CALMET MODELLING
FOR THE
WILLIAMS LAKE AIRSHED

Prepared for:

Ministry of Environment
Cariboo Region
400 – 640 Borland Avenue
Williams Lake, BC V2G 4T1
Phone (250) 398-4762
Fax (250) 398-4214

Attention: Earle Plain

Prepared by:

Levelton Consultants Ltd.
150 - 12791 Clarke Place
Richmond, BC
V6V 2H9

Kathy Ostermann, M.Sc.
Alex Schutte, B.Sc., CCEP

November 2004 File: 1504-0043

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1 INTRODUCTION

The British Columbia Ministry of Environment (MOE) Cariboo Region identified air quality modelling as one of the tools to advance their airshed management planning for the Williams Lake airshed. Air quality dispersion modelling is being used as a tool to assist in the management of pollutants in the Williams Lake airshed. Levelton Consultants Ltd. (Levelton) was retained by MOE to assist the ministry in running CALMET as a precursor to running CALPUFF.

An air quality model offers many benefits for airshed planning. The model could help manage sources in the region by determining the effects of changing emissions on ambient air quality. Trends in air quality over time can be examined using forecasts and backcasts. Sources can be apportioned to determine the most cost-efficient method to improve air quality in the airshed. The platform can be used for future modelling work as new industrial projects are proposed for the airshed, or as the community emissions change, spatially or temporally.

The following sections provide a description of the methodologies, the meteorological input data used, and the CALMET modelling results for one year from June 2003 through May 2004.

2 METHODOLOGY

2.1 INTRODUCTION

The City of Williams Lake is located in the central Cariboo region, 540 km north northeast of Vancouver and 238 km south of Prince George on the interior plateau of British Columbia. The city is situated just to the east of the Fraser River at the west end of Williams Lake. It is in a northwest-southeast oriented direction within the valley. The elevation of the Williams Lake airport is 940.3 m above sea level, while the city itself is at an elevation of 586 m. Neighbourhoods are at various elevations on the nearby hills of the city.

The meteorological modelling boundaries in this study are defined by UTM grid coordinates 540000 to 585000 E and 5754000 to 5795000 N, an area of approximately 45km by 41km. The meteorological modelling domain is defined by the map of the Williams Lake region shown in Figure 2-1. This area provides suitable coverage for which to run CALMET, and would encompass all of the sources with an additional 10 km on all sides to account for any potential meteorological influences on the airshed.

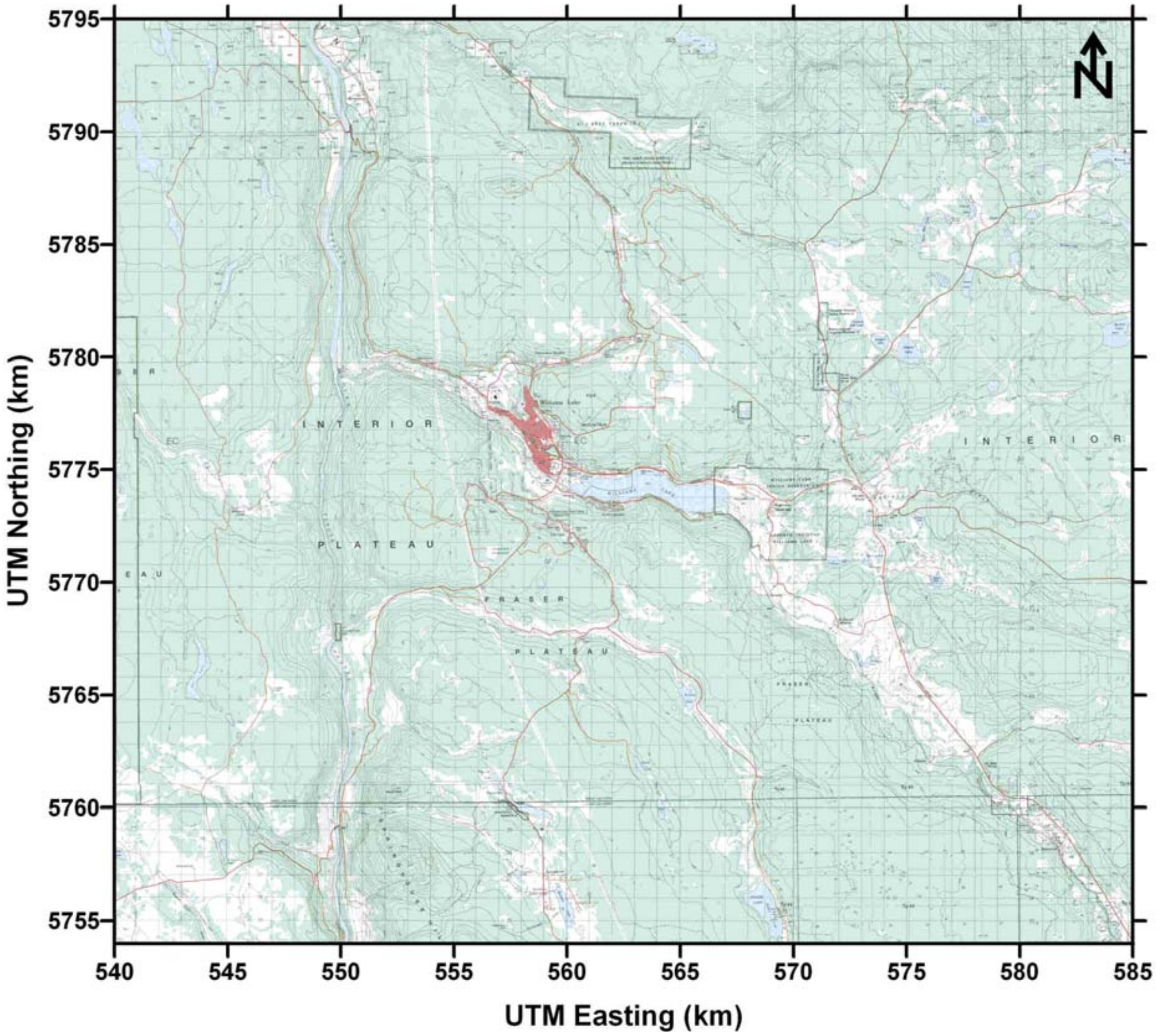


Figure 2-1 Map of the Williams Lake Modelling Domain

2.2 CALMET MODEL INPUT DATA

CALMET is a diagnostic computer model that produces detailed three-dimensional fields of meteorological parameters based on surface and upper air measurements, digital land use data digital terrain data and prognostic meteorological data. The three-dimensional fields produced by CALMET can be used by CALPUFF to calculate the dispersion of emissions over distances of a few metres to hundreds of kilometres.

In this application, CALMET was executed for 12 months (June, 2003 through May, 2004), using meteorological input data from three surface stations and one upper air station. Digital terrain and land use data covering the model domain were included in the CALMET input data set. Prognostic wind data from the MM5 model were also included.

2.2.1 Land Use and Terrain Data

A modelling domain that encompasses the main topographical features of the Williams Lake airshed (45 km x 41 km) was used for generating the CALMET three-dimensional diagnostic meteorological fields. The UTM grid coordinates 540000 to 585000 E and 5754000 to 5795000 N define the modelling domain.

In CALMET, terrain data, along with other parameters, are used to determine the simulated wind field at a specified resolution. In complex terrain situations, a higher terrain resolution will allow greater resolution of the wind field, enabling local scale effects to be captured. For the Williams Lake airshed, a 500 m grid resolution was used in the application of CALMET.

Digital terrain files (TRIM files) with a 1:20000 scale were obtained for the entire modelling domain and used to generate the CALMET grid cells. MOE supplied land use characteristics for each grid cell based on LandData B.C. datasets. The B.C. land use class codes were translated into the land use class codes used by CALMET. Table 2-1 shows the assumed equivalent USGS (CALMET) land use codes from the B.C. codes.

Table 2-1 Translated B.C. Landuse Codes to the Required CALMET Codes

B.C. Land Class Code	B.C. Landuse Category	CALMET Code	CALMET Landuse Category
2	Agriculture	-20	Agricultural land – irrigated
3	Barren surfaces	70	Barren land
4	Fresh water	50	Water
5	Mining	70	Barren land
6	Old forest	40	Forest land
7	Rangelands	30	Rangeland
8	Recently burned	30	Rangeland
9	Recently logged	30	Rangeland
10	Recreation activities	40	Forest land
11	Residential/agriculture mixtures	20	Agricultural land
12	Selectively logged	40	Forest land
13	Urban	10	Urban
14	Wetlands	60	Wetland
15	Young forest	40	Forest land

2.2.2 Surface Meteorological Data

Williams Lake is characterised by a continental climate, with cold winters and warm summers. Based on the 1971 to 2000 climatology, mean monthly temperatures range from –8.3 to 15.6ºC. Annual precipitation measured at the airport is 450.3 mm with an annual average rainfall of 295.7 mm and annual average snowfall of 192.7 cm. The Appendix gives a summary of climatological data collected at the Williams Lake airport between 1970 and 2000, along with meteorology from June 2003 through May 2004. This section describes a summary of the model input data and how that data was applied in CALMET.

The meteorological input file for CALMET contains hourly information with date and time, wind speed, wind direction, ceiling height, cloud cover, temperature, relative humidity, station pressure, and a precipitation code. Meteorological data were available from three local surface stations to use as input into the CALMET model. More information on the stations is found in the Appendix. The stations included:

- Meteorological Service of Canada Williams Lake airport (YWL) – wind speed, wind direction, temperature, relative humidity, cloud ceiling, cloud cover, surface pressure
- MOE Williams Lake Canadian Tire station (WLAPCT) – wind speed, wind direction, temperature, relative humidity
- MOE Glendale station (WLAPGD) – wind speed, wind direction, temperature

The CALMET model requires each parameter to be measured for every hour for at least one of the stations. The CALMET model is capable of modelling calm conditions, and this feature was incorporated into the modelling.

2.2.3 Precipitation Data

Precipitation data in the Williams Lake airshed was available hourly from the B.C. Ministry of Forests' Fire Weather Station network for 11 of the 12 months that were modelled. The station used in the modelling is located near the south-eastern edge of the modelling domain. Data on wind speed and direction, temperature and humidity were also available from this station but when wind roses were compared to the other three meteorology stations, the pattern was quite different and the quality of the data could not be determined. Therefore, the meteorological values from this station were not included in the modelling.

Daily precipitation values were also available from the airport. These were used when the hourly values were missing. During the period of June 1, 2003 – May 31, 2004, the total precipitation for the airport station was 439.0 mm while total rainfall at the Ministry of Forests site over the same period was 380.0 mm. This is slightly less than climate normals. Therefore, if CALPUFF is used for chemical transformation or deposition of pollutants, the resultant dry deposition would be slightly higher than one may expect, conversely wet deposition would be slightly lower.

CALMET requires the parameter of precipitation code to be used to identify the type of precipitation. The type of precipitation is important in the calculation of chemical transformations that are modelled in CALPUFF. Precipitation codes were based on temperature and rates during hours where precipitation occurred. If the temperature was above 0°C, then the hour was given a code for liquid precipitation, and below 0°C the code for frozen precipitation was used. Rates were based on the Federal Meteorological Handbook of the USA with categories given in Table 2-2.

Table 2-2 Precipitation Categories

Category	Temperature	Rate (mm/hr)	Code
Light Rain	>0°C	R < 2.5	1
Moderate Rain	>0°C	2.5 ≤ R < 7.6	2
Heavy Rain	>0°C	R ≥ 7.6	3
Light Snow	≤0°C	R < 2.5	19
Moderate Snow	≤0°C	2.5 ≤ R < 7.6	20
Heavy Snow	≤0°C	R ≥ 7.6	21

2.2.4 Upper Air Data

The nearest upper air station to the Williams Lake airshed is in Prince George, 238km to the north of the city. Data were downloaded from Forecast Systems Laboratory (FSL), processed and used as input to CALMET. The model was run with 10 vertical layers in the atmosphere. These levels were bound by the height above ground level (in metres) as outlined in Table 2-3.

Table 2-3 Weighting Factors for Surface Stations and Upper Air Station Used in CALMET

Vertical Layer Number	Height at Top of Layer (m)	Bias Value
1	20	-1.000
2	40	-.9874
3	80	-.9568
4	160	-.9136
5	300	-.8344
6	500	-.7120
7	1000	-.4600
8	1500	-.1000
9	2000	.2600
10	3000	.8000

There are a number of options for use of upper air data in the CALMET model. A control variable defines the distance from a surface station that an upper air station must exceed in order for surface extrapolation of wind and temperature data to take place. The CALMET model has the option of 1) no extrapolation of surface data, 2) extrapolation using a power lay equation, 3) extrapolation using similarity theory, and 4) extrapolation using user defined scaling factors.

The United States Environmental Protection Agency (U.S. EPA) recommends extrapolating data using similarity theory. Scaling factors were used to give greater bias to the upper air data at the higher levels. This method utilises similarity theory and observed data to extend the influence of the surface wind speed and direction into the layers aloft. Without this extrapolation, the initial guess field at layers above the surface would be solely derived from the upper air data. Winds at the surface level were solely derived from surface observations. Because the upper air station for this application is well outside the modelling domain, the vertical extrapolation of surface winds was calculated to the vertical levels with final extrapolation of the winds utilising the biasing option. Table 2-3 presents the bias values given to each vertical layer where wind speed and direction were calculated. Because the upper station is

2.2.5 Other Variables Required by CALMET

Ceiling height, cloud cover, relative humidity and station pressure were available only for the Williams Lake Airport (YWL) station. April and May 2004 station pressure was not available at the time of generating this report. For these two months, station pressure was derived from sea level pressure using the hydrostatic equation:

$$p_g = \frac{p_o}{\exp(z_g / H)}$$

where p_g = ground-level (station) pressure (mb)

p_o = sea-level pressure (mb)

z_g = elevation of station (m)

H = scale height (m)

The scale height, H, is approximately 8000 m for the observed range of ground temperatures on earth, provided that z_g is less than 1000 m (z_g = 940 for Williams Lake Airport).

2.2.6 MC2 Data

The Mesoscale Compressable Community Model (MC2), operated by UBC, can be converted to provide the prognostic data necessary for input into CALMET (Mesoscale Model version 5 or MM5 format). The data is in a terrain-following coordinate system designed to simulate or predict local and regional-scale atmospheric circulation. Through an agreement with UBC, MOE has been collecting MC2 data since May 2003.

The prognostic data can be used as input into CALMET in a number of different ways. 1) as the “initial estimate” field; 2) as the Step 1 wind field; 3) as "observations".

When option 2 or option 3 is selected, the prognostic winds are not adjusted to the fine-scale effects. Selecting the correct method is especially important to account for local surface effects.

The "initial estimate" wind field is calculated by interpolating the winds to the fine CALMET scale and then adjusting them for terrain and land-use effects. Utilising the data in combination with the first option allows for maximum use of actual surface data, while allowing the MC2 data to replace the surface extrapolated data described in the upper air section, and thus overall, an improved wind field is generated, both at the surface and aloft.

2.2.7 Missing Data Processing

CALMET requires a measured data value for every hour from at least one of the meteorological stations in order to simulate the 3-D fields. For wind speed, wind direction, ceiling height, cloud cover, temperature and relative humidity, there were no hours in which none of the three stations had a measurement. For station pressure, missing data of less than 5 consecutive hours were replaced with the previous hours’ data using the US EPA recommended method (Atkins, 1999).

For station pressure, only one hour of missing data was processed for June 1, 2003 through May 31, 2004.

CALMET requires hourly precipitation data which will be used in CALPUFF to model chemical transformations. Therefore the Ministry of Forests precipitation data were used whenever possible. No hourly precipitation data were available from February 29 through April 1, 2004. There were an additional 60 hours without hourly data. When hourly data were not available, the daily data was substituted into the hourly record according to the following procedure:

1. If the daily total is zero, substitute zero for all hours of that day.

2. If the daily total is greater than zero, divide the daily total rain value in mm by the number of hours in the day where the cloud cover is greater than or equal to 7/10ths. Fill in the hourly fraction of the daily rainfall for those hours where cloud cover is greater than or equal to 7/10ths, otherwise, use zero.

Missing upper air data were processed as follows:

1. For a sounding where only the lower or upper level (~500mb) temperature and/or wind data were missing, it was filled in by taking the average temperature and/or wind data from the previous and next soundings. There were 28 occasions from June, 2003 through May, 2004 that required this processing.

2. When 1 or 2 soundings were missing, the previous day sounding at the same time was used. There were 5 missing soundings in the dataset.

2.2.8 CALMET Model Options

The CALMET model has a number of user-specified input switches and options that determine how the model handles terrain effects, interpolation of observational input data, etc. This section briefly outlines the options that were used that have not been previously described. As a general method, the current recommended US EPA regulatory default parameters were used.

The CALMET wind field module uses a two-step approach to the computation of the wind fields. In the first step, an initial guess wind field is adjusted for kinematic effects of terrain, slope flows, and terrain blocking effects to produce a Step 1 wind field. The second step consists of an objective analysis procedure to introduce observational data into the Step 1 wind field to produce a final wind field.

Prognostic meteorological data, such as MC2 (in MM5 format) data can be introduced into CALMET as well. Prognostic data is commonly used to enhance a CALMET model simulation.

An inverse-distance method is used to introduce observational data into the Step 1 wind field. This interpolation scheme allows observational data to be heavily weighted in the vicinity of the observational station, while the Step 1 wind field dominates in regions with no observational data. The user-specified parameters R1 and R2 determine the relative weighting given to the observational data in the surface layer and in the layers aloft, respectively. An observation is excluded from interpolation if the distance from the observational station to a particular grid point exceeds the user-specified maximum radius of influence, RMAX1, RMAX2 or RMAX3, for the surface layer, layers aloft and over-water layers respectively. In this application, various combinations of weighting parameters and maximum radii of influence were tested for CALMET to produce final wind fields that are representative of the meteorological wind fields in the area. The final parameter selection is listed in Table 2-4.

Table 2-4 Selected CALMET Wind Field Model Options

Parameter	Option Selected	US EPA Default
Froude Number Adjustement Effects Calculated?	Yes	✓
Kinematic Effects Computed?	No	✓
Slope Effects Computed?	Yes	✓
Surface Wind Observations Extrapolated to Upper Layers?	Yes	✓
Surface Winds Extrapolated even if Calm?	No	✓
Maximum Radius of Influence over Land in the Surface Layer (RMAX1)	8 km	No default
Maximum Radius of Influence over Land Aloft (RMAX2)	10 km	No default
Maximum Radius of Influence over Water (RMAX3)	12 km	No default
Radius of Influence of Terrain Features	4.5 km	No default
Relative Weighting of the First Guess Field and Observations in the Surface Layer (R1)	.25 km	No default
Relative Weighting of the First Guess Field and Observations in the Layers Aloft (R2)	2 km	No default

CALMET has a number of options to deal with terrain effects and data interpolation to generate the wind field. The default critical Froude number of 1 was used. It is the ratio of the inertial force of the wind, to the force due to gravity. The number is calculated for each grid point and compared to the critical Froude number. If it is less than 1 and the wind has an uphill component, then it is adjusted to be tangent to the terrain, and the speed remains unchanged. If it is greater than the critical Froude number, then no adjustment is made.

Due to the complex terrain in the area, the maximum radius of influence for any of the surface stations was set to 8 kilometres. This was extended to 10 kilometres aloft as the valley widens at higher levels. At the surface, in a narrow and turning valley, larger values of R1 would have an influence on the valley sides that would not provide appropriate model results for those areas, therefore, the relative weighting distance was set to 0.25km.

3 QUALITY ASSURANCE AND CONTROL

There are a wide variety of quality assurance and control (QA/QC) procedures that could be conducted for CALMET modelling. This section deals with checking and determining the quality of the CALMET results produced based on the parameters and methods.

Data were extracted from the CALMET output for a grid cell located within the Williams Lake valley and compared with the three surface station's data. Figure 3-1 shows the relative locations of the meteorological station and the extracted data point in the modelling domain. The extracted point is located at (558250mE, 5777250mN) with an elevation of 648.5m. Since the Williams Lake airport is located outside the valley some differences are expected from the valley to plateau locations.

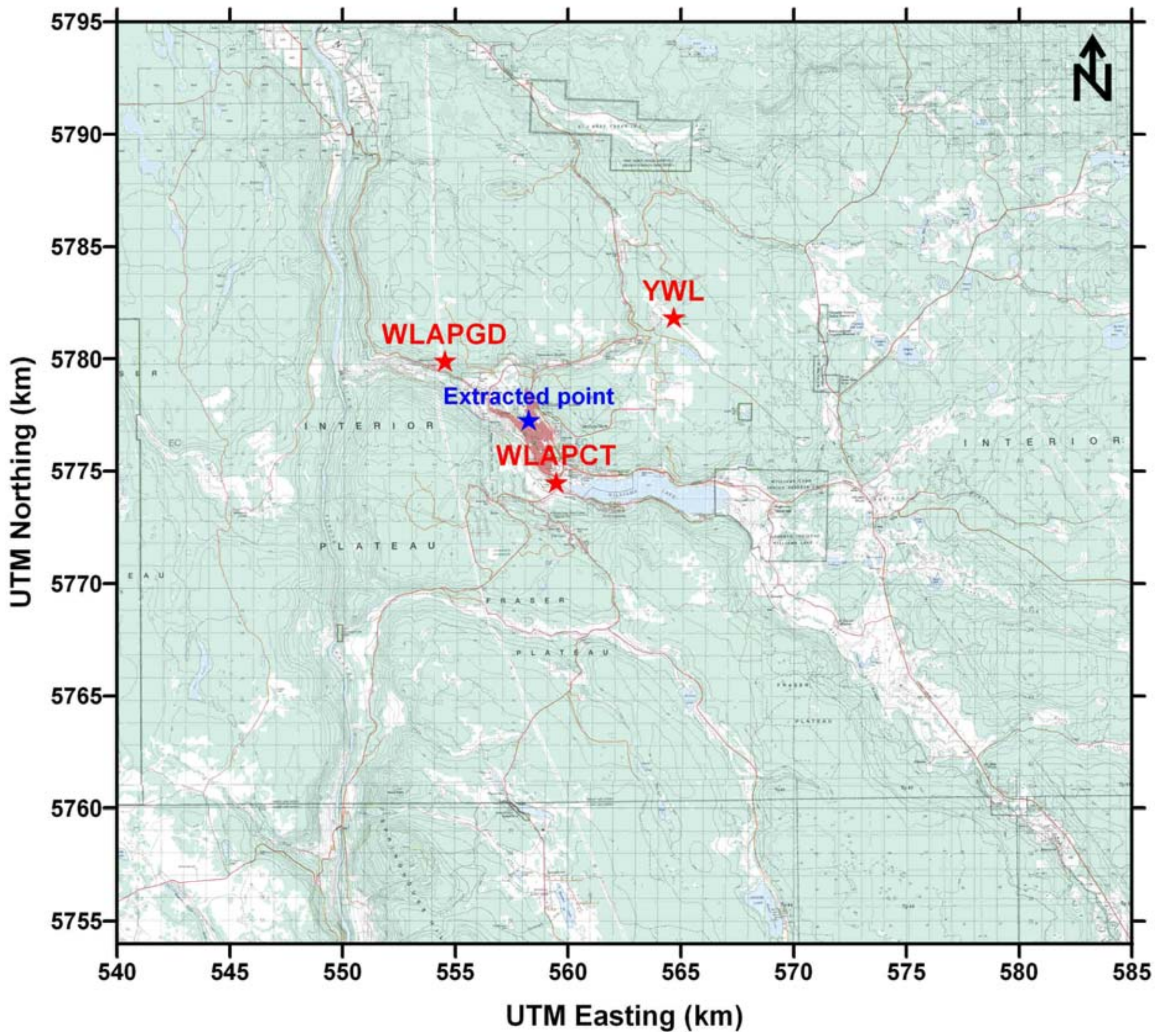


Figure 3-1 Meteorological station locations and extracted data point

Figure 3-2 shows the frequency distribution of surface winds for YWG, Canadian Tire (WLAPCT) and Glendale (WLAPGD) stations along with the predicted values for the extracted point shown in Figure 3-1. The predicted winds at the extracted point were calmer than those that were observed at all three locations. The differences can be explained by a number of reasons which are discussed in further detail in Section 4.

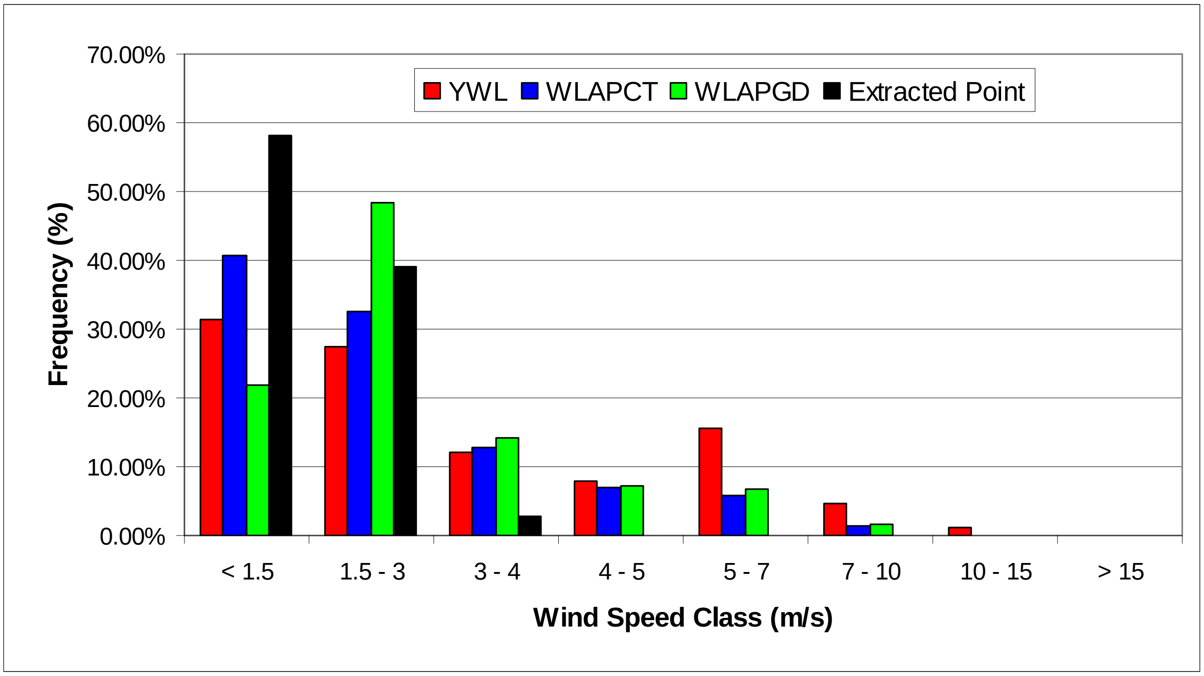


Figure 3-2 Frequency Distribution of Surface Wind Speeds for the Three Surface Stations and the Extracted Point from CALMET

The annual surface wind rose predicted by CALMET is given in Figure 3-3. The observed wind roses are found in the Appendix. The wind rose also illustrates how calm the predicted winds were. Calm winds were predicted 14.1% of the time, which is much higher than at the other two valley stations. The predominant direction is from the east-southeast, which is the air being channelled through the valley.

Figure 3-4 shows the time series of average surface temperature by month for the YWL, Canadian Tire and Glendale station along with the predicted values. The lower temperatures at YWL are expected given that the station is located at an elevation over 300 m higher than the stations in the valley. Temperatures are also plotted for the time of day in Figure 3-5. Again the temperatures at the airport are lower than the valley stations and the predicted values. The diurnal pattern is evident at all locations.

Figure 3-6 shows the observed precipitation along with the predicted values from CALMET. As there was only one station with precipitation, the values are the same.

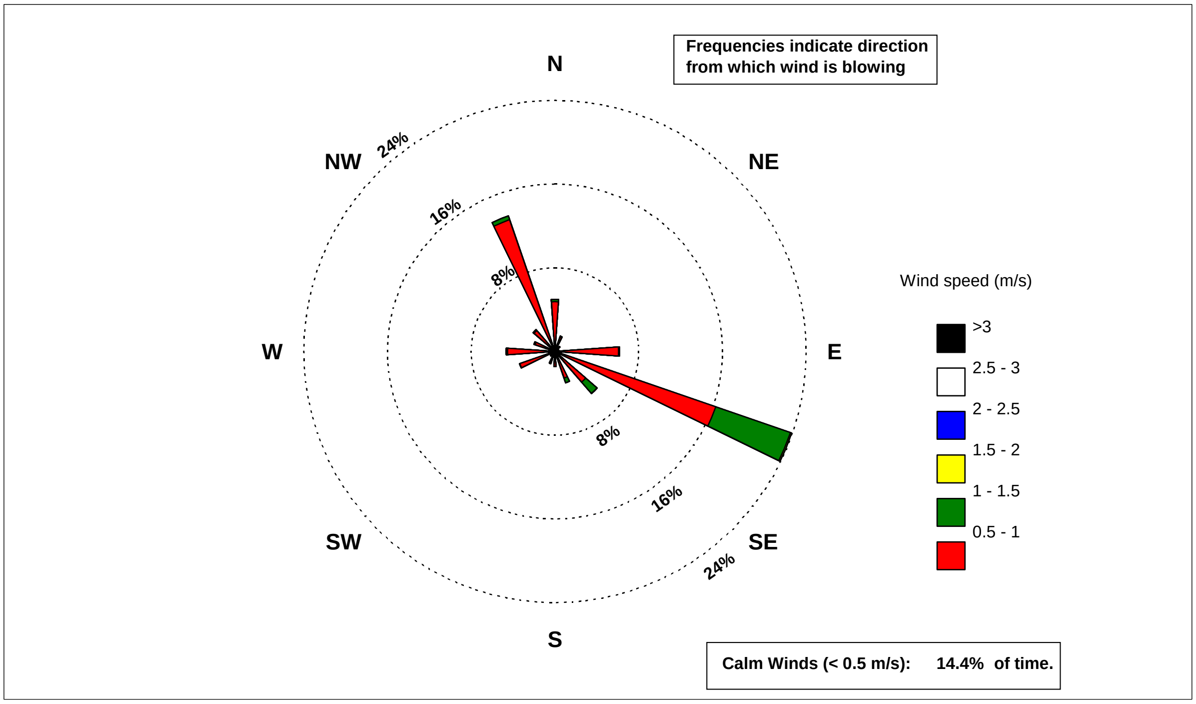


Figure 3-3 Predicted Annual Surface Wind Rose

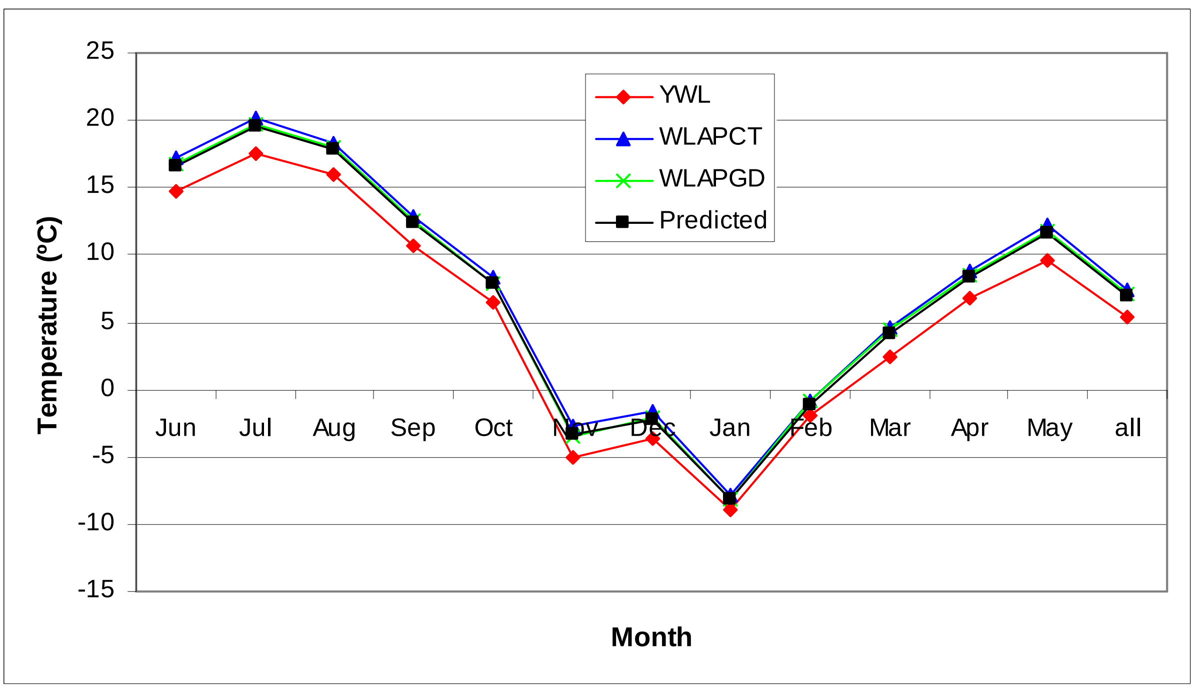


Figure 3-4 Monthly Temperatures at the Three Surface Stations and Predicted Values from CALMET

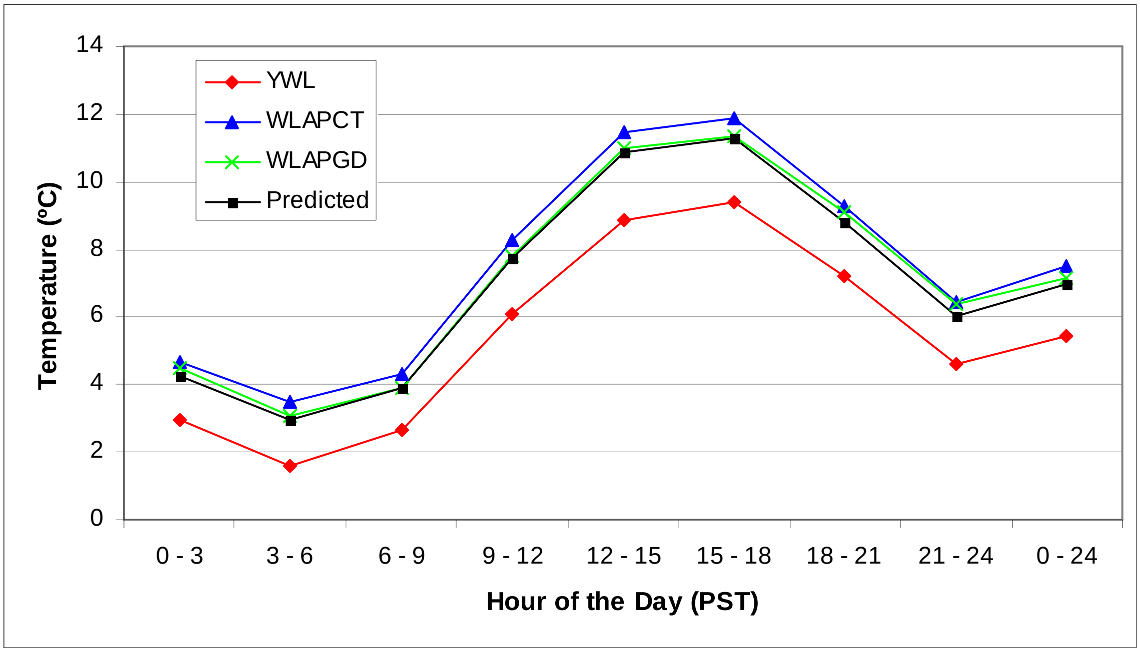


Figure 3-5 **Hourly Temperatures at the Three Surface Stations and Predicted Values from CALMET**

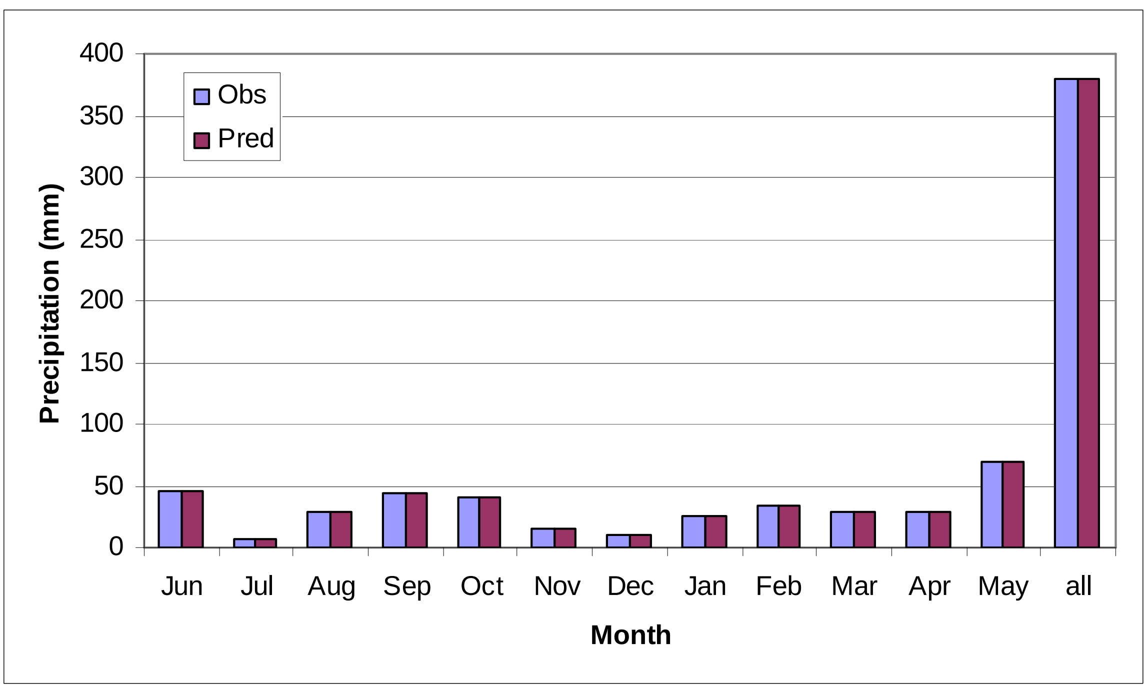


Figure 3-6 **Monthly Precipitation as Observed and Predicted Values from CALMET**

Hourly stability class and frequency of occurrence for each class for the CALMET modelling domain was calculated in the CALMET grid field for each grid, using the Pasquill-Gifford coefficients for rural land use conditions (ISC curves) and MacElroy Pouler coefficients for urban land use areas. Figure 3-7 shows the frequency distribution of the predicted stability at the extracted point along with calculated stability from the meteorological station variables. The model seems to underpredict neutral conditions.

Predicted mixing heights from CALMET are shown in Figures 3-8 and 3-9. Mixing heights were not generated from the input data but the predicted values appear representative of the region based on a comparison of means[1].

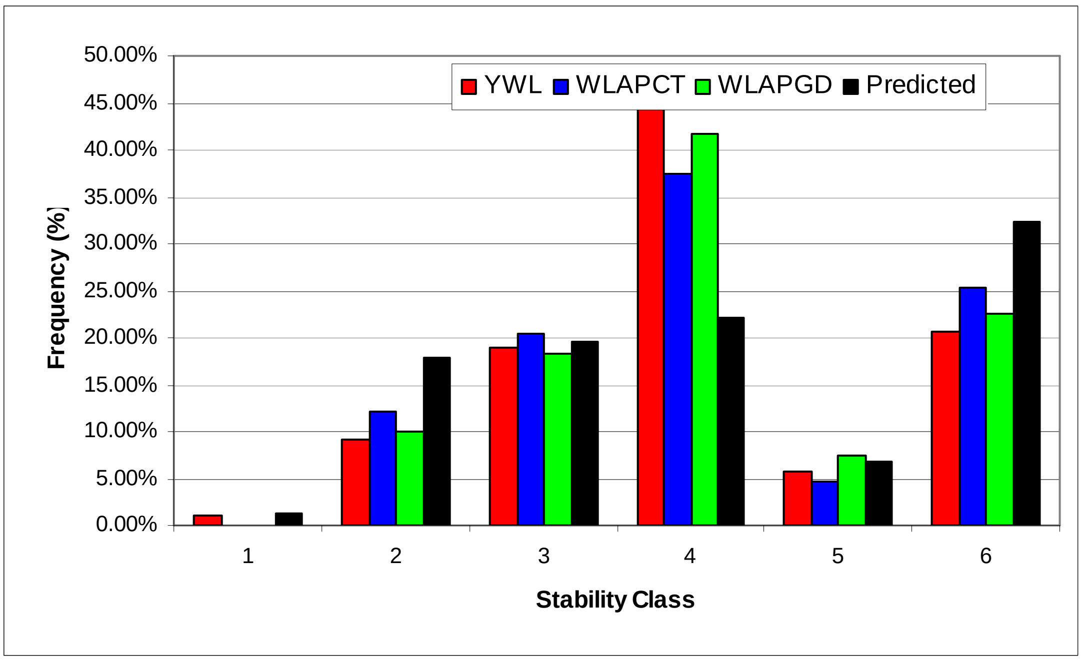


Figure 3-7 Frequency Distribution of Stability Class

[1] SENES et al "A Mixing Height Study for North America (1987-1991), 1997

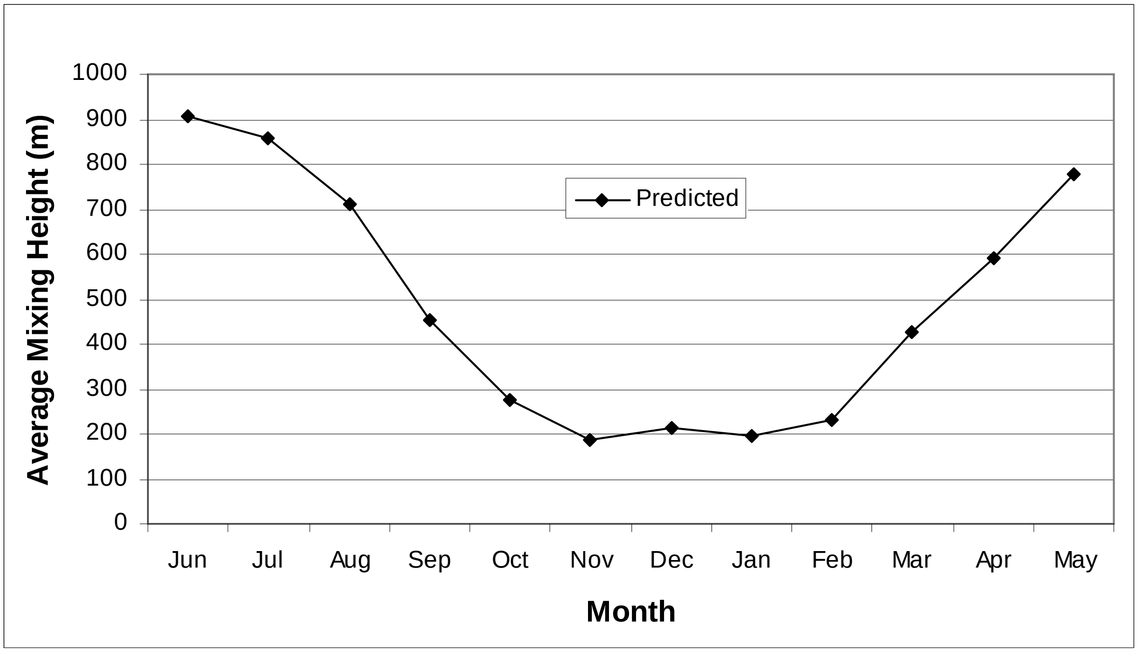


Figure 3-8 Monthly Mixing Heights at extracted point

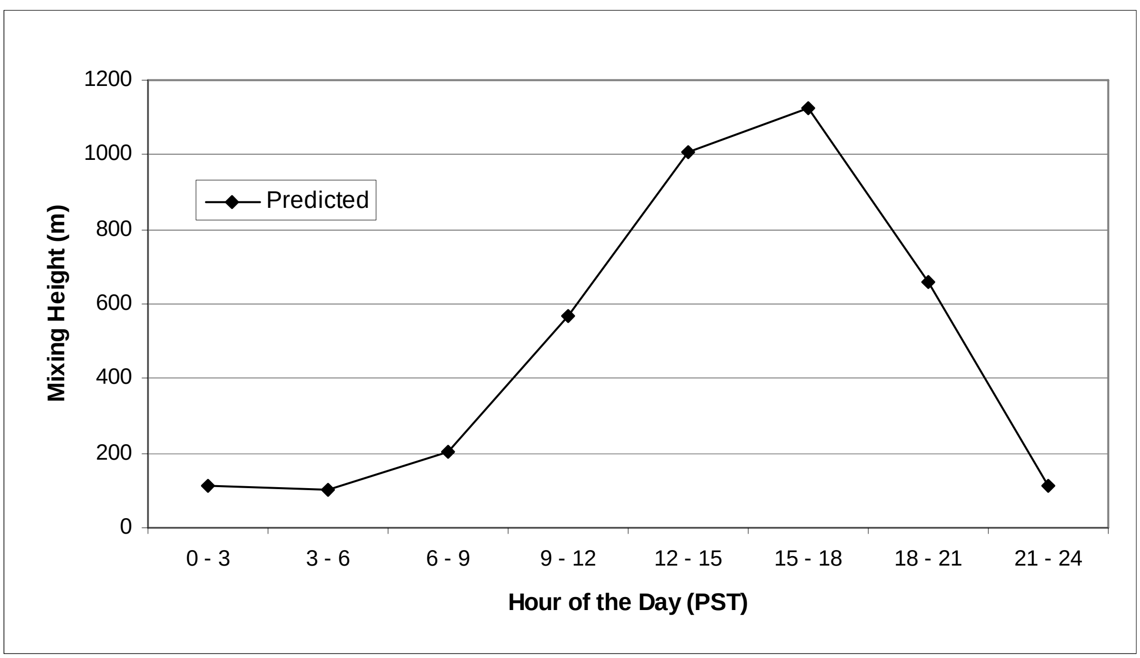


Figure 3-9 Hourly Predicted Mixing Heights from CALMET

3.1 Sample Wind Field

A subset of the model data was tested utilising a variety of parameters prior to selecting the final parameters outlined in the previous section. Figure 3-10 through Figure 3-12 show the resulting wind fields for a 1-hour period utilising all of the options outlined above. Figure 3-10 represents a 10 m height above the ground, while Figure 3-11 shows the mid-level wind field at 1250 m and Figure 3-12 represents a 2500 m height above ground. The time period of January 5, 2003 at 5:00 AM was selected. The meteorological conditions during this hour were stable and had an average measured wind speed of 1.3 m/s. As shown in the first figure, the surface layer wind field is influenced by the terrain as the wind passes through the modelling domain. In the second figure, the winds at the higher level show a slight direction shift and winds speeds are much higher and uniform. At the upper level, the winds are strong and uniform.

Figure 3-13 gives a 3-dimensional view of the surface wind field. The terrain effects are more noticeable in this representation.

4 Representativeness of Model Output

A comparison of the input meteorology with Climate Normals is presented in Appendix A. The data shows that the data from the surface stations is climatologically representative of the region. Thus, in applying CALPUFF, one would not expect extreme predictions to be a result of extreme meteorological events.

The QA/QC of the CALMET model results when compared with the input meteorology, shows that overall, the temperatures, mixing heights, precipitation, and distribution of wind directions were a representative simulation of the actual data. The stability class distribution results also appear reasonable. There were more than anticipated stable conditions and fewer neutral conditions, which is likely a result of the wind speed distribution resulting from the model. It was noted that the distribution of wind speeds in the model at the extracted point were more frequently lower than the measured data, which prompted further analysis.

A second point in the model domain was selected for data extraction and the data was examined to see if the low winds were specific to the valley point. Figure 4-1 shows the frequency of wind distribution for the second point (approximately 10km east of YWL). The distribution of wind speeds was higher and more representative at this point.

A number of modelling scenarios were conducted, and an analysis of the MC2 data was conducted. The model was run in two ways, first (as presented in sections 1 through 3 of this report) where there is a relatively strong reliance on the MC2 data, and second without the MC2 data, relying almost completely on surface observations. To examine what the effect on MC2 data had on the model, the frequency distribution of wind speeds was also generated and are in Figure 4-1. The raw MC2 data is also presented for the data point.

A comparison of the distribution shows that the surface level of the raw MC2 data (in MM5 format) has lower wind speeds than was is being measured in the airshed. The model results are a product a result of this input. Sample wind fields of the model run without the MC2 data are shown in Figures 4-2 through 4-5. Running the model without the MC2 data, produced wind fields at the surface that were representative of the area, and closer in distribution to the measured values at the station. However, aloft, the wind fields are very different than the MC2 model run because of the surface extrapolation of wind.

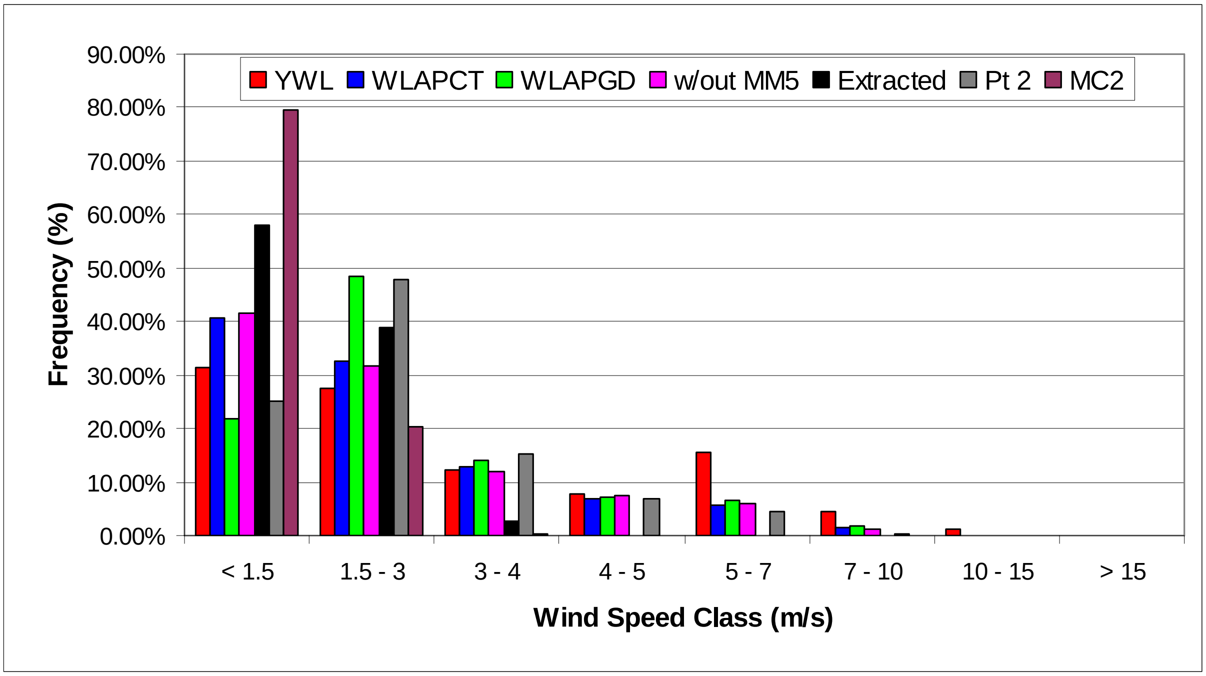
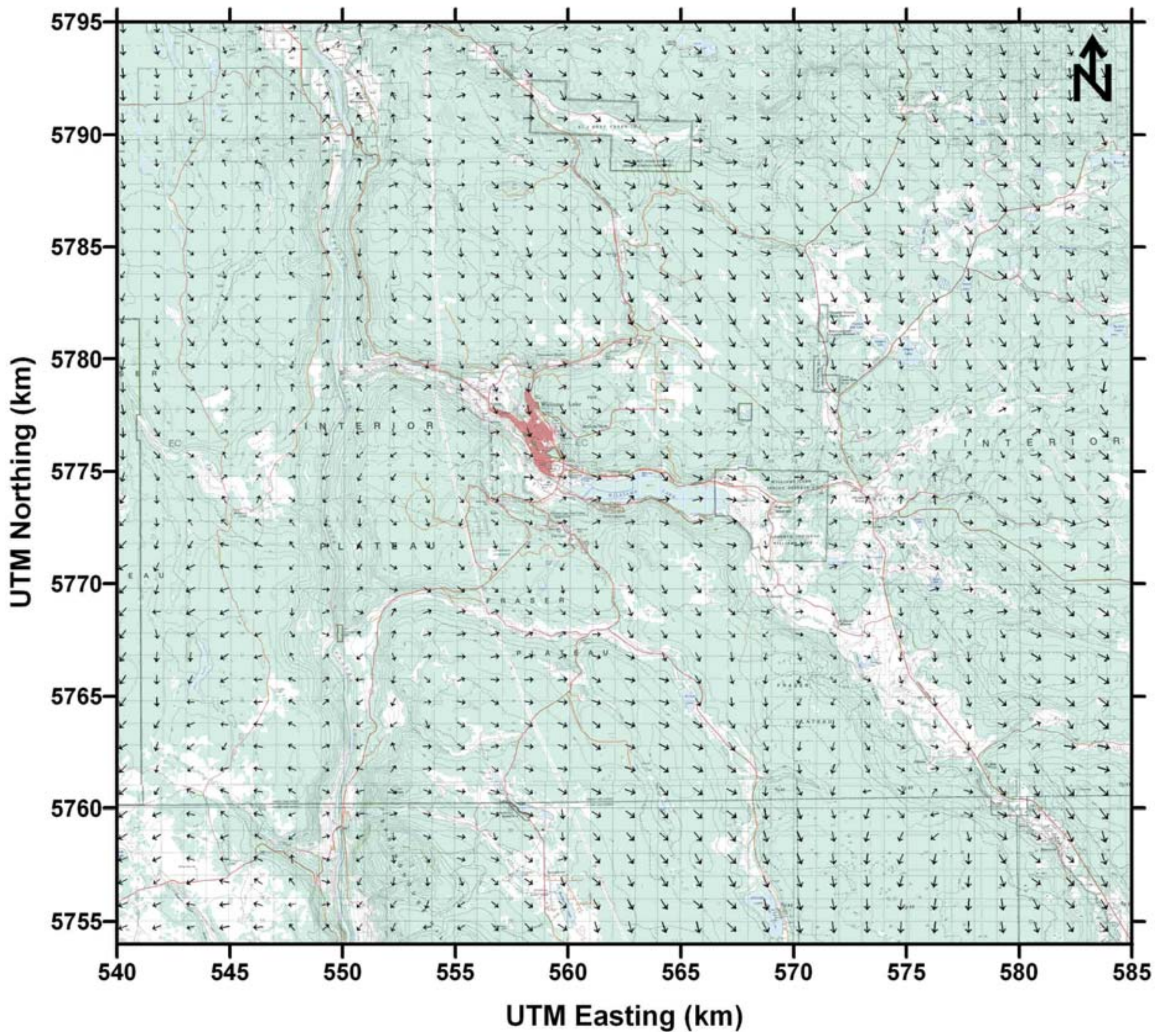


Figure 4-1 Frequency Distribution of Surface Wind Speeds for Three Surface Stations, 2 Predicted Values from CALMET and the raw MC2 (same location as Extracted point)

The quality of the output that is generated by this model is somewhat reliant on the perceived quality of the MC2 data and the believed representativeness of the surface stations. In each case, there are advantages and disadvantages as to how the model was run. The model run with the MC2 is provides simulated meteorological reflective of the MC2 data at all levels in the atmosphere, with a slight bias at the surface towards lighter wind speeds (Figure 4-6 shows the raw MC2 windrose at the extracted point). While the model run without MC2 data produces simulated meteorology representative at the surface, with upper air extrapolation that could be considered questionable.

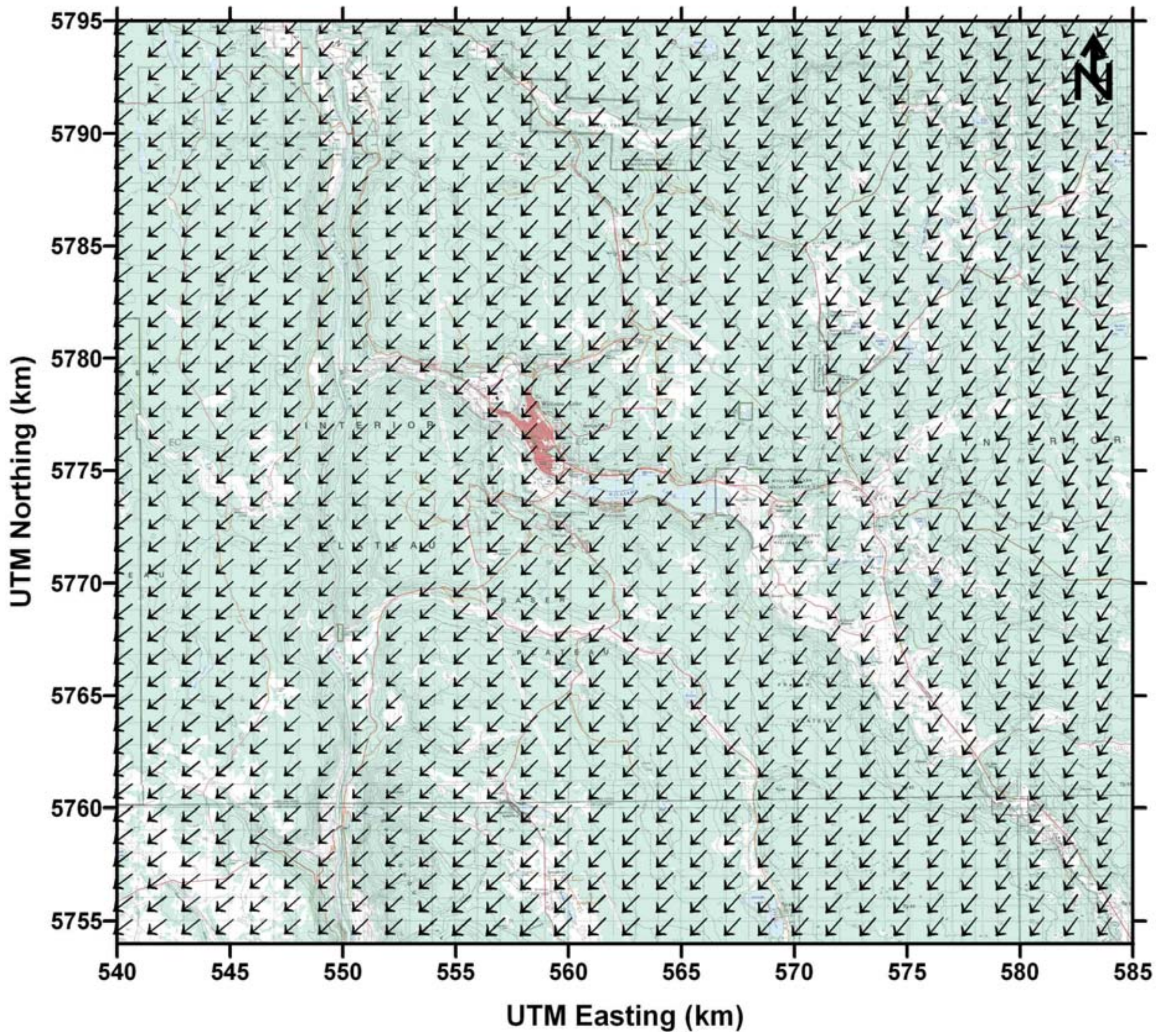
Although a bias to lighter wind speeds at the surface exists when using the MC2 data, if it is used in applications of pollutant modelling, conservative results would be anticipated for ground based sources as a result of less dispersion. Therefore, the model used with MC2 data is deemed to be suitable for CALPUFF modelling as it is presented in this report, with some potential for future improvements.

To potentially improve the CALMET model results in the future the following is recommended: Remove some of the levels from the MC2 data near the surface so that there is greater reliance on the surface stations at the low levels, while retaining the MC2 data at higher levels in the atmosphere. It is not recommended to try to improve the model by increasing R1 (relative weighting of the initial guess), as this would result in conflicting winds between MC2 and the surface conditions over certain areas in the domain (i.e. a doughnut like effect around the surface stations).



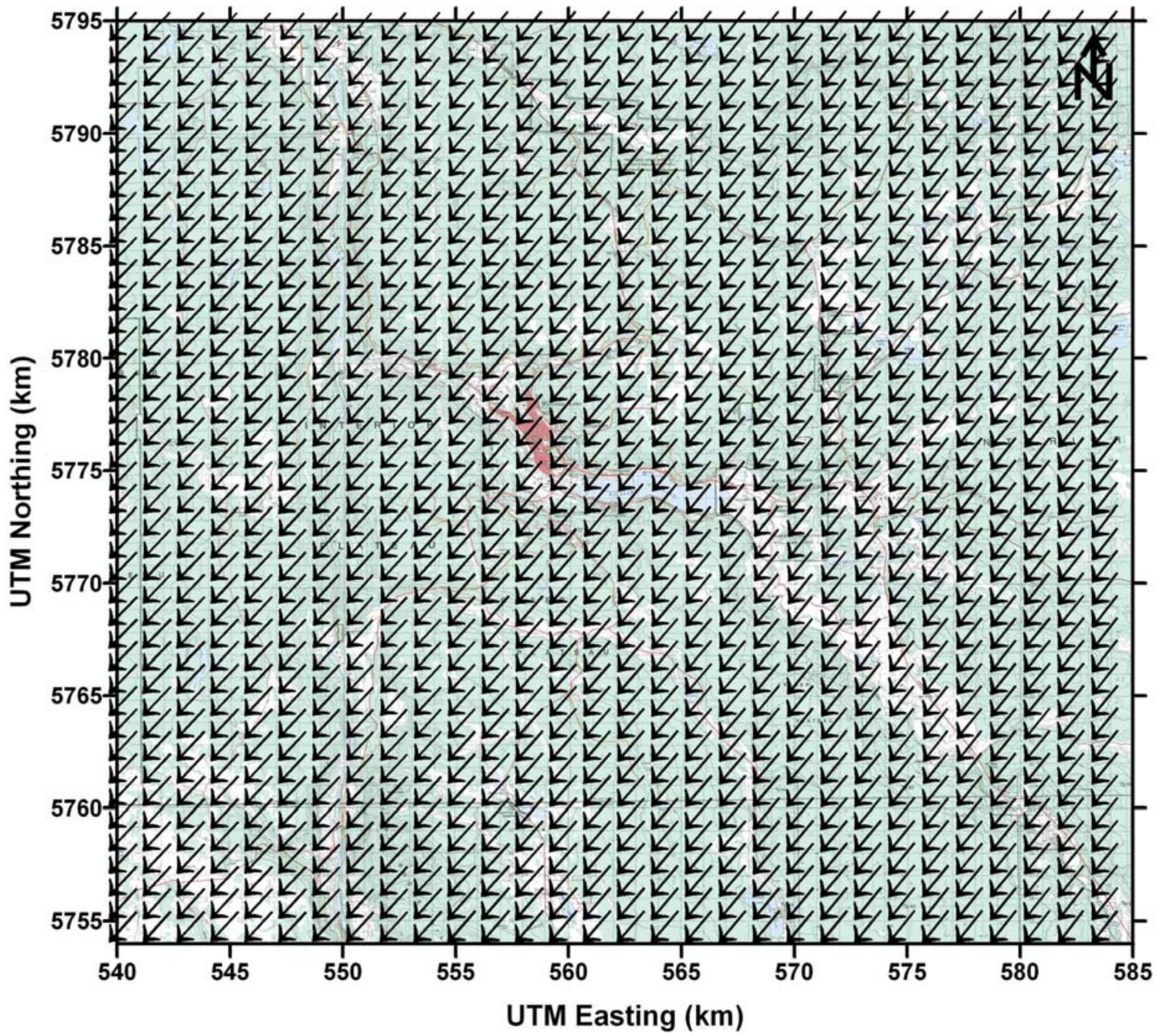
Arrow scale is 0 m/s to 8.5 m/s

Figure 3-10 Example Generated CALMET Wind Field for the Surface Level with MC2 data (January 5, 2004, 5:00 AM)



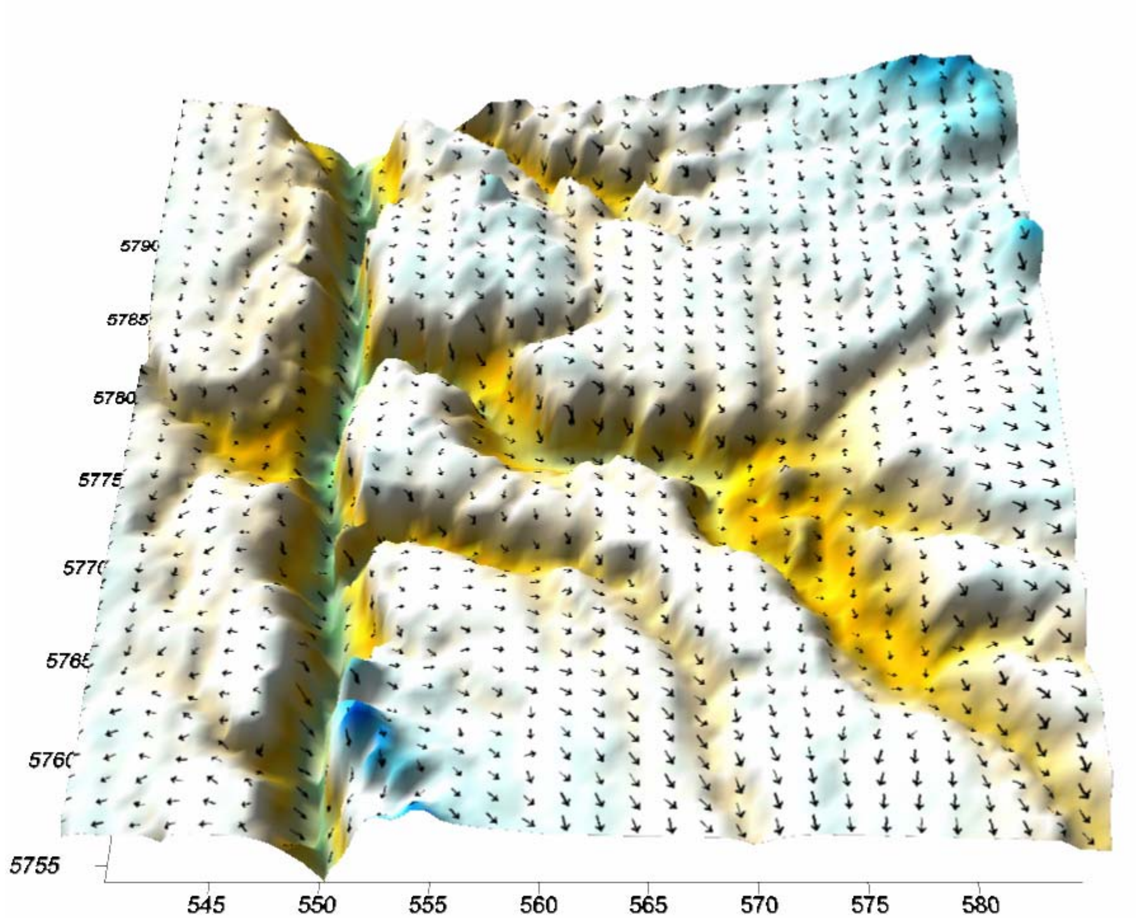
Arrow scale is 0 m/s to 8.5 m/s

Figure 3-11 Example Generated CALMET Wind Field for the 1250 m Level with MC2 data (January 5, 2004, 5:00 AM)



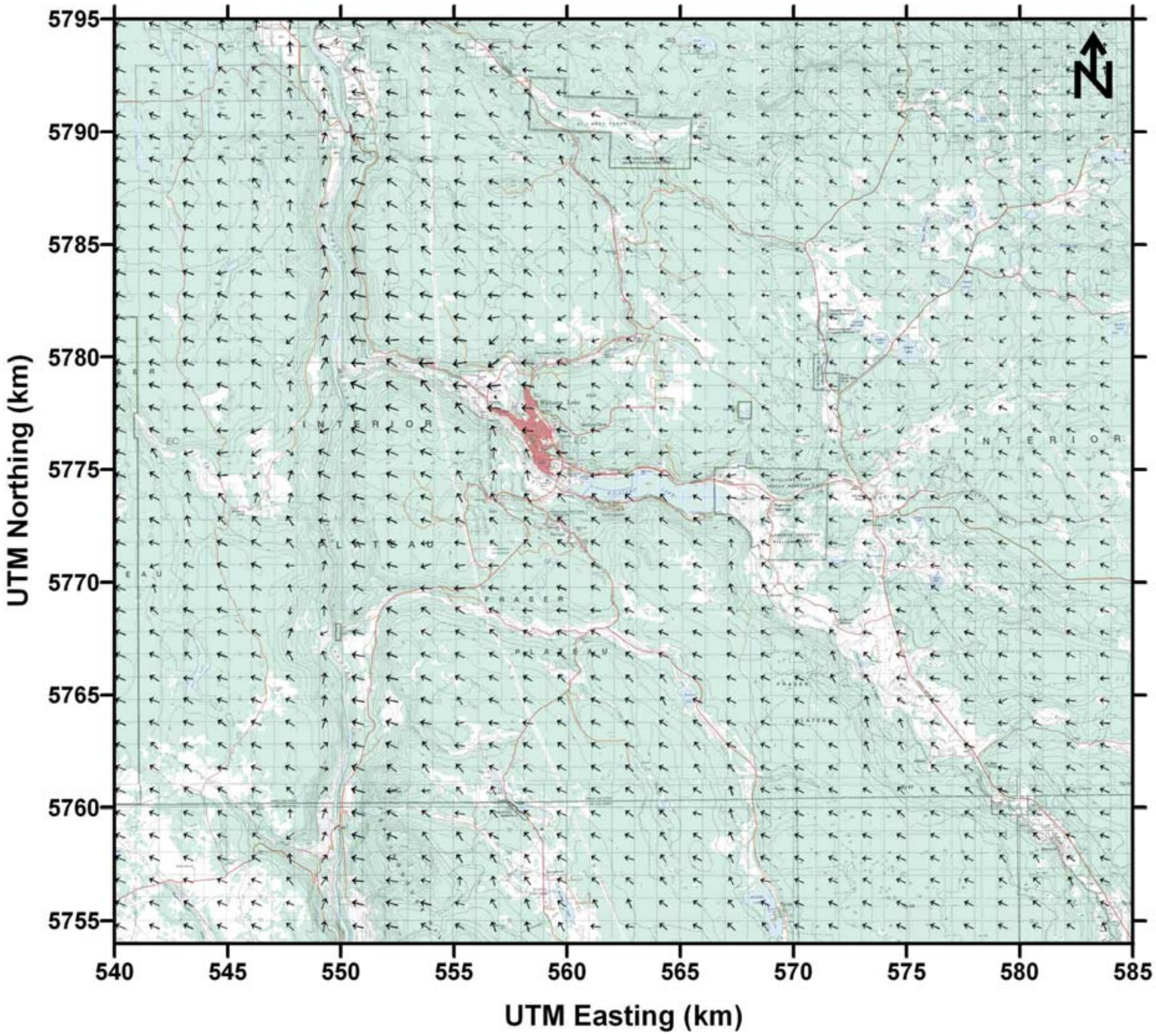
Arrow scale is 0 m/s to 8.5 m/s

Figure 3-12 Example Generated CALMET Wind Field for the 2500 m Level with MC2 data (January 5, 2004, 5:00 AM)



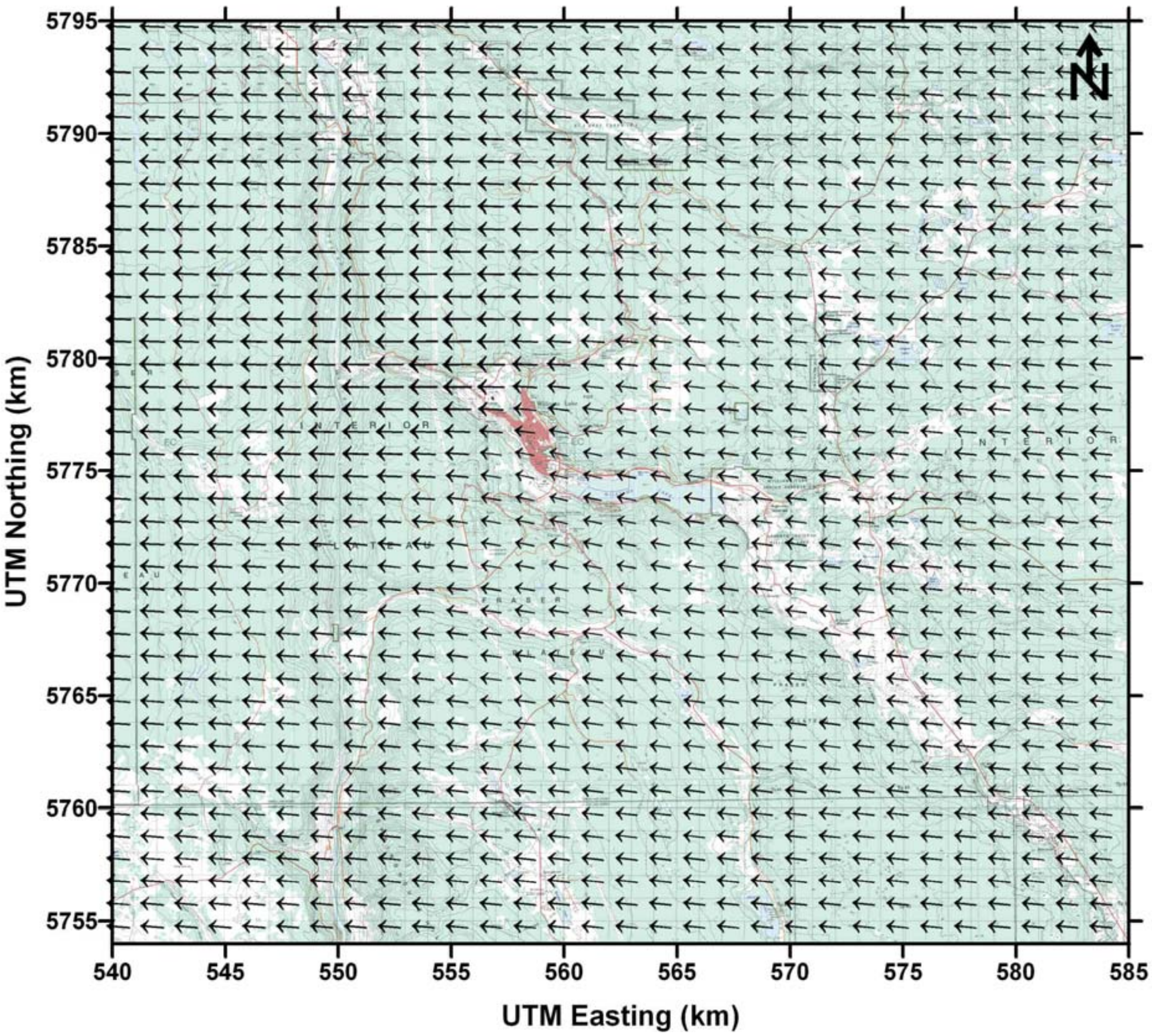
Arrow scale is 0 m/s to 3.5 m/s

Figure 3-13 3-Dimensional Example Generated CALMET Wind Field for the Surface Level with MC2 data (January 5, 2004, 5:00 AM)



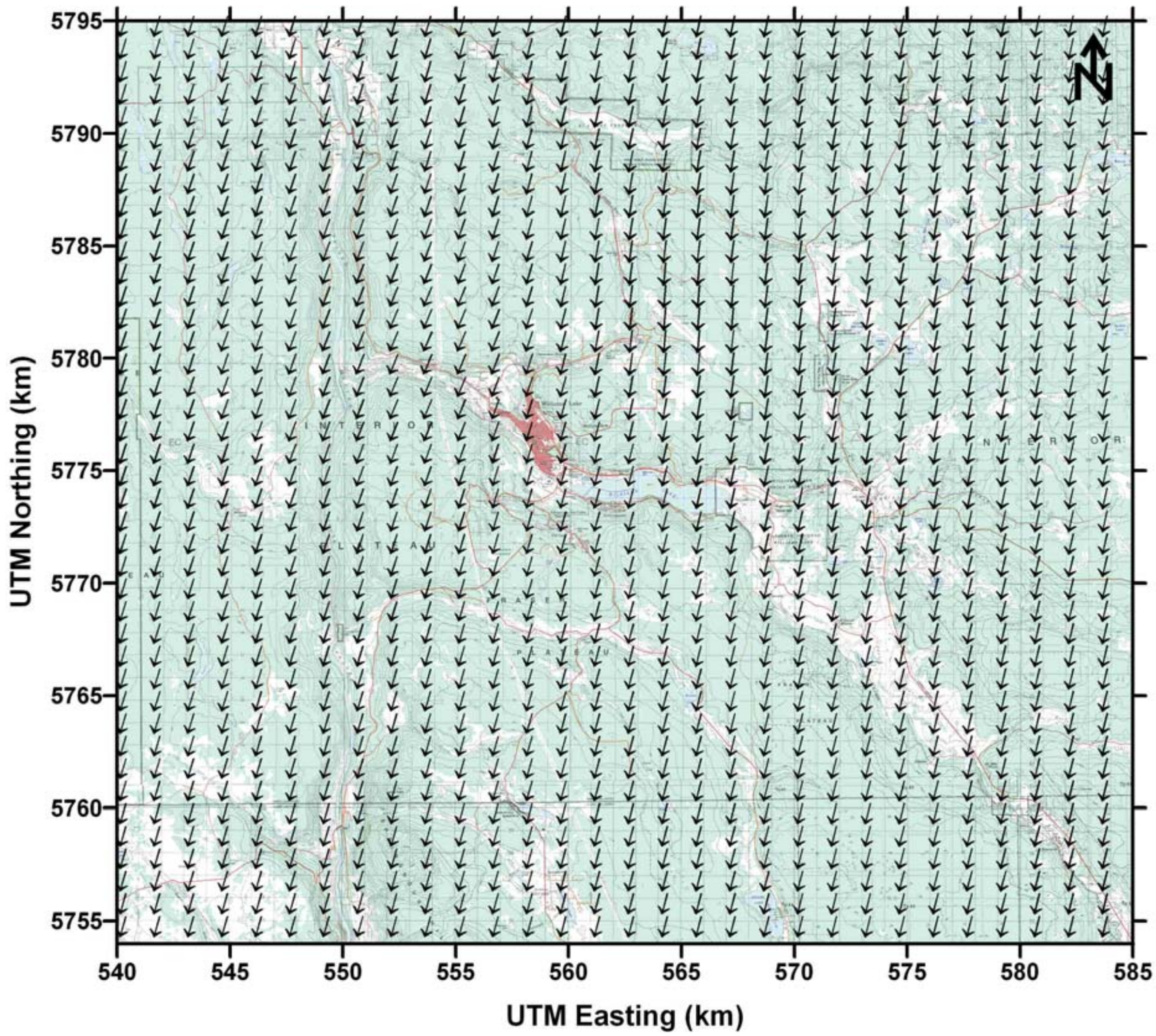
Arrow scale is 0 m/s to 8.5 m/s

Figure 4-2 Surface Level Wind Field from CALMET without MC2 Data (January 5, 2004, 5:00 AM)



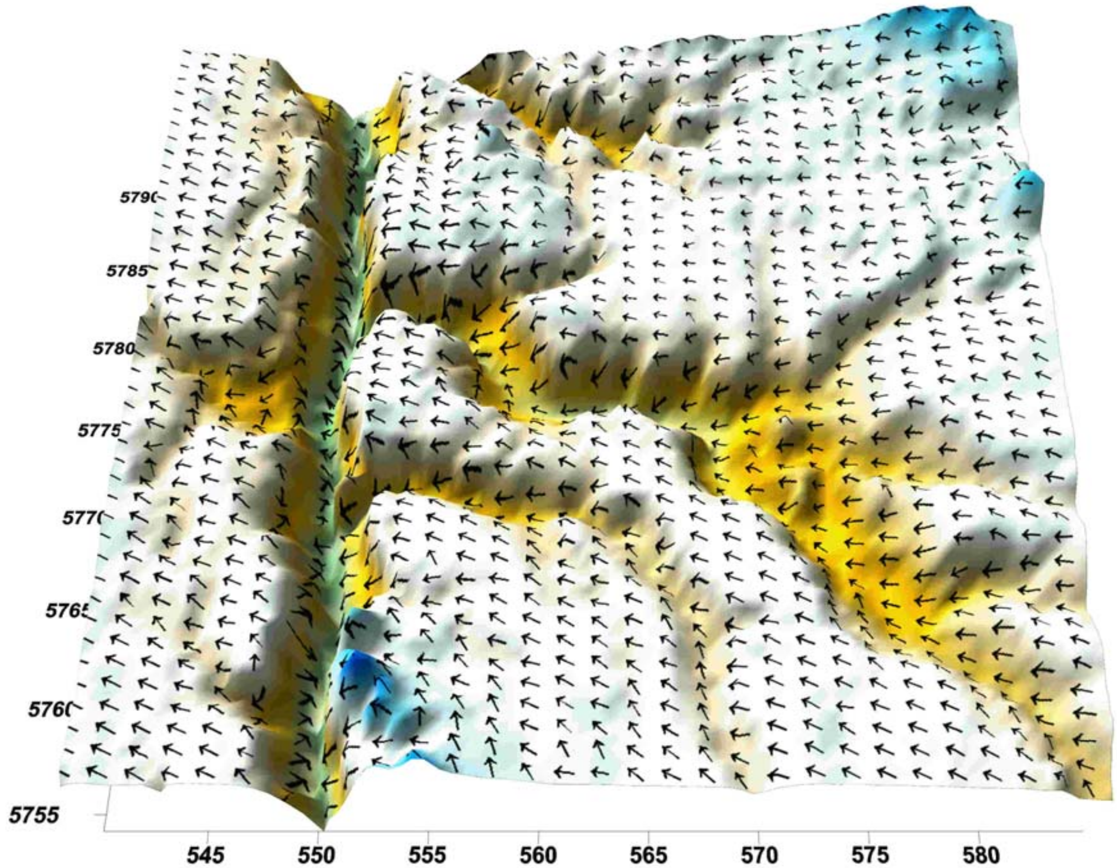
Arrow scale is 0 m/s to 8.5 m/s

Figure 4-3 Mid-Level (1250 m) Wind Field from CALMET without MC2 Data (January 5, 2004, 5:00 AM)



Arrow scale is 0 m/s to 8.5 m/s

Figure 4-4 Upper-Level (2500 m) Wind Field from CALMET without MM5 Data (January 5, 2004, 5:00 AM)



Arrow scale is 0 m/s to 3.5 m/s

Figure 4-5 3-Dimensional Wind Field for the Surface Level Generated by CALMET without MC2 Data (January 5, 2004, 5:00 AM)

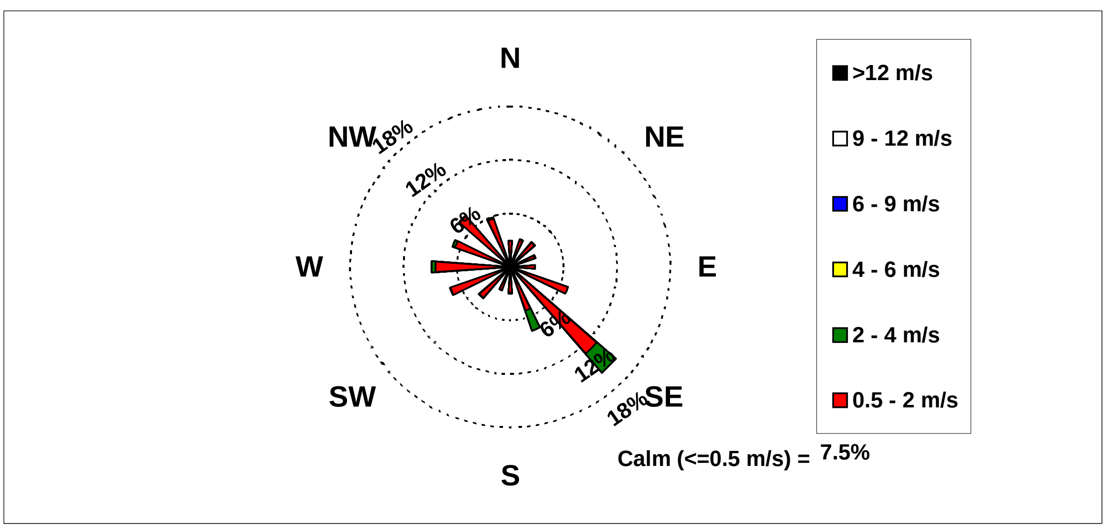


Figure 4-6 Windrose of the Raw MC2 Data at the Extracted Point

A APPENDIX

A.1 SOURCES OF DATA

Two types of meteorological data were used to determine the representativeness of the meteorological data to the Williams Lake airshed. Climate Normals, summarising the period from 1971 to 2000, obtained from Environment Canada were used to estimate the average wind conditions, temperature and frequency of precipitation in the vicinity of Williams Lake. In addition, hourly meteorological data from three different weather stations were used.

Surface wind data from June 2003 through May 2004 were available from three stations within the Williams Lake airshed, presented in Table A-1. The Williams Lake airport station is operated by Environment Canada while the Canadian Tire and Glendale stations are operated by the Ministry of Environment (MOE).

Table A-1 Surface Meteorological Stations in the Williams Lake Airshed

Station Name	UTM Location (m)	Elevation (m)	Anemometer Height (m)
Williams Lake Airport YWL (EnvCan)	564678 E 5781814 N	940	10
Williams Lake Canadian Tire (MOE)	559473 E 5774462 N	578	17.31
Glendale (MOE)	554524 E 5779879 N	628	14.93

A.2 WINDS

Wind roses showing the frequency of wind speeds and directions measured the airport, Canadian Tire and Glendale stations respectively are shown in Figure A-1 through A-3. The wind directions at all three sites reflect the topography and flow of winds in the river valley, with the airport showing the strongest influence. Winds speeds are usually less than 6 m/s, with both MOE station not recording any winds speeds greater than 9 m/s. Calm conditions (where measured wind speeds are less than 0.5 m/s) occur approximately 20.1%, 5.1% and 2.3% of the time at the airport, Canadian Tire and Glendale station.

Wind data from the Canadian Tire and Glendale stations required minimal processing, while data from the airport station required unit conversion (from km/h to m/s) of the wind speed and randomising of the wind directions within a 10 degree range. Environment Canada wind direction data is only available in 10s of degrees and requires randomisation within the 10 degree range (e.g. a value of 20 degrees is assigned a random value between 15 and 25 degrees) so that the modelled wind fields are more realistic. Calm hours (0 m/s wind speeds and 0 wind direction) were not subject to randomisation.

The mean wind speed from the Climate Normals is 2.8 m/s. The mean wind speed at each of the meteorological stations was 2.8 m/s, 2.2 m/s and 2.6 m/s for the airport, Canadian Tire and Glendale stations respectively.

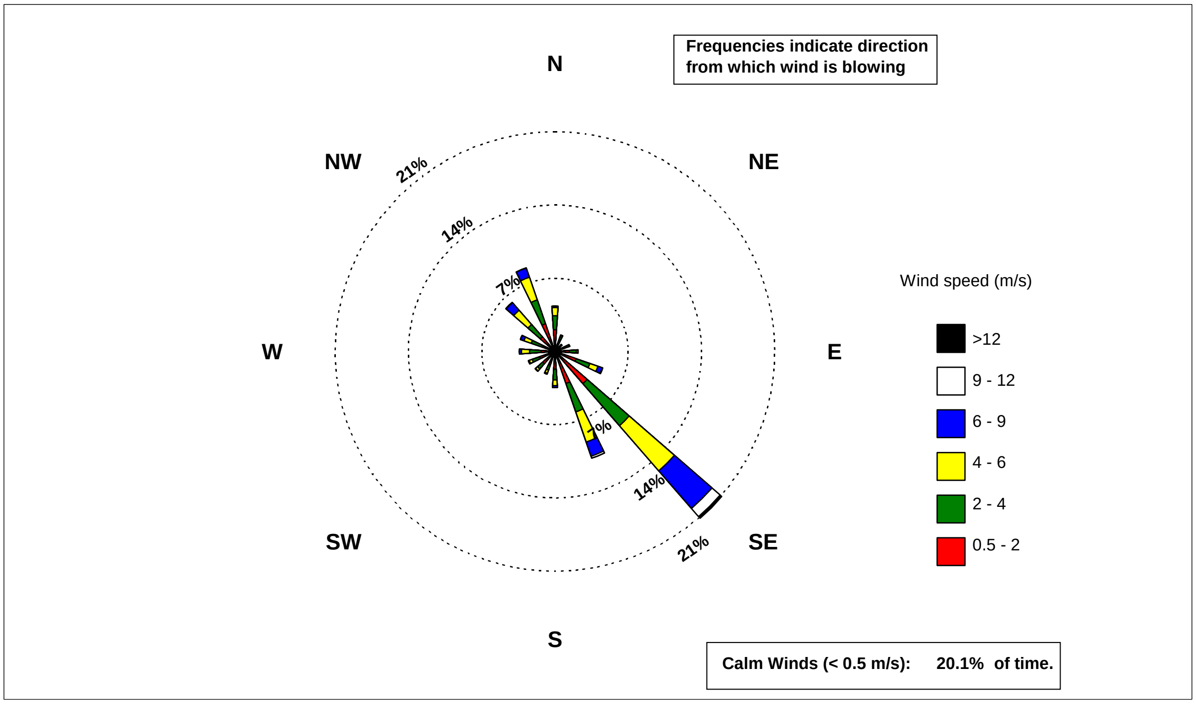


Figure A-1 Williams Lake YWL wind rose for June 2003 - May, 2004.

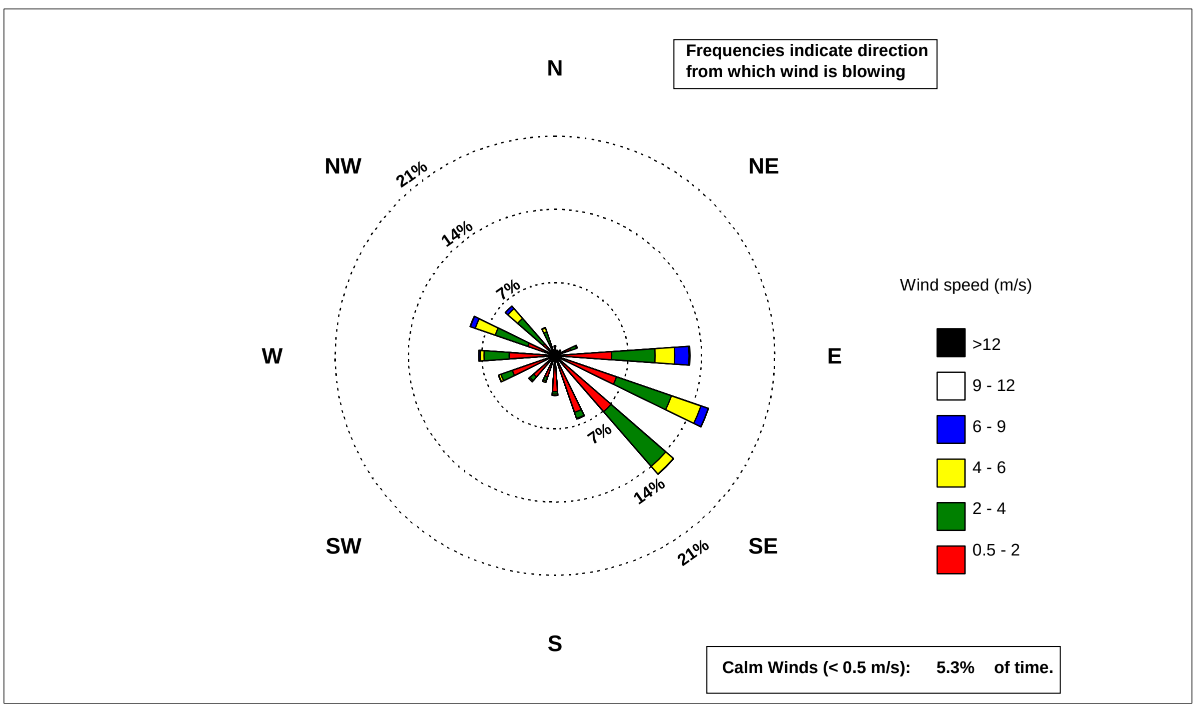


Figure A-2 Williams Lake Canadian Tire wind rose for June, 2003 – May, 2004

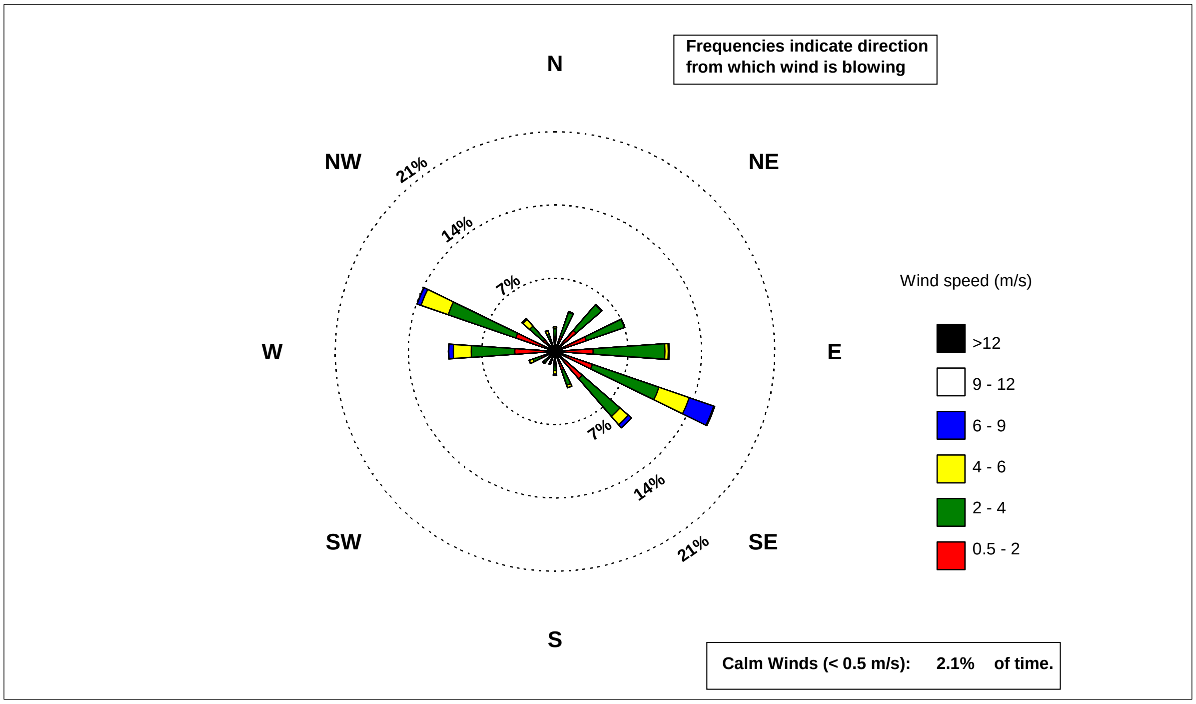


Figure A-3 Glendale wind rose for June, 2003 – May, 2004

A.3 TEMPERATURE

Temperature data was available for all three station (YWL, Canadian Tire and Glendale). A summary of the mean, maximum and minimum monthly temperatures is given in Table A-2. Figure A-4 shows the Climate Normals measured at the Williams Lake airport. The figure and tables show the measured data for the modelled year fall within the Climate Normals for the area.

The Climate Normals average daily temperatures listed in the figure were calculated by averaging the daily mean temperature over the entire monitoring period for each month. The mean daily maximum and minimum temperatures were calculated by averaging daily maximum and minimum temperatures for the month. The extreme maximum and minimum temperatures are the maximum and minimum temperatures for the monthly period.

Table A-2 Mean, Maximum and Minimum Temperatures Recorded at the Williams Lake Meteorological Stations

		YWL	Canadian Tire	Glendale
June	Maximum	28.5	31.9	31.0
	Minimum	2.3	5.2	4.8
	Mean	14.7	17.3	16.8
July	Maximum	32.7	35.5	35.2
	Minimum	4.4	7.5	7.4
	Mean	17.5	20.2	19.7
August	Maximum	30.0	33.0	32.6
	Minimum	1.4	4.8	4.2
	Mean	16.0	18.4	18.0
September	Maximum	28.6	30.5	31.2
	Minimum	-1.0	2.1	1.5
	Mean	10.8	12.9	12.6
October	Maximum	24.0	25.1	25.8
	Minimum	-16.0	-10.5	-11.0
	Mean	6.4	8.3	7.9
November	Maximum	4.4	7.0	7.2
	Minimum	-18.5	-14.0	-14.6
	Mean	-5.0	-2.7	-3.4
December	Maximum	4.8	8.2	8.0
	Minimum	-15.4	-13.6	-13.9
	Mean	-3.6	-1.7	-2.1
January	Maximum	8.1	9.8	11.1
	Minimum	-35.4	-33.5	-33.4
	Mean	-8.9	-7.9	-8.1
February	Maximum	6.8	8.7	9.6
	Minimum	-15.9	-16.9	-13.6
	Mean	-2.0	-0.9	-0.8
March	Maximum	16.9	20.0	20.1
	Minimum	-8.0	-5.2	-5.0
	Mean	2.4	4.6	4.5
April	Maximum	22.7	26.2	25.2
	Minimum	-8.1	-4.3	-5.0
	Mean	6.8	8.8	8.6
May	Maximum	22.2	25.8	24.9
	Minimum	-2.9	0.0	0.0
	Mean	9.6	12.3	11.8

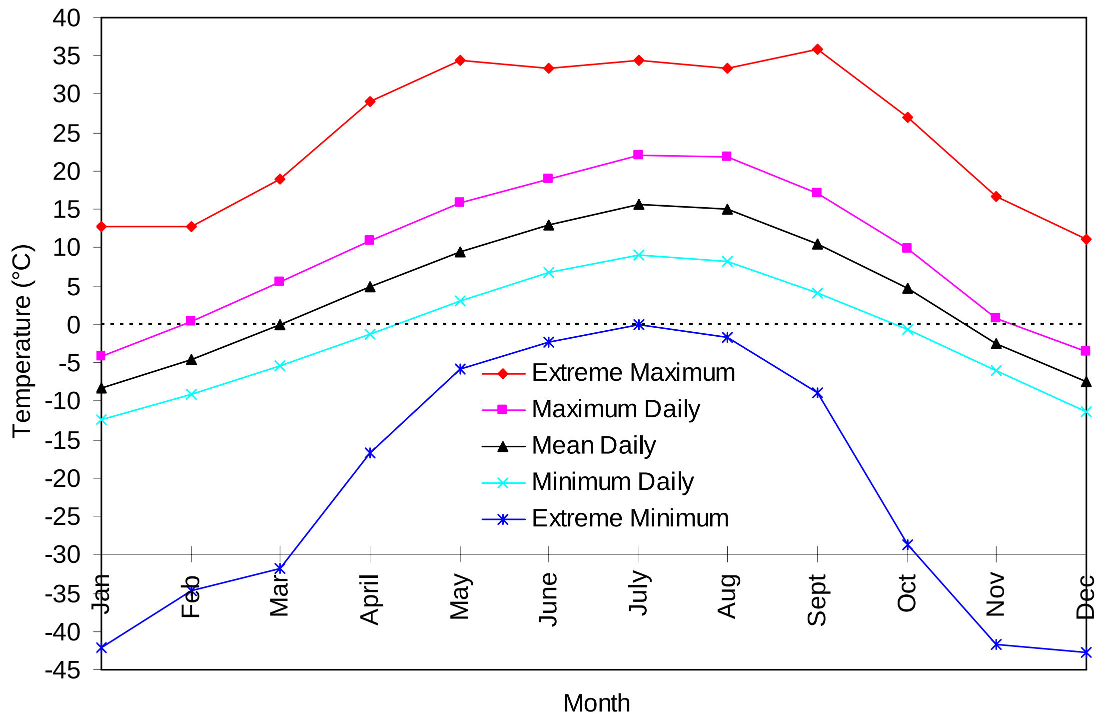


Figure A-4 Climate Normals of Temperature for the Williams Lake Airport

A.4 PRECIPITATION

Precipitation normals from the Williams Lake airport station are summarised in Figure A-5 and Figure A-6. The mean rainfall, snowfall and total precipitation data were found by averaging the mean monthly precipitation data over the entire monitoring period. The number of days with measurable precipitation was determined by averaging the total number of days of precipitation per month over the monitoring period. The greatest rainfall, snowfall and precipitation data are the maximums measured during the monitoring period.

Precipitation data in the Williams Lake airshed was available hourly from the B.C. Ministry of Forests' Fire Weather Station network for 11 of the 12 months that were modelled. Daily precipitation values were also available from the airport. These were used when the hourly values were missing. During the period of June 1, 2003 – May 31, 2004, the total precipitation for the airport station was 439.0 mm while total rainfall at the Ministry of Forests site over the same period was 380.0 mm.

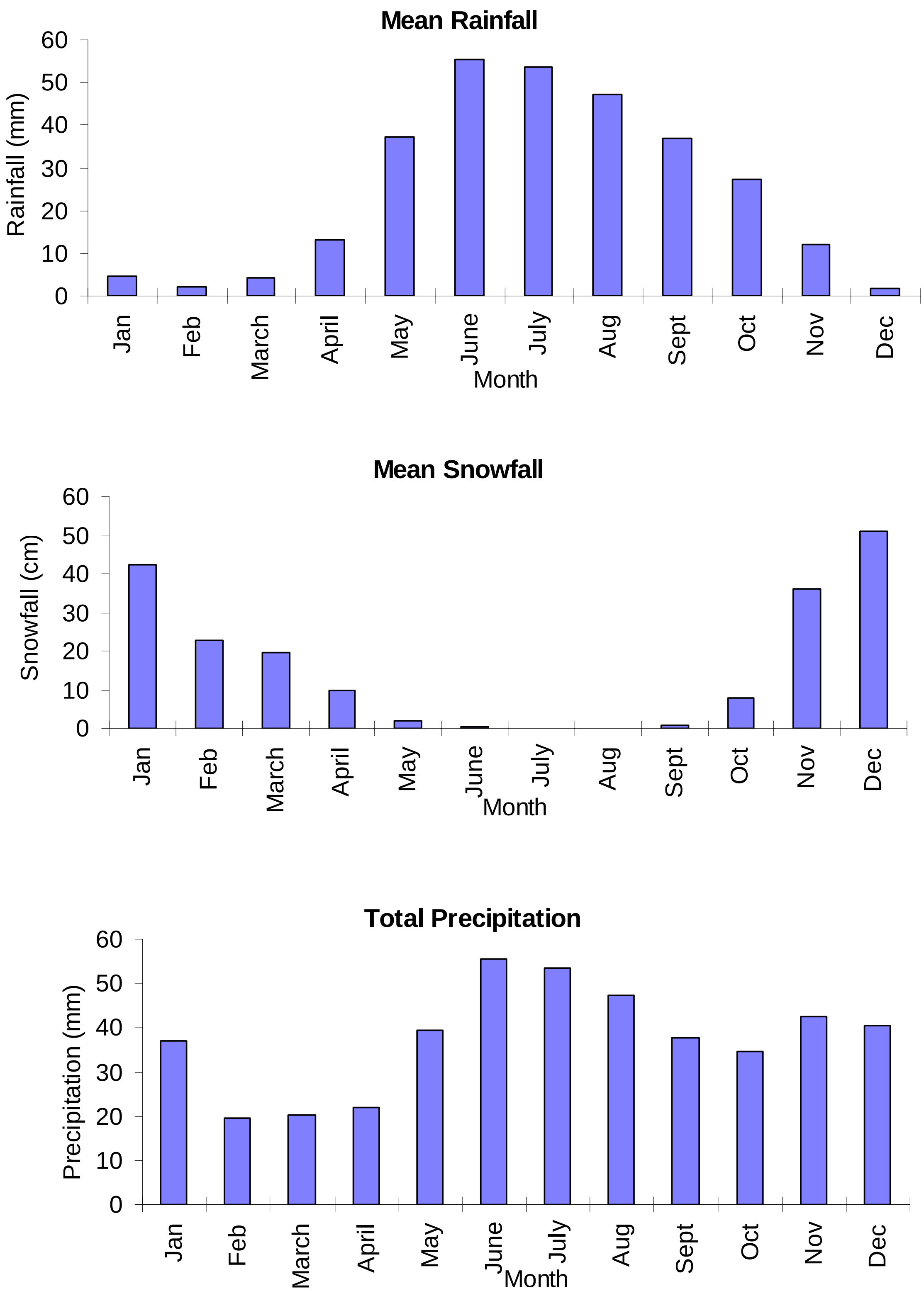


Figure A-5 Precipitation Summary for the Williams Lake Airport (Normals)

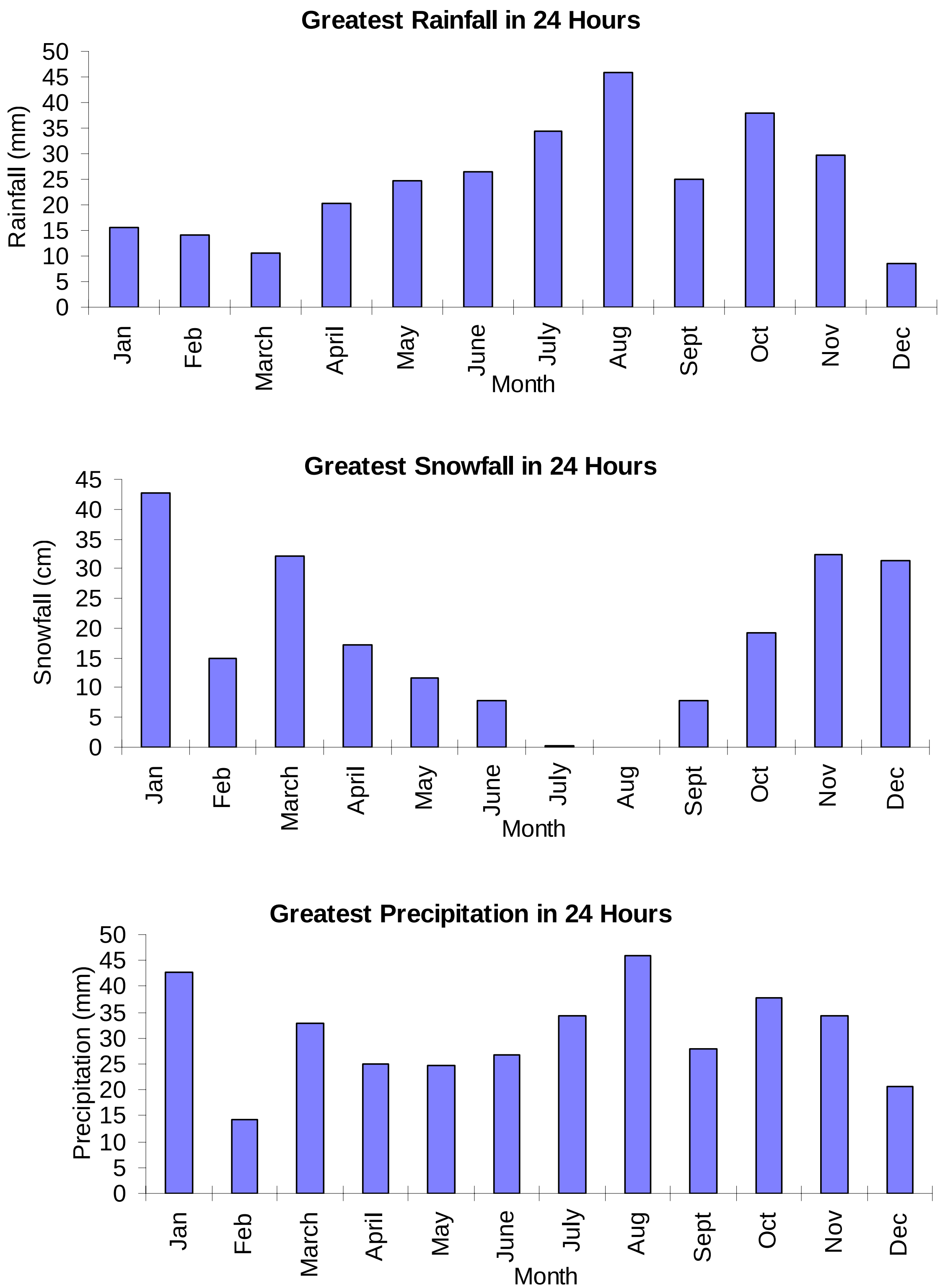


Figure A-6 Precipitation Summary for the Williams Lake Airport (Normals)