	14.9%	18.5%
2080s	50	2	-20.6%	-16.0%	-8.8%	-5.9%	-0.2%	10.4%	21.7%	29.6%	41.5%	51.0%	67.6%	12.0%	15.9%
2080s	50	3	-18.8%	-16.1%	-10.7%	-8.5%	0.4%	6.8%	15.7%	33.1%	38.0%	52.3%	53.1%	9.4%	15.5%
2080s	50	4	-16.9%	-15.7%	-12.4%	-10.5%	-3.6%	4.8%	15.9%	30.5%	35.5%	42.4%	51.6%	7.3%	14.4%
2080s	50	5	-14.4%	-13.7%	-12.9%	-8.8%	-3.4%	3.1%	13.2%	23.5%	30.4%	42.9%	54.6%	5.7%	13.4%
2080s	50	6	-14.3%	-14.1%	-12.5%	-10.8%	-5.5%	-0.2%	13.0%	20.7%	25.1%	42.2%	45.7%	3.7%	13.0%
2080s	50	7	-15.7%	-15.3%	-13.9%	-12.2%	-8.8%	-0.4%	12.2%	19.7%	25.4%	38.6%	42.7%	2.2%	13.1%

Extreme Rainfall Statistics for Selected Return Periods and Durations

Period	Return Period (years)	Duration (days)	Minimum	1%	5%	10%	25%	50%	75%	90%	95%	99%	Maximum	Mean	Standard Deviation
2080s	50	10	-19.7%	-19.3%	-18.6%	-16.8%	-12.1%	-0.9%	7.9%	19.8%	23.4%	32.4%	35.6%	-0.2%	13.5%
2080s	50	20	-27.7%	-27.1%	-19.8%	-17.5%	-11.0%	-0.9%	7.5%	14.3%	18.7%	26.6%	30.1%	-1.0%	12.5%
2080s	50	30	-26.6%	-26.4%	-22.9%	-15.3%	-9.0%	0.6%	8.9%	15.0%	17.8%	32.4%	35.6%	0.2%	13.0%
2080s	50	50	-26.8%	-26.2%	-19.6%	-15.0%	-6.7%	0.4%	8.4%	16.1%	17.9%	26.2%	27.3%	0.3%	12.0%
2080s	50	75	-29.9%	-28.0%	-21.7%	-17.3%	-7.6%	-0.7%	6.6%	11.0%	16.8%	23.9%	33.5%	-1.4%	11.8%
2080s	50	90	-28.4%	-27.8%	-20.4%	-15.2%	-6.5%	0.9%	7.7%	12.3%	15.9%	23.9%	31.7%	-0.3%	11.6%
2080s	50	120	-23.6%	-23.2%	-15.4%	-9.0%	-4.7%	4.4%	9.2%	13.3%	16.3%	28.5%	33.8%	2.7%	10.4%
2080s	100	1	-18.5%	-18.3%	-11.8%	-8.8%	-0.2%	14.2%	28.9%	35.4%	40.9%	71.1%	85.7%	15.2%	19.5%
2080s	100	2	-23.0%	-17.5%	-9.0%	-6.8%	-0.9%	10.7%	22.9%	31.2%	42.5%	53.0%	69.5%	12.3%	16.8%
2080s	100	3	-19.8%	-17.6%	-11.5%	-9.3%	-0.5%	7.4%	16.8%	34.8%	40.3%	54.0%	56.4%	9.7%	16.4%
2080s	100	4	-17.6%	-17.1%	-14.2%	-11.7%	-4.5%	4.5%	16.9%	31.4%	37.7%	45.7%	55.6%	7.6%	15.4%
2080s	100	5	-15.0%	-15.0%	-13.6%	-9.9%	-4.2%	3.4%	13.6%	24.1%	32.8%	46.0%	58.9%	5.9%	14.3%
2080s	100	6	-15.7%	-15.1%	-13.3%	-11.7%	-6.1%	-0.6%	13.2%	21.5%	27.4%	45.4%	49.2%	3.9%	13.8%
2080s	100	7	-16.4%	-16.3%	-14.7%	-12.6%	-9.3%	-0.5%	12.6%	20.6%	26.4%	41.3%	45.9%	2.3%	13.8%
2080s	100	10	-20.2%	-20.0%	-18.9%	-17.7%	-12.6%	-1.0%	8.2%	20.1%	23.7%	34.3%	37.2%	-0.2%	14.2%
2080s	100	20	-28.0%	-27.6%	-20.5%	-18.1%	-11.4%	-1.1%	7.7%	15.4%	19.6%	27.9%	31.3%	-0.9%	13.0%
2080s	100	30	-27.2%	-27.0%	-24.3%	-16.4%	-9.3%	0.5%	9.0%	16.1%	18.4%	33.8%	38.1%	0.2%	13.6%
2080s	100	50	-28.3%	-27.4%	-20.4%	-16.2%	-7.4%	0.5%	8.2%	16.7%	18.3%	27.0%	27.7%	0.1%	12.5%
2080s	100	75	-31.8%	-29.4%	-23.1%	-18.0%	-8.1%	-0.9%	6.5%	10.8%	17.8%	24.3%	34.5%	-1.7%	12.3%
2080s	100	90	-29.7%	-29.2%	-21.5%	-15.6%	-7.2%	0.4%	7.6%	13.2%	16.5%	24.5%	32.4%	-0.5%	12.1%
2080s	100	120	-24.5%	-24.0%	-16.4%	-9.4%	-5.7%	3.8%	9.0%	13.7%	17.5%	29.1%	34.6%	2.6%	10.8%
2080s	200	1	-19.9%	-19.4%	-12.7%	-9.6%	-0.7%	14.7%	30.4%	36.7%	41.7%	74.0%	88.2%	15.4%	20.4%
2080s	200	2	-25.0%	-18.8%	-9.9%	-7.6%	-1.4%	11.0%	23.9%	32.6%	44.4%	55.3%	71.2%	12.5%	17.6%
2080s	200	3	-20.7%	-18.9%	-12.2%	-10.4%	-0.8%	7.9%	17.8%	36.3%	42.3%	55.6%	59.4%	10.0%	17.3%
2080s	200	4	-18.3%	-18.2%	-15.0%	-12.7%	-5.0%	4.8%	18.0%	32.2%	39.6%	48.5%	59.2%	7.8%	16.3%
2080s	200	5	-16.7%	-15.8%	-14.0%	-10.7%	-4.5%	3.5%	14.1%	24.7%	35.0%	48.7%	62.7%	6.1%	15.1%
2080s	200	6	-16.9%	-16.0%	-13.6%	-12.2%	-6.6%	-0.4%	13.5%	22.5%	28.6%	48.2%	52.3%	4.0%	14.5%
2080s	200	7	-17.7%	-17.1%	-15.2%	-12.4%	-9.8%	-0.4%	13.0%	21.6%	27.6%	43.6%	48.7%	2.4%	14.4%
2080s	200	10	-21.4%	-21.2%	-19.3%	-18.3%	-12.9%	-1.1%	8.6%	19.9%	24.0%	36.0%	38.7%	-0.2%	14.8%
2080s	200	20	-28.3%	-28.0%	-21.1%	-18.7%	-11.6%	-1.4%	7.7%	16.3%	20.5%	29.0%	32.4%	-0.9%	13.5%
2080s	200	30	-27.8%	-27.5%	-25.4%	-16.9%	-9.6%	0.1%	9.6%	17.0%	18.9%	35.1%	40.3%	0.3%	14.2%
2080s	200	50	-29.5%	-28.4%	-21.5%	-17.1%	-8.0%	0.6%	7.9%	17.4%	18.9%	27.6%	28.1%	-0.1%	12.9%
2080s	200	75	-33.3%	-30.6%	-24.2%	-18.6%	-8.8%	-0.7%	6.7%	11.5%	18.0%	24.7%	35.4%	-1.9%	12.7%
2080s	200	90	-30.9%	-30.4%	-22.6%	-15.9%	-7.8%	0.0%	7.7%	14.1%	17.1%	25.1%	33.0%	-0.6%	12.5%
2080s	200	120	-25.3%	-24.7%	-17.3%	-9.7%	-6.1%	4.2%	9.4%	14.4%	18.4%	29.6%	35.3%	2.6%	11.1%
2080s	500	1	-21.7%	-20.4%	-13.6%	-10.5%	-1.4%	15.3%	32.1%	38.2%	43.7%	77.3%	90.9%	15.7%	21.4%
2080s	500	2	-27.2%	-20.3%	-11.1%	-8.6%	-1.8%	11.2%	25.0%	34.2%	46.5%	57.8%	73.1%	12.8%	18.5%
2080s	500	3	-21.7%	-20.3%	-13.0%	-11.5%	-0.8%	8.5%	18.9%	38.7%	44.5%	57.3%	62.8%	10.4%	18.3%
2080s	500	4	-19.8%	-19.0%	-16.4%	-13.7%	-5.5%	5.5%	18.8%	33.1%	41.8%	51.8%	63.2%	8.1%	17.3%
2080s	500	5	-18.7%	-16.9%	-14.9%	-11.7%	-5.0%	4.1%	15.1%	25.4%	37.5%	51.7%	67.0%	6.4%	15.9%
2080s	500	6	-18.2%	-16.9%	-14.5%	-12.6%	-7.2%	-0.2%	14.0%	23.7%	29.8%	51.4%	55.8%	4.2%	15.3%
2080s	500	7	-19.2%	-18.5%	-15.3%	-13.3%	-9.8%	-0.8%	13.2%	23.0%	29.5%	46.2%	51.9%	2.5%	15.1%
2080s	500	10	-22.7%	-22.5%	-19.7%	-18.2%	-13.0%	-1.4%	9.2%	20.9%	25.1%	37.8%	40.3%	-0.1%	15.5%
2080s	500	20	-28.6%	-28.5%	-22.0%	-19.2%	-11.5%	-1.7%	7.8%	17.3%	21.5%	30.2%	33.6%	-0.9%	14.0%
2080s	500	30	-28.4%	-28.0%	-26.6%	-17.3%	-9.9%	0.7%	10.1%	18.1%	20.1%	36.5%	42.8%	0.4%	14.8%
2080s	500	50	-30.9%	-29.5%	-22.9%	-18.0%	-8.5%	0.1%	7.6%	18.0%	19.5%	28.4%	28.6%	-0.3%	13.5%
2080s	500	75	-35.0%	-31.9%	-25.4%	-20.0%	-9.2%	-1.2%	6.8%	12.7%	18.3%	25.2%	36.5%	-2.2%	13.3%
2080s	500	90	-32.1%	-31.7%	-23.8%	-16.6%	-8.4%	-0.1%	7.5%	15.1%	17.8%	25.7%	33.6%	-0.8%	13.0%
2080s	500	120	-26.1%	-25.4%	-18.2%	-10.1%	-6.2%	3.7%	9.6%	15.1%	19.1%	30.3%	36.2%	2.6%	11.6%
2080s	1000	1	-22.9%	-21.1%	-14.2%	-11.0%	-1.7%	15.6%	33.2%	39.4%	45.0%	79.4%	92.6%	15.9%	22.1%
2080s	1000	2	-28.6%	-21.2%	-11.8%	-9.1%	-2.0%	11.4%	25.5%	35.2%	47.9%	59.4%	74.3%	13.0%	19.1%
2080s	1000	3	-22.3%	-21.2%	-13.7%	-12.2%	-1.1%	8.6%	19.6%	40.4%	46.0%	58.5%	65.0%	10.6%	18.9%
2080s	1000	4	-20.8%	-19.5%	-17.0%	-14.4%	-5.9%	5.9%	19.2%	33.6%	42.9%	54.0%	65.8%	8.3%	17.9%
2080s	1000	5	-19.9%	-17.7%	-15.6%	-12.3%	-5.3%	4.6%	15.7%	25.8%	39.1%	53.8%	69.8%	6.6%	16.5%
2080s	1000	6	-19.1%	-17.4%	-15.2%	-12.8%	-7.3%	0.3%	14.2%	24.5%	30.7%	53.5%	58.1%	4.3%	15.8%
2080s	1000	7	-20.1%	-19.4%	-15.8%	-13.9%	-9.9%	-1.0%	13.1%	24.0%	30.2%	47.9%	53.9%	2.6%	15.5%

Extreme Rainfall Statistics for Selected Return Periods and Durations

Period	Return Period (years)	Duration (days)	Minimum	1%	5%	10%	25%	50%	75%	90%	95%	99%	Maximum	Mean	Standard Deviation
2080s	1000	10	-23.5%	-23.4%	-19.8%	-18.8%	-13.1%	-1.5%	9.6%	21.6%	25.9%	39.3%	41.4%	-0.1%	15.9%
2080s	1000	20	-28.8%	-28.8%	-22.7%	-19.6%	-11.6%	-1.6%	8.4%	18.0%	22.2%	31.0%	34.4%	-0.8%	14.4%
2080s	1000	30	-28.8%	-28.5%	-27.4%	-17.8%	-10.3%	1.0%	10.3%	18.6%	21.0%	37.5%	44.5%	0.4%	15.2%
2080s	1000	50	-31.7%	-30.2%	-23.8%	-18.5%	-8.8%	-0.3%	7.8%	18.1%	19.9%	28.9%	28.9%	-0.4%	13.8%
2080s	1000	75	-36.1%	-32.8%	-26.1%	-20.9%	-9.7%	-1.7%	6.5%	13.3%	18.5%	26.0%	37.1%	-2.4%	13.6%
2080s	1000	90	-32.9%	-32.6%	-24.6%	-17.3%	-8.7%	-0.4%	7.4%	15.7%	18.3%	26.1%	34.1%	-0.9%	13.3%
2080s	1000	120	-26.7%	-25.9%	-18.8%	-10.5%	-6.2%	3.6%	9.8%	15.5%	19.6%	30.7%	36.7%	2.6%	11.9%
2080s	2000	1	-23.9%	-21.7%	-14.8%	-11.5%	-2.1%	16.0%	33.9%	40.4%	46.1%	81.3%	94.2%	16.1%	22.7%
2080s	2000	2	-29.9%	-22.0%	-12.5%	-9.6%	-2.4%	11.6%	25.5%	36.2%	49.0%	60.9%	75.4%	13.2%	19.6%
2080s	2000	3	-22.9%	-22.0%	-14.4%	-12.7%	-1.4%	8.7%	20.3%	41.8%	47.4%	59.5%	67.0%	10.8%	19.5%
2080s	2000	4	-21.6%	-20.3%	-17.6%	-15.0%	-6.1%	6.1%	19.5%	34.2%	44.5%	56.0%	68.2%	8.5%	18.5%
2080s	2000	5	-20.9%	-18.5%	-16.3%	-12.8%	-5.6%	4.9%	16.3%	26.2%	40.2%	55.6%	72.4%	6.7%	17.1%
2080s	2000	6	-19.8%	-18.0%	-15.9%	-13.2%	-7.5%	0.6%	14.4%	25.2%	31.8%	55.4%	60.2%	4.5%	16.3%
2080s	2000	7	-20.9%	-20.2%	-16.2%	-14.4%	-10.1%	-1.1%	13.1%	24.7%	30.7%	49.4%	55.8%	2.6%	15.9%
2080s	2000	10	-24.2%	-24.2%	-20.3%	-19.3%	-13.2%	-1.8%	10.0%	22.2%	26.5%	41.0%	42.3%	0.0%	16.3%
2080s	2000	20	-29.1%	-29.0%	-23.2%	-19.9%	-11.6%	-1.3%	8.8%	18.5%	22.9%	31.7%	35.1%	-0.8%	14.7%
2080s	2000	30	-29.2%	-29.0%	-28.1%	-18.3%	-10.7%	1.0%	10.2%	18.9%	21.8%	38.4%	46.0%	0.5%	15.6%
2080s	2000	50	-32.4%	-30.9%	-24.5%	-19.0%	-9.2%	-0.6%	7.9%	18.5%	20.3%	29.2%	29.3%	-0.5%	14.2%
2080s	2000	75	-37.1%	-33.5%	-26.8%	-21.7%	-9.9%	-2.1%	6.3%	13.7%	18.6%	26.7%	37.8%	-2.6%	13.9%
2080s	2000	90	-33.6%	-33.3%	-25.2%	-17.9%	-9.0%	-0.5%	7.3%	16.1%	18.9%	26.5%	34.4%	-1.0%	13.6%
2080s	2000	120	-27.2%	-26.4%	-19.3%	-11.1%	-6.2%	3.9%	10.0%	15.9%	20.0%	31.0%	37.2%	2.6%	12.2%
2080s	10000	1	-25.8%	-22.8%	-15.8%	-12.5%	-2.8%	16.6%	35.5%	42.2%	48.3%	85.1%	97.2%	16.4%	23.8%
2080s	10000	2	-32.2%	-23.6%	-13.7%	-10.5%	-3.0%	12.6%	25.7%	38.4%	51.3%	63.8%	77.4%	13.6%	20.7%
2080s	10000	3	-24.0%	-23.5%	-15.6%	-13.8%	-2.0%	9.2%	21.5%	44.7%	50.3%	61.6%	70.9%	11.2%	20.7%
2080s	10000	4	-23.3%	-22.2%	-18.6%	-15.9%	-6.7%	6.8%	20.5%	35.9%	47.0%	59.9%	72.9%	8.9%	19.7%
2080s	10000	5	-23.0%	-19.8%	-17.5%	-13.8%	-6.1%	5.5%	17.1%	26.9%	42.2%	59.2%	77.4%	7.1%	18.1%
2080s	10000	6	-21.2%	-19.3%	-16.8%	-14.0%	-8.1%	0.7%	14.7%	26.3%	34.0%	59.2%	64.3%	4.7%	17.2%
2080s	10000	7	-22.4%	-21.7%	-17.1%	-15.0%	-10.2%	-1.3%	13.2%	25.8%	31.7%	52.4%	59.5%	2.7%	16.7%
2080s	10000	10	-25.8%	-25.7%	-21.1%	-19.8%	-13.5%	-2.1%	11.1%	22.9%	27.8%	44.2%	44.2%	0.0%	17.1%
2080s	10000	20	-29.6%	-29.3%	-24.3%	-20.5%	-11.7%	-0.9%	9.0%	19.4%	24.1%	33.1%	36.5%	-0.7%	15.3%
2080s	10000	30	-30.1%	-29.9%	-29.0%	-19.2%	-11.4%	1.6%	10.4%	19.5%	23.4%	40.1%	49.0%	0.6%	16.3%
2080s	10000	50	-33.8%	-32.0%	-26.1%	-20.0%	-9.9%	-0.8%	8.1%	19.3%	21.4%	29.9%	30.2%	-0.7%	14.8%
2080s	10000	75	-38.9%	-34.9%	-28.1%	-22.9%	-10.3%	-2.5%	5.9%	14.0%	18.9%	28.2%	39.0%	-2.9%	14.5%
2080s	10000	90	-35.0%	-34.8%	-26.6%	-19.2%	-9.4%	-1.1%	6.9%	16.8%	20.3%	27.2%	35.2%	-1.1%	14.2%
2080s	10000	120	-28.1%	-27.2%	-20.1%	-12.4%	-6.7%	3.8%	10.1%	16.7%	20.8%	31.7%	38.2%	2.5%	12.7%

Variable	Drought/Surplus SPEI Index
Units	%
Area	Nearest Grid Cell to Mine site
Baseline	Projected changes calculated from model baseline (1991 - 2020)

Drought/Surplus Statistics Based on Annual Minimum/Maximum SPEI Index for Select Return Periods

Type	Period	Return Period (years)	Minimum	1%	5%	10%	25%	50%	75%	90%	95%	99%	Maximum	Mean	Standard Deviation
Drought	2050s	2	-22.5%	-19.1%	-16.5%	-10.4%	-5.0%	-1.0%	6.3%	12.2%	13.0%	17.9%	17.9%	0.2%	9.1%
Drought	2050s	5	-12.9%	-12.5%	-9.4%	-8.4%	-4.7%	-0.6%	4.9%	7.6%	9.1%	12.2%	12.3%	-0.4%	6.3%
Drought	2050s	10	-14.2%	-14.2%	-11.0%	-9.5%	-6.3%	-1.5%	3.3%	9.0%	12.1%	16.6%	17.4%	-0.9%	7.1%
Drought	2050s	25	-21.0%	-18.8%	-15.7%	-14.5%	-10.0%	-1.5%	3.9%	10.1%	16.1%	28.1%	33.8%	-1.5%	10.4%
Drought	2050s	50	-25.8%	-23.3%	-20.1%	-17.2%	-11.3%	-3.1%	6.2%	12.9%	19.6%	36.5%	45.6%	-1.9%	13.3%
Drought	2050s	100	-30.1%	-27.4%	-24.8%	-20.2%	-13.7%	-4.5%	8.5%	16.8%	23.9%	44.5%	56.9%	-2.1%	16.2%
Drought	2050s	200	-33.9%	-32.1%	-29.2%	-22.2%	-16.0%	-6.4%	11.0%	20.1%	28.8%	52.0%	67.6%	-2.3%	19.0%
Drought	2050s	500	-39.1%	-38.5%	-33.4%	-24.7%	-18.3%	-8.5%	12.3%	24.9%	37.9%	61.3%	80.9%	-2.4%	22.4%
Drought	2050s	1000	-44.5%	-42.1%	-35.9%	-26.4%	-19.5%	-9.9%	13.7%	28.9%	42.4%	67.8%	90.2%	-2.5%	24.8%
Drought	2050s	2000	-49.4%	-46.0%	-39.1%	-28.1%	-20.4%	-10.5%	14.9%	32.0%	46.1%	73.8%	99.0%	-2.5%	27.0%
Drought	2050s	10000	-59.2%	-53.9%	-45.6%	-31.7%	-23.2%	-12.0%	17.2%	38.3%	53.7%	86.1%	117.1%	-2.4%	31.6%
Drought	2080s	2	-23.8%	-19.3%	-16.8%	-12.5%	-5.7%	-0.4%	6.0%	10.7%	12.5%	17.3%	17.3%	-0.3%	8.7%
Drought	2080s	5	-19.5%	-13.0%	-9.7%	-7.4%	-5.2%	-0.8%	3.1%	8.4%	10.6%	16.9%	22.7%	-0.5%	6.7%
Drought	2080s	10	-15.4%	-14.5%	-10.2%	-8.7%	-6.0%	-0.7%	3.8%	10.7%	13.2%	16.5%	24.9%	-0.4%	7.5%
Drought	2080s	25	-21.1%	-19.0%	-15.5%	-13.0%	-8.0%	-0.5%	6.7%	14.0%	16.5%	21.5%	26.6%	-0.2%	10.3%
Drought	2080s	50	-28.6%	-24.3%	-19.8%	-16.0%	-9.7%	0.3%	8.9%	17.3%	20.0%	25.4%	27.4%	0.1%	12.7%
Drought	2080s	100	-35.5%	-29.9%	-23.4%	-18.2%	-11.8%	-0.1%	10.7%	22.3%	24.6%	29.1%	32.9%	0.4%	15.3%
Drought	2080s	200	-41.7%	-34.8%	-26.3%	-20.2%	-13.3%	2.0%	13.1%	26.0%	28.6%	34.7%	40.5%	0.8%	17.8%
Drought	2080s	500	-49.1%	-40.5%	-30.9%	-23.7%	-15.2%	1.7%	18.2%	29.1%	34.1%	46.0%	49.9%	1.3%	21.0%
Drought	2080s	1000	-54.0%	-44.3%	-33.8%	-25.7%	-15.9%	1.1%	20.0%	30.6%	38.3%	54.3%	56.4%	1.8%	23.3%
Drought	2080s	2000	-58.5%	-47.6%	-36.5%	-27.4%	-16.5%	0.3%	21.2%	33.3%	42.1%	62.4%	62.6%	2.2%	25.4%
Drought	2080s	10000	-67.1%	-54.0%	-41.6%	-30.5%	-18.5%	-0.6%	25.9%	41.8%	50.2%	76.3%	82.6%	3.2%	30.0%
Surplus	2050s	2	-21.3%	-19.1%	-16.7%	-15.8%	-9.8%	-0.6%	4.5%	11.0%	14.1%	19.5%	21.5%	-1.6%	9.9%
Surplus	2050s	5	-16.6%	-13.7%	-9.7%	-7.9%	-5.8%	-1.6%	3.0%	6.3%	8.2%	15.8%	16.5%	-1.2%	6.2%
Surplus	2050s	10	-17.0%	-16.9%	-11.5%	-10.7%	-4.4%	-0.4%	4.4%	7.7%	11.6%	17.1%	19.2%	-0.5%	7.3%
Surplus	2050s	25	-25.0%	-21.7%	-16.5%	-13.2%	-7.3%	1.4%	5.8%	16.9%	19.2%	22.4%	22.5%	0.7%	10.9%
Surplus	2050s	50	-30.1%	-27.4%	-19.7%	-16.8%	-8.5%	2.1%	8.7%	21.4%	25.7%	28.8%	30.5%	1.6%	14.0%
Surplus	2050s	100	-34.4%	-32.1%	-23.2%	-18.9%	-10.5%	2.8%	12.9%	25.8%	33.9%	36.7%	38.2%	2.6%	17.1%
Surplus	2050s	200	-38.2%	-36.2%	-27.0%	-21.4%	-11.7%	2.9%	16.6%	30.5%	40.6%	44.5%	45.5%	3.7%	20.1%
Surplus	2050s	500	-42.4%	-40.6%	-30.2%	-25.5%	-14.4%	4.3%	20.9%	38.8%	51.9%	54.5%	54.6%	5.1%	24.0%
Surplus	2050s	1000	-45.1%	-43.4%	-32.3%	-27.7%	-16.3%	5.2%	24.9%	45.1%	59.9%	62.7%	63.4%	6.2%	26.8%
Surplus	2050s	2000	-47.5%	-45.8%	-34.2%	-29.3%	-17.2%	6.1%	28.3%	51.1%	66.7%	71.5%	72.5%	7.2%	29.5%
Surplus	2050s	10000	-51.9%	-50.2%	-38.1%	-33.3%	-18.2%	8.1%	34.5%	62.9%	78.6%	92.3%	94.5%	9.7%	35.4%
Surplus	2080s	2	-15.3%	-14.8%	-11.7%	-8.7%	-5.4%	-0.5%	5.5%	10.3%	14.6%	21.9%	29.0%	0.4%	8.4%
Surplus	2080s	5	-12.1%	-11.7%	-8.5%	-7.3%	-3.2%	-0.5%	4.4%	9.2%	10.1%	13.0%	13.1%	0.5%	5.9%
Surplus	2080s	10	-14.0%	-13.1%	-10.3%	-8.1%	-2.7%	0.7%	5.3%	8.4%	10.4%	13.4%	14.2%	0.7%	6.3%
Surplus	2080s	25	-19.5%	-18.9%	-15.0%	-11.2%	-4.6%	1.4%	6.8%	11.2%	12.4%	19.2%	27.2%	1.0%	8.8%
Surplus	2080s	50	-23.0%	-22.8%	-18.4%	-12.9%	-6.2%	2.7%	9.3%	14.7%	15.5%	23.0%	37.2%	1.4%	11.1%
Surplus	2080s	100	-26.9%	-26.5%	-21.4%	-15.4%	-8.4%	3.0%	10.6%	17.3%	20.1%	29.4%	46.5%	1.8%	13.6%
Surplus	2080s	200	-31.0%	-29.8%	-24.1%	-18.5%	-10.1%	3.6%	12.8%	21.2%	24.7%	38.0%	55.2%	2.3%	16.0%
Surplus	2080s	500	-35.6%	-33.5%	-27.2%	-23.2%	-11.1%	3.7%	16.2%	26.0%	30.5%	49.4%	65.7%	2.9%	19.2%
Surplus	2080s	1000	-38.6%	-35.9%	-29.2%	-26.7%	-11.4%	3.5%	18.4%	28.9%	34.8%	58.0%	72.9%	3.5%	21.4%
Surplus	2080s	2000	-41.2%	-38.0%	-31.0%	-29.0%	-11.4%	3.4%	20.0%	31.6%	40.1%	66.5%	79.5%	4.0%	23.6%
Surplus	2080s	10000	-46.1%	-41.9%	-37.1%	-32.0%	-12.7%	2.7%	22.7%	39.2%	51.2%	85.8%	92.6%	5.3%	28.2%

Variable	Projected Changes in Wet and Dry Year Statistics at the 50th Percentile
Units	%
Area	Nearest Grid Cell to Mine site
Baseline	Projected changes calculated from model baseline (1991 - 2020)

Projected Changes in Wet and Dry Year for Selected Return Periods

Return Period (years)	2050s		2080s	
	Drier	Wetter	Drier	Wetter
5	3%	4%	6%	7%
10	4%	4%	7%	7%
20	4%	4%	7%	8%
50	4%	3%	7%	8%
100	3%	4%	8%	8%

Appendix D

ECCE Snow Survey Comparison



APPENDIX D – ECCC SNOW SURVEY COMPARISON

1.0 BACKGROUND

Environment and Climate Change Canada (ECCC) provides estimates of combined rainfall and snowmelt extremes for that are readily available for individual climate stations across Canada by using air temperature and precipitation observations to apply the methodology of Louie and Hogg (1980). However, these estimates being provided only for individual stations comes with a set of limitations. Climate stations that are co-located are not combined into a single record, and for the Great Bear Project, more than one station is needed to represent current climate conditions, such that a longer period of record can be achieved, and missing data gaps can be filled (see Section 5.1 of the related main report; *Detailed Climate Change Dataset*). For analysis of combined rainfall and snowmelt extremes, a longer period of record is ideal to gain a more complete representation of extreme events over the historical record. Additionally, missing values in the observational record can impact estimates of combined rainfall and snowmelt extremes, as snowfall that is not captured can artificially reduce the amount of snowpack prior to melting during spring freshet.

For these reasons, combined rainfall and snowmelt extremes are estimated for the Great Bear Project using the same approach as ECCC applied to the current climate baseline to model snow accumulation and melt (see Appendix A of *Detailed Climate Change Dataset* for further details on the methodology). In that appendix, modelled snow accumulation and melt for the Great Bear Project is compared to ECCC snow survey measurements for the Red Lake A climate station to validate the modelled snowpack depth, as this is the driving factor in generating combined rainfall and snowmelt extremes for longer durations (e.g., greater than 10 days) where snowmelt plays an important role. The snow survey measurements are provided by ECCC for the period of 1946 to 1993, while the period of comparison is over the period of 1951 to 1993 where the modelled results and snow depth measurements intersect.

2.0 ECCC SNOW SURVEY

Snow survey measurements are provided by ECCC for the Red Lake A and Ear Falls climate stations. These measurements are obtained through gravimetric samples that are taken from the snowpack to estimate depth-averaged snow density, which is then used to calculate the snow water equivalent. Further details on instrumentation and sampling methods are provided in MNRF (2019).

For comparison to modelling results for the Great Bear Project, snow survey measurements from the Red Lake A station are used. These measurements were collected between January and May from 1946 to 1993, and include information on snow depth in units of height and snow water equivalent. The Ear Falls station also has information available from the snow survey, however, snow depth is not provided in snow water equivalent, which limits comparison to the modelling results as no assumptions are made for snow density (modelling is carried out solely in units of snow water equivalent).

Using the snow water equivalent and snow depth measurements from Red Lake, snow density is estimated as a means to understand if the measurements are in line with typical values for snow density over time. In **Figure 1** the snow density over time is presented covering the period of 1946 to 1993. Over this period, snow density ranges between 50 and 450 kg/m³, where 50 to 200 kg/m³ can represent fresh snow or new top snow that is uncompacted, and 300-500 kg/m³ can represent snow that is compacted by grooming machines or deeply buried snow (Muskett 2012). Each year, the estimated snow density increases throughout the winter to late spring.

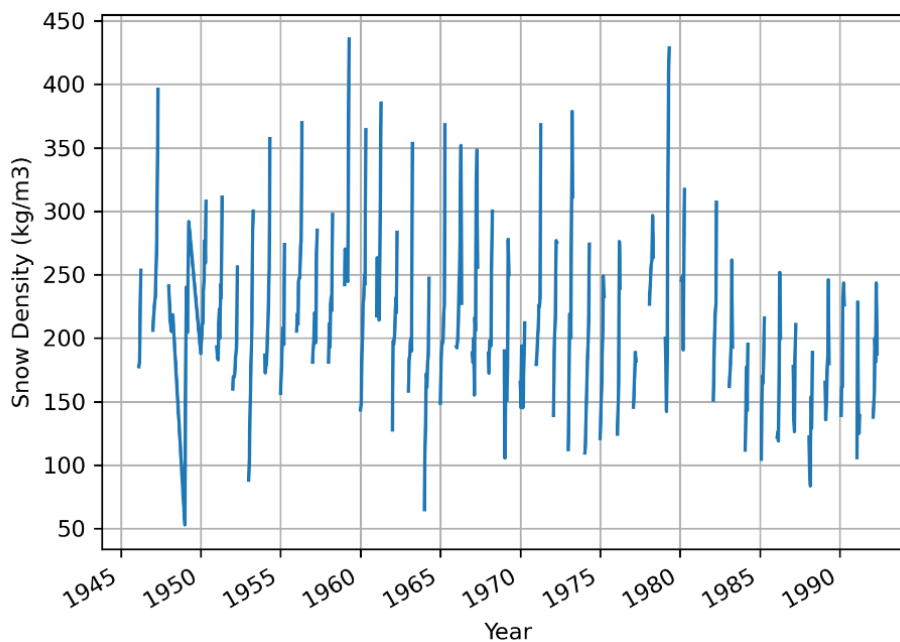


Figure 1: Snow Density Timeseries Measured at the Red Lake Station

In Figure 2 a box and vertical line plot are used to show the pattern of snow density estimates for the calendar months of January through May across years. The orange horizontal line represents the median, while the box represented the interquartile range (25th to 75th percentile). The vertical lines represent 1.5x the interquartile range, and values outside of the vertical lines are deemed as outlier and shown as points. Figure 2 more clearly shows the pattern of increasing snow density across the calendar months of January through May, likely due to the natural process of snow compacting and accumulating moisture as the winter season progresses. There is also a wider spread in snow density estimates in April and May, which could be due to variability in total snowpack in mid to late spring depending on how much snow falls in the previous months and the timing of freshet.

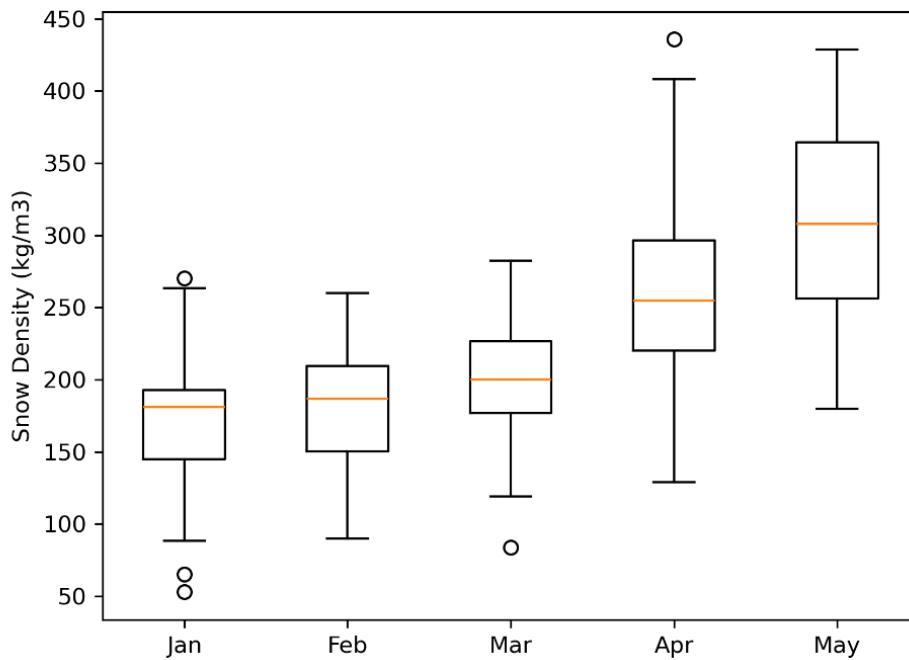


Figure 2: Monthly Snow Density Measured at the Red Lake Station

This review of the data confirms that the range and seasonal variation in snow densities observed at the Red Lake A station are plausible and will be taken as accurate and credible information to compare the snowpack modelling outputs.

3.0 COMPARISON TO MODELLED OUTPUTS

A comparison is made between modelled results and measurements from the Red Lake A station (for days where measurements are available), using a cumulative mass plot in **Figure 3**. In general, the cumulative mass plot indicates good agreement in snow depths over time, as the cumulative amounts at the end of the 1951 to 1993 period are very close between measured and modelled snow depth. However, differences within this period are present, as there are periods when either the cumulative modelled or measured results are higher or lower than each other.

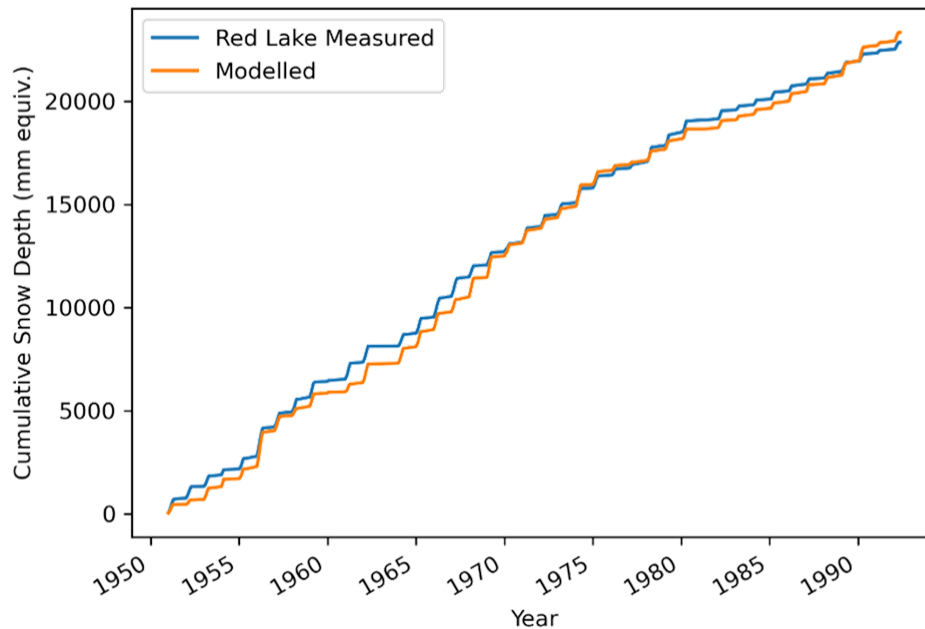


Figure 3: Comparison of Measured and Modelled Cumulative Snow Depth Timeseries

To investigate these differences further, each snow depth measurement is compared to the corresponding modelled estimate in Figure 4 through a scatter plot, which shows the correlation between the modelled and measured snow depth over 1951 to 1993. The line of best fit for the data points shown is represented as a solid black line. In general, a strong correlation is found, with an R^2 value¹ of 0.83 and a linearly fitted slope of 0.95 (close to 1). However, the modelled results tend to be higher than the measured values at the upper end.

These points represent the snowpack later into the season prior to spring freshet, suggesting that the differences may be due to the lack of sublimation in the modelled results, as this process is occurring over the course of the season and could explain why the modelled results are generally higher at this point. At the lower end, there are multiple instances where the measured snow depth reaches up to 75 mm water equivalent, while the modelled depth is zero. These points represent the late spring period after spring freshet has begun and most of the snowpack has melted, indicating that the model may melt the snowpack faster than observed.

¹ The R^2 value refers to the squared Pearson correlation coefficient, which is a common way to measure the strength of a correlation between two independent variables. A value close to 1 indicates a strong correlation, while a value close to 0 indicates a weak correlation.

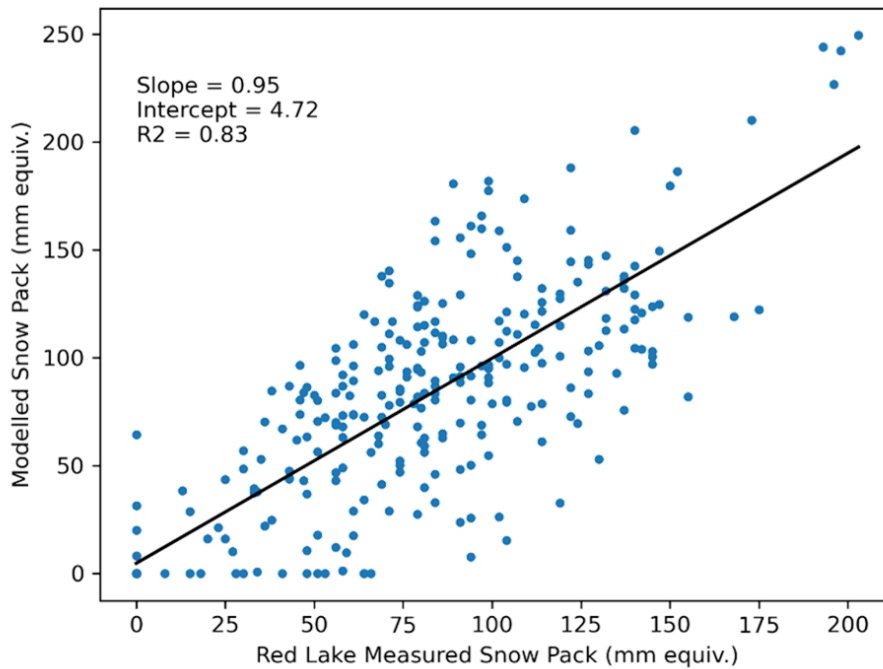


Figure 4: Correlation between Modelled and Measured Snowpack

A boxplot is used to illustrate the difference between the measured and modelled results by calendar month, where the orange solid line represents the median percentage difference, the lower and upper edge of the box represents the interquartile range (25th to 75th percentile) of the percentage differences, the vertical lines extending outside of the box represent 1.5 times the interquartile range (a common representation of data spread), and points outside of the vertical lines represent outliers for each calendar month (Figure 5).

In the months of January through March, the median percentage differences are close to 0% and slightly higher than 0, indicating a good match but also the potential for slightly greater model estimates due to lack of sublimation in the model results. For the month of April, many data points are less than 0%, indicating modelled estimates of snowpack that are lower than modelled. This is likely due to greater drying rates in the model and supports findings discussed previously for Figure 4. The percentage differences in the month of May also indicate greater drying rates, as half of the percentage differences are at a value of 100%, meaning that the model indicates that the snowpack is fully melted, while the measured data points indicate that some amount of snowpack is still present.

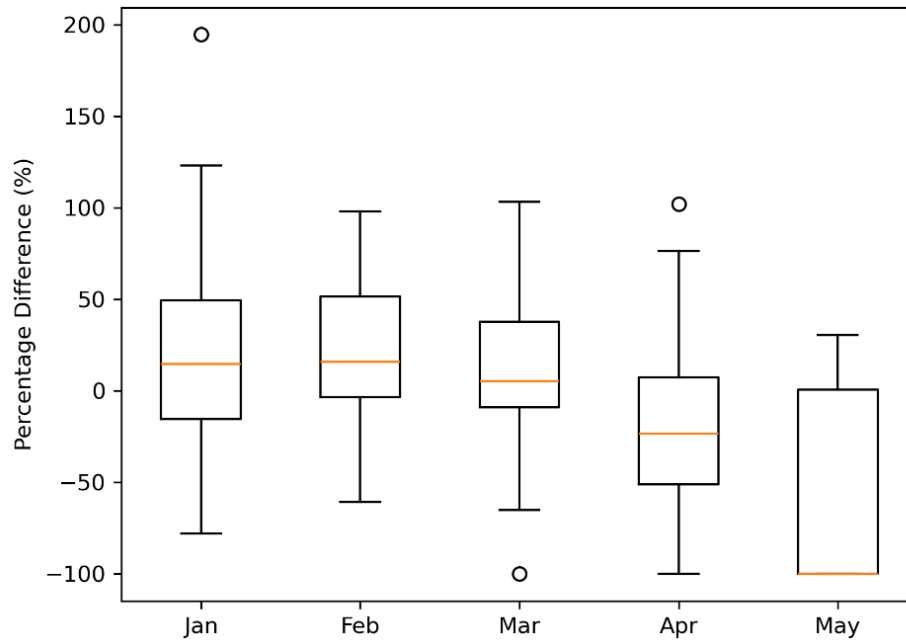


Figure 5: Percentage Differences between Modelled and Measured Snowpack

4.0 CALIBRATION TO SNOW DEPTH MEASUREMENTS

To improve the representation of modelled snowpack, particularly to address higher modelled drying rates in April and May which lead to earlier and fast melt a calibration is performed against the snow survey measurements for Red Lake A. This calibration is performed by parameterizing the degree-day potential snowmelt equation based on Pysklywec et al. (1968) in Equation 1, such that the parameters *A* and *B* are adjusted using a non-linear solver to minimize the sum of squared error between modelled and measured snowpack.

$$SM = A (1.8 \cdot T_a + B) \frac{mm}{day} \quad \text{Equation 1}$$

Where T_a is the mean daily air temperature in °C. Table 1 presents the default values alongside the adjusted values for *A* and *B*. The calibrated *A* parameter is substantially lower than the default value, which indicates that calibration reduces the influence of air temperature on the melting rate, as the previous results indicated faster modelled drying rates than measured. The calibrated *B* parameter is greater than the default value, which compensates for the reduction in *A* on base melting rates, while still reducing the influence of air temperature on melting during spring freshet.

Table 1: Snowmelt Model Parameters

Model Parameter	Default	Calibrated
A	1.008	0.386
B	4.4	11.0

While the calibrated snowmelt equation reduces the drying rates during spring freshet, there is only limited improvement in the comparison between modelled and measured snowpack. The mass curve in

Figure 6 indicates a closer match in cumulative snow depth over the years of 1951 to 1993 overall, as the cumulative values at the end of this period are more similar between modelled and measured values, however there are still differences over this period that are not accounted for.

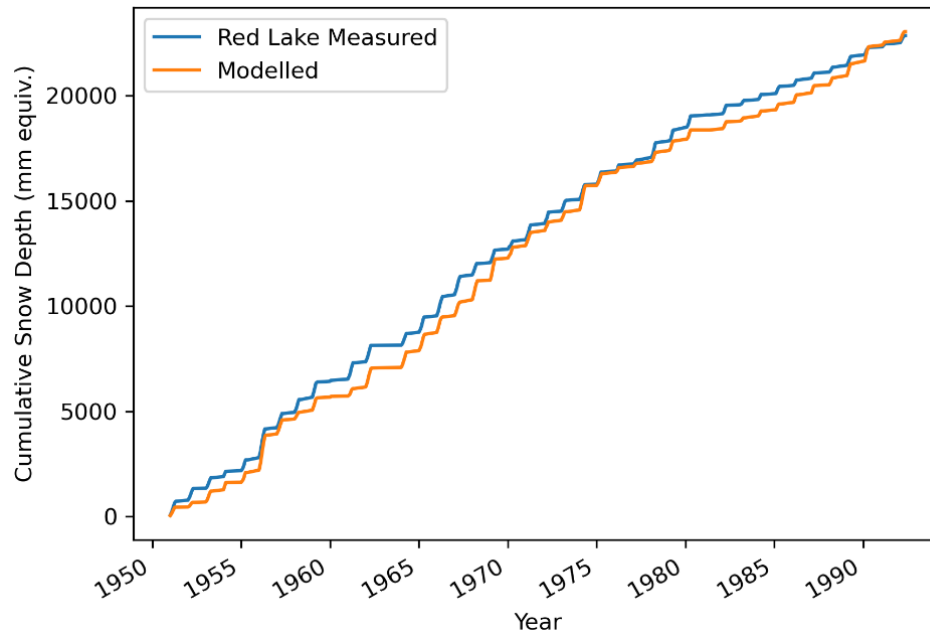


Figure 6: Comparison of Measured and Modelled (Calibrated) Cumulative Snow Depth Timeseries

Similarly, the correlation between modelled and measured snowpack in **Figure 7** indicates fewer points where modelled snowpack is zero and measured snowpack is present compared to Figure 4, however the R^2 value is slightly lower and the slope of 0.87 is slight reduced compared to the previous value of 0.95 (slope of 1 is ideal as this would indicate no systematic over or under prediction on average).

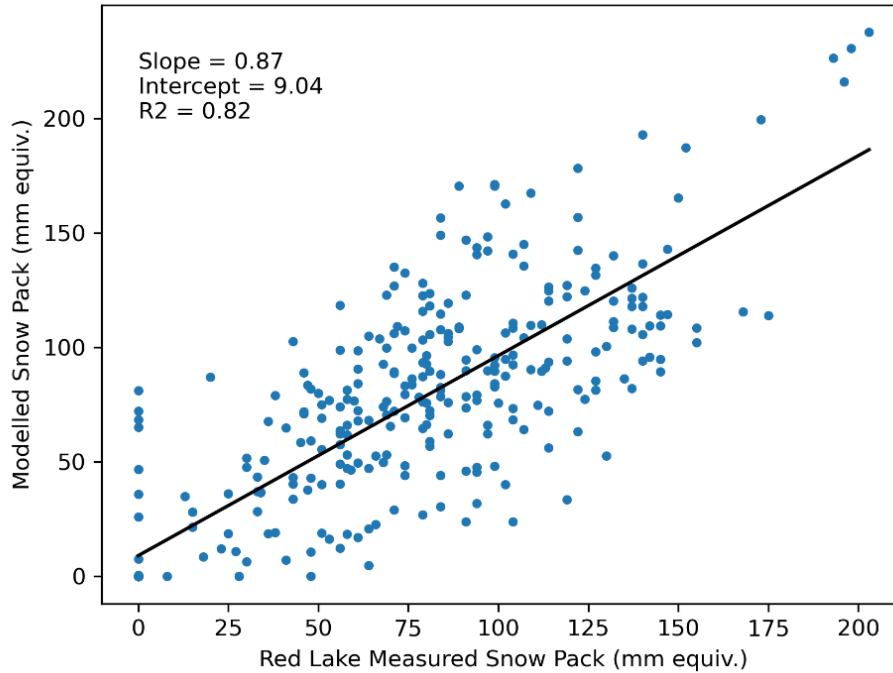


Figure 7: Correlation between Modelled (Calibrated) and Measured Snowpack

Based on this result, calibration of the snowmelt equation does not provide a substantial improvement over the default parameters. Beyond adjustments to the snowmelt equation there is limited opportunity to further improve the simulation of snow accumulation and melt, given that the default parameters already provide a good approximation of measured snowpack overall.

5.0 SUMMARY OF FINDINGS

The methodology adopted by ECCC is applied to the current climate dataset established for the Great Bear Project and compared to snow survey measurements of snow depth in units of snow water equivalent for the nearby Red Lake A climate station. Based on the results presented, the model estimates of snowpack over the period of 1951 to 1993 (common period of modelled results and snow depth measurements) compare well with the snow survey measurements, considering that the ECCC methodology is simple, empirically based, and that the comparison covers a substantial amount of data points over the historical record.

A calibration for the empirical melting equation against the ECCC snow survey measurements was attempted and resulted in limited improvements to the comparison of modelled and measured snow depth. Further improvements to the snow depth estimates may be possible through accounting for sublimation in the modelling approach and reviewing additional melting equations outside of the degree-day methods put forward by ECCC. Regardless, the application of the Louie and Hogg (1980) methodology adopted by ECCC for the current climate dataset established for the Great Bear Project provides a longer and more complete record for the estimation of combined rainfall and snowmelt extremes provided in Section 5.7 of the main report (*Detailed Climate Change Dataset*).

6.0 REFERENCES

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Appendix E

Potential Evapotranspiration Comparison



APPENDIX E – Potential Evapotranspiration Comparison

Estimates of potential evapotranspiration for the Great Bear site provide an indication of how much water can be lost to the atmosphere under ideal conditions (i.e., no soil moisture limitations). Often potential evapotranspiration estimates are provided as reference evapotranspiration, considering a well-watered vegetated surface (most commonly a grass surface). Lake evaporation is an important input for water balance assessments of the Great Bear site, however estimation methods such as energy balance methods and Penman-based methods rely on detailed measurements and/or climate variables that have limited data availability (e.g., wind speed and relative humidity).

This appendix compares a set of commonly used potential evapotranspiration methods to the existing measured regional pan evaporation data to support the selection of a method that will provide a reasonable approximation of lake evaporation for water balance assessments at the site for both current and under future climate scenarios.

1.0 LAKE EVAPORATION ESTIMATES

Pan evaporation measurements for a set of climate stations surrounding the Great Bear site were obtained from Environment and Climate Change Canada. Measurements from the set of stations were combined through inverse-distance weighting to establish long-term average pan evaporation rates for each calendar month at the location of the site, covering the period of 1962-2005. A pan coefficient of 0.75 was applied to the long-term average pan evaporation rates to represent lake evaporation. The lake evaporation estimates are used here for comparison purposed to the potential evapotranspiration methods described in Section 2.0.

Table 1: Climate Stations Considered for Pan Evaporation Measurements

Station Name	Climate ID	Coordinates	Distance to Site (km)	Elevation (m)
Pickle Lake A	6016528	51°26'47"N, 90°12'51"W	248	386.2
Rawson Lake	6036904	49°39'00"N, 93°43'00"W	137	358.1
Indian Bay	5031320	49°37'26"N, 95°11'50"W	179	326.7
Bissett	5031320	49°37'26"N, 95°11'50"W	145	326.7
Gimli	5031038	50°38'00"N, 97°01'00"W	242	222.8

2.0 POTENTIAL OR REFERENCE EVAPOTRANSPIRATION METHODS

There are several methods to estimate potential evapotranspiration, each with a set of trade-offs relating to data requirements, applicability to the location of interest, and ability to apply the method for both current climate (observations) and future climate (model projections) conditions in this study. In this appendix, potential evapotranspiration estimates are compared using 4 different temperature-based methods including:

- Hargreaves (Hargreaves and Samani 1985)
- Thornthwaite (Thornthwaite 1948)
- Priestley-Taylor (Priestley and Taylor 1972)

■ Hamon (Hamon 1963)

Temperature-based methods are used here to avoid data limitations for relative humidity and wind speed that are required by Penman-based methods. This is because relative humidity and wind speed often have low data availability or are missing from observational records in Canada, and the future climate projections from ClimateData.ca used in this study do not include these climate variables (only precipitation, minimum and maximum temperature are provided).

For comparison to the lake evaporation estimates described in Section 1, potential evapotranspiration is calculated using each method for the same period where lake evaporation estimates are available (1962-2005) and is assessed using default values for reference or crop coefficients embedded in each equation. The results of each potential or reference evapotranspiration method outlined in Section 2 are compared to the lake evaporation estimates described in Section 1 for each calendar month in Table 2 and Figure 1. Lake evaporation for the Great Bear site is estimated at an annual total of 557 mm, with the majority of the total being in the months of May to October. June and July have the highest lake evaporation rates on average at 122.0 mm and 131.5 mm. Over the period of November through March, temperatures are close to freezing resulting in little to no measured evaporation.

Table 2: Comparison of Lake Evaporation Estimates and Potential Evapotranspiration Methods for the Great Bear Site

Month	Lake Evaporation (mm)	Potential Evapotranspiration (mm)			
		Hargreaves	Thornthwaite	Hamon	Priestley-Taylor
1	0.0	2.1	0.0	5.5	11.2
2	0.0	5.7	0.0	7.8	19.6
3	0.9	23.2	0.0	16.3	52.5
4	12.7	60.7	0.0	32.0	112.2
5	96.9	108.4	42.1	57.4	188.0
6	122.0	130.2	90.6	78.0	221.1
7	131.5	140.7	111.0	90.9	234.9
8	108.7	111.8	93.9	76.5	196.2
9	63.6	62.3	51.8	47.1	121.0
10	20.7	29.0	9.5	27.9	64.8
11	0.0	8.6	0.0	12.9	27.1
12	0.0	2.8	0.0	6.8	13.8
Annual	557.0	685.6	398.9	459.1	1262.5
May-Oct ¹	543.5	582.4	398.9	377.8	1026.0
Difference (%) May-Oct ²	—	7%	-27%	-30%	89%

Notes:

- 1) Represents the sum of lake evaporation or potential evapotranspiration estimates over the months of May through October.
- 2) Difference is calculated between each the results of each potential evapotranspiration method and the measured lake evaporation amounts for the May through October total.

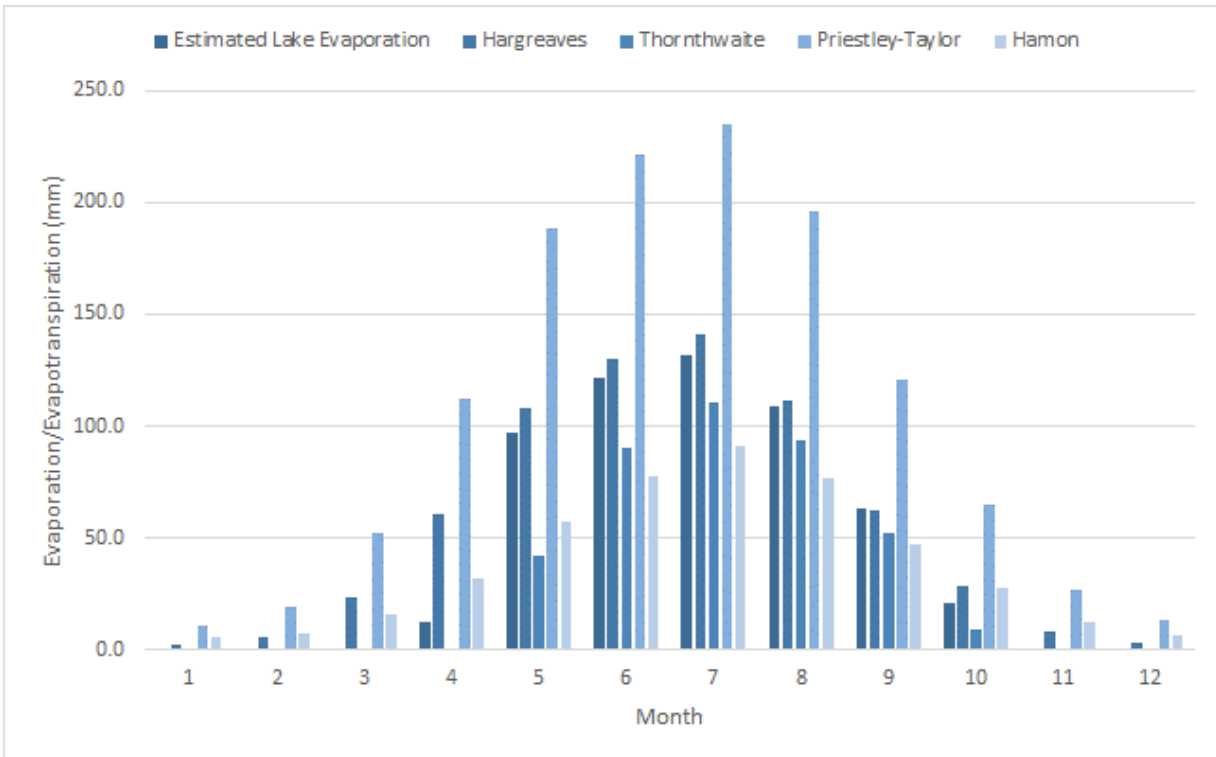


Figure 1: Visual Comparison of Lake Evaporation Estimates and Potential Evapotranspiration Methods for the Great Bear Site

The Thornthwaite method includes a temperature index, which acts as a threshold that limits potential evapotranspiration during the late fall to early spring months and is why November through April are estimated at a rate of 0 mm/month. The Hargreaves, Hamon, and Priestley-Taylor methods do not include a similar effect and estimate low rates of potential evapotranspiration for November through April, which may be representing other atmospheric losses.

For the period of May to October, the Hargreaves method provides potential evapotranspiration rates that are closest (slightly higher) to lake evaporation estimates for the Great Bear site, with a period total of 582.4 mm compared to 543.5 mm for lake evaporation (+7%). The next closest estimates are lower than lake evaporation at a period total of 398.9 mm (-27%) and 377.8 mm (-30%) for the Thornthwaite and Hamon methods respectively. The Priestley-Taylor method gives results that are substantially greater than lake evaporation, at a period total of 1026.0 mm (+89%). As each equation is temperature-based, differences between equations are likely driven by simplifications related to other climatic factors such as wind speed and relative humidity that may play a larger role for the region and/or climatic conditions that each equation is calibrated to (for the default values of reference or crop coefficients).

3.0 SUMMARY OF FINDINGS

In this appendix four different potential or reference evapotranspiration methods are compared against lake evaporation estimates for the Great Bear site. The Hargreaves method provides potential evapotranspiration results that are the most similar to lake evaporation estimated for Great Bear (7% difference), while the Thornthwaite and Hamon methods are generally lower than lake evaporation, and the Priestley-Taylor estimates are substantially higher.

For the purpose of providing potential evapotranspiration estimates for the Great Bear site (and a means to estimate lake evaporation), it is assumed that during the months of November through April when temperatures are near to or below freezing on average, potential evapotranspiration is assumed to be 0 mm/month across all methods, consistent with the results of the Thornthwaite method. The potential

evapotranspiration results for the Hargreaves method with this assumption applied are summarized in Table 3 for the current climate baseline period of 1950-2022.

Table 3: Hargreaves Potential Evapotranspiration Estimates for the Great Bear Site for Current Climate Baseline Period (1950-2022)

Month	Mean	Minimum	Maximum
January	0	0	0
February	0	0	0
March	0	0	0
April	0	0	0
May	107.9	84.0	130.8
June	131.9	106.9	157.5
July	140.5	115.9	165.6
August	112.1	87.3	137.5
September	63.0	50.4	77.2
October	29.3	19.7	46.9
November	0	0	0
December	0	0	0
Annual	584.7	464.2	715.5

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