CONSULTING ENGINEERS & SCIENTISTS

REPORT

Air Quality Analysis for the Industrial Land Use Plan - Prince George Airport West

Project Number: # W08-1103 **September 2008**

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September 23, 2008

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Attention: **Heather Oland**

Subject: **Prince George Light Industrial Land Use Air Quality Study**

Please find enclosed our revised report for the air quality investigation of the proposed light industrial land-use zone west of the Prince George Airport that includes the latest changes to the net developable area, site-specific traffic estimates and expected vehicle mix. Both fugitive dust and vehicle emissions of particulate matter (PM) were assessed. Based on the latest development plan, exceedances of the PM_{10} and $PM_{2.5}$ objectives are not expected due to emissions from the proposed land-use zone alone. However, exceedances of the PM objectives are currently observed in Prince George and when the contribution of PM emissions from the proposed light industrial area are added to observed PM concentrations, the frequency of observed exceedances increases.

If you have any questions or require further information, please contact the undersigned at (604) 730-5688 ext. 3227 or Kathy Preston at (604) 730-5688 ext. 3223.

Sincerely,

RWDI AIR Inc.

Geoff Doerksen, M.Sc.
Project Manager

EXECUTIVE SUMMARY

RWDI AIR Inc. (RWDI) was engaged to conduct an air quality investigation in support of an industrial land use plan for an area north and west of the Prince George Airport. The area, which is currently within the Agricultural Land Reserve and designated as a rural resource, is situated between the Prince George Airport and downtown Prince George. It is proposed to designate this area as a light industrial zone (M1 and M2). The proposed area occupies approximately 1180 hectares although the net developable area is expected to be 856 hectares. Given the potential for particulate matter emissions from traffic in the land use area and close proximity of residents to the proposed light industrial area, this air quality investigation was conducted.

This report includes a summary of regulatory processes, a meteorological analysis, results from atmospheric computer modelling, and recommendations for best management practices and design. The atmospheric computer modelling builds on work conducted by the University of Northern British Columbia (UNBC). Predictions of particulate matter (PM) are based on the potential for fugitive dust and vehicle emissions resulting from traffic on paved roads and storage areas in the proposed light industrial development plan.

An initial meteorological investigation of Prince George was performed with a computer model. Predicted meteorology was examined at locations within the proposed light industrial land-use zone as well as one location in downtown. The wind patterns at the proposed zone were shown to have dominant south winds with a smaller component from the north and from the south-southwest while downtown experienced a greater range of predominant winds directions. Considering these wind patterns, the eastern part of downtown is most likely to be impacted by particulate matter emissions blown from the western-most part of the proposed light industrial zone. However, since the dispersion or movement of pollutants in the air is determined by several factors in addition to prevailing winds it is common practice to use a dispersion model to simulate the behaviour and movement of air pollutants in the atmosphere based on local emissions and meteorology.

The contribution of vehicle emissions of PM was found to be much smaller than the contribution of fugitive dust emissions. Emission estimation was based on vehicle traffic volumes and trip generation statistics for the light industrial zone provided by L&M Engineering Ltd. These traffic statistics match the traffic impact study and equate to approximately 16.1 vehicles/1000 m^2/d (1.5 vehicles/1000 ft^2-d) based on the area occupied by buildings. To assess the sensitivity of the model to traffic volume, twice this traffic generation (i.e., 32.3

vehicles/100m^2/d) was also assessed. A one-way travel distance of 1.5 km was assumed, corresponding to the approximate road distance from one end of a sub-area to the centre. It was also assumed that 70% of the vehicles would be passenger cars, 20% light-duty trucks and 10% heavy-duty trucks.

Particulate matter emissions were estimated for two basic surfaces: (1) paved roads and parking lots and (2) paved storage areas. The scenario thought to best represent the proposed land-use area is comprised of 25% paved roads and parking lots, 30% paved storage areas, 30% buildings, and 15% undeveloped or landscaped areas. There will be no unpaved surfaces in the proposed development plan. Results show that the largest potential source of PM emissions is traffic on paved roads. The paved storage areas represent a very minor contribution. Also, concentrations of suspended PM less than 10 µm in diameter (PM_{10}) are estimated to be about nine times greater than concentrations of suspended PM less than 2.5 µm in diameter ($PM_{2.5}$). This is important because the $PM_{2.5}$ size fraction is understood to be more closely associated with health effects than the PM_{10} size fraction.

Modelling was performed to predict ambient $PM_{2.5}$ and PM_{10} concentrations due to vehicle PM emissions and fugitive dust from the two surface types. For the expected traffic generation rate (16.1 vehicles/1000m^2/d), the maximum predicted 24-hour PM_{10} concentration is 23 µg/m^3 (micrograms per metre cubed) located in the vicinity of the proposed zone, and 13 µg/m^3 in downtown Prince George. For the same scenario, the maximum predicted $PM_{2.5}$ concentrations are 2.6 µg/m^3 in the immediate vicinity of the proposed zone and 1.5 µg/m^3 in downtown Prince George. These concentrations are less than the 24-hour provincial objectives for PM_{10} (50 µg/m^3) and $PM_{2.5}$ (25 µg/m^3). The maximum predicted annual average PM_{10} concentrations for the expected traffic generation scenario are 9.0 µg/m^3 in the vicinity of the zone and 3.0 µg/m^3 downtown. The maximum predicted annual average $PM_{2.5}$ concentration in the vicinity of the zone is 0.9 µg/m^3 while the maximum predicted downtown is 0.3 µg/m^3. These concentrations are much less than the proposed annual $PM_{2.5}$ objective of 8 µg/m^3. When the expected traffic generation rate in the light industrial zone is doubled, predicted $PM_{2.5}$ concentrations are still much less than the provincial objectives and predicted PM_{10} concentrations are less than half the objective in downtown Prince George.

From 2001 to 2005, exceedances of the 24-hour PM_{10} and $PM_{2.5}$ objectives were observed 3.7% (13.5 days/year) and 5.1% (18.6 days/year) of the time, respectively, at the Plaza 400 monitoring station in downtown Prince George. The proposed annual $PM_{2.5}$ objective was exceeded 80% of the time during this period. When the maximum predicted concentrations were combined with the observed concentrations, it was found that the proposed land use development plan may increase the frequency of exceedance of the 24-hour PM_{10} and $PM_{2.5}$ objectives by a maximum of 17% and 2% in the entire study area and 6% and 1% in downtown Prince George. However, these increases are based on the assumption that the worst case predicted concentrations would occur at the same time and the same place as the worst case observed concentrations. This is unlikely. Therefore more realistic combinations of predicted and observed concentrations were also assessed and the increases in the frequency of exceedance are less for such scenarios. For example, when the median (50^{th} percentile) PM_{10} concentration predicted for the downtown area and associated with the expected traffic generation rate is added to concentrations observed at Plaza 400, the resultant increase in frequency of exceedance of the PM_{10} objective is 0.7% (2.6 days/year) in the downtown area. Similarly, when the 50^{th} percentile predicted $PM_{2.5}$ concentration associated with the expected traffic generation rate is added to observed concentrations, the increase in the frequency of exceedance in downtown is 0.2% (0.7 days/year).

Mitigation measures to minimize road dust emissions include covering loads on trucks with heavy tarpaulins to prevent spillage of material, application of coarser winter traction material as opposed to finer sands, minimizing activities during PM episodes and removing any material that has deposited on the travel lanes via vacuum sweeping or water flushing. Factors affecting paved road dust emissions include the road surface silt loading, mean vehicle weight, and traffic volumes. The use of tracked vehicles and heavy trucks should be restricted to prevent damage to road surface and base. Furthermore, storm-water drainage should be addressed such that curbing or ditching drains erosion from surrounding land away from the paved roads and the road shoulders should be either paved or stabilized with gravel or vegetation.

TABLE OF CONTENTS

EXECUTIVE SUMMARY .... **I**

1.0 INTRODUCTION **1**

2.0 REGULATORY REQUIREMENTS **2**

2.1 PROVINCIAL AMBIENT AIR QUALITY STANDARDS 2

2.2 PRINCE GEORGE ZONING BYLAWS 3

3.0 STUDY AREA **3**

4.0 METHODOLOGY **4**

4.1 CALMET 5

4.2 CALPUFF 7

4.3 EMISSION ESTIMATION 9

4.3.1 Paved Road Vehicle and Fugitive Emissions 10

4.3.2 Paved Storage Areas 11

4.3.3 Natural Mitigation 12

4.4 BACKGROUND CONTRIBUTION 12

5.0 RESULTS **14**

5.1 CALMET ANALYSIS 14

5.1.1 Surface Winds 14

5.1.2 Stability Classes 16

5.1.3 Mixing Heights 17

5.1.4 Wind Vector Plots 18

5.2 MODELLING RESULTS AND DISCUSSION 23

5.2.1 Combined Results 26

5.3 CONCLUSIONS 35

6.0 BEST MANAGEMENT PRACTICES AND DESIGN **36**

7.0 RECOMMENDATIONS FOR FURTHER INVESTIGATION **37**

8.0 REFERENCES **38**

LIST OF TABLES

Table 2-1: Provincial Ambient Air Quality Objectives and Standards for Particulate Matter... 2

Table 2-2: Bylaws Applicable to this Study........ 3

Table 4-1: Changes made to CALMET Input Files 6

Table 4-2: Changes made to CALPUFF input file........ 8

Table 4-3: Empirical Constants for Paved Road Dust Emissions........ 10

Table 4-4: Summary of 24-Hour PM_{10} and $PM_{2.5}$ Concentrations at Plaza 400........ 13

Table 4-5: Summary of Annual PM_{10} and $PM_{2.5}$ Concentrations ($\mu g/m^3$) at Plaza 400 13

Table 5-1: CALMET Derived PGT Stability Classes........ 16

Table 5-2: CALMET Mixing Heights Above Ground by PGT Stability Class 17

Table 5-3: Maximum Predicted 24-Hour PM_{10} and $PM_{2.5}$ Concentrations ($\mu g/m^3$) in the Study Area by Source Type and Sub-Area 23

Table 5-4: Maximum Predicted 24-Hour PM_{10} and $PM_{2.5}$ Concentrations ($\mu g/m^3$) in Downtown Prince George by Source Type and Sub-Area........ 23

Table 5-5: Maximum Predicted 24-Hour PM_{10} and $PM_{2.5}$ Concentrations for All Source Types and All Sub-areas 27

Table 5-6: Maximum Predicted Annual PM_{10} and $PM_{2.5}$ Concentrations for All Source Types and All Sub-areas........ 27

Table 5-7: Predicted Project Contribution Plus Background Greater than Objective or Half the Objective – Traffic Generation Rate of 16.1 vehicles/m^2/d........ 33

Table 5-8: Predicted Project Contribution Plus Background Greater than Objective or Half the Objective – Traffic Generation Rate of 32.3 vehicles/m^2-d........ 34

LIST OF FIGURES

Figure 3-1: Topography of Prince George Region. Location of Proposed Industrial Land-Use Zone in Prince George is Outlined in Orange 4

Figure 4-1: Terrain elevations and meteorological stations (shown as a blue cross) used in CALMET. The three sub-areas of the proposed industrial land-use zone are shown in red. 6

Figure 4-2: Three Source Areas Used in CALPUFF Shown in Black........ 8

Figure 4-3: Receptor Grid Applied in CALPUFF Modelling........ 9

Figure 5-1: Surface wind roses extracted from four locations in the model domain, one for each sub-division and one at the Plaza 400 downtown 15

Figure 5-2: Mixing Heights on a Typical Summer Afternoon (July 8, 2004 at 16:00 LST) Plotted on Land Use Data 18

Figure 5-3: Surface Vector Wind Fields during PG Stability Class 1 (Very Unstable) on *June 4, 2005 at 13:00 LST*. Arrow lengths give relative wind speed from 0 to 1.8 m/s. 20

Figure 5-4: Surface Vector Wind Fields during PG Stability Class 2 (Unstable) on *May 6, 2001 at 11:00 LST*. Arrow lengths give relative wind speed from 0 to 1.4 m/s. . 20

Figure 5-5: Surface Vector Wind Fields during PG Stability Class 3 (Slightly Unstable) on *January 29, 2001 at 13:00 LST*. Arrow lengths give relative wind speed from 0 to 4.0 m/s. 21

Figure 5-6: Surface Vector Wind Fields during PG Stability Class 4 (Neutral) on *March 30, 2002 at 20:00 LST*. Arrow lengths give relative wind speed from 0 to 6.5 m/s. . 21

Figure 5-7: Surface Vector Wind Fields during PG Stability Class 5 (Slightly Stable) on *November 30, 2004 at 01:00 LST*. Arrow lengths give relative wind speed from 0 to 4.2 m/s. 22

Figure 5-8: Surface Vector Wind Fields during PG Stability Class 6 (Stable) on *January 11, 2001 at 04:00 LST*. Arrow lengths give relative wind speed from 0 to 1.2 m/s. . 22

Figure 5-9: Contour Plot of 24-hour Averaged Unitless PM_{10} for Sub-area 1 Modelled with a Unit Emission Flux 24

Figure 5-10: Contour Plot of 24-hour Averaged Unitless PM_{10} for Sub-area 2 Modelled with a Unit Emission Flux 25

Figure 5-11: Contour Plot of 24-hour Averaged Unitless PM_{10} for Sub-area 3 Modelled with a Unit Emission Flux 26
Figure 5-12: Contour Plot of Maximum Predicted 24-Hour $PM_{2.5}$ Concentrations from all Three Sub-areas for Expected Traffic Generation Rate (16.1 vehicles/1000 m^2/d) 28
Figure 5-13: Contour Plot of Maximum Predicted 24-Hour PM_{10} Concentrations from all Three Sub-areas for Expected Traffic Generation Rate (16.1 vehicles/1000 m^2/d)........ 29
Figure 5-14: Contour Plot of Maximum Predicted 24-Hour $PM_{2.5}$ Concentrations from all Three Sub-areas for Higher Traffic Generation Rate (32.3 vehicles/1000 m^2/d) . 30
Figure 5-15: Contour Plot of Maximum Predicted 24-Hour PM_{10} Concentrations from all Three Sub-areas for Higher Traffic Generation Rate (32.3 vehicles/1000 m^2/d)............ 31

1.0 INTRODUCTION

L & M Engineering Limited (L&M) has been engaged by Henry Rempel of 0743999 BC Ltd. and the City of Prince George to complete an industrial land use plan for an area north and west of the Prince George Airport. The area is currently within the Agricultural Land Reserve (688 ha) and designated as a Rural Resource by the Official Community Plan. The proposed area, 1180 hectares in size, is situated between the Prince George Airport and downtown Prince George. The proposed area will be designated a light industrial zone (M1 and M2). Given the potential for fugitive dust emissions and close proximity of residents near the proposed light industrial area, an air quality investigation has been conducted.

RWDI AIR Inc. (RWDI) was engaged to conduct an air quality investigation that includes a summary of regulatory processes, a meteorological analysis, simplified dispersion modelling, and recommendations for best management practices and design. The University of Northern British Columbia (UNBC) is currently performing dispersion modelling for the City of Prince George. Given this partnership, UNBC has kindly allowed their modelling to be used in this study. Modelling inputs for the CALMET/CALPUFF modelling suite were obtained from UNBC. These inputs were checked to ensure that they were consistent with the Model Guidelines for Air Quality Dispersion Modelling in British Columbia (Model Guidelines) (BC MOE 2008) and also to ensure that the CALMET results were realistic. This review indicated some discrepancies with the Model Guidelines and therefore changes were made to the inputs and the CALMET and CALPUFF models were re-run for this study.

The primary air contaminant of concern for this project is particulate matter (PM). This report contains the results of an investigation of the potential for fugitive dust and vehicle PM emissions resulting from the proposed light industrial land use area.

2.0 REGULATORY REQUIREMENTS

A summary of the provincial air quality regulatory requirements that are relevant to the project are presented in this section.

2.1 PROVINCIAL AMBIENT AIR QUALITY STANDARDS

Air quality objectives are developed by environmental and health authorities to provide guidance for environmental protection decisions. They are based on scientific studies that consider the effects of the contaminant on such receptors as humans, wildlife, vegetation, as well as aesthetic qualities such as visibility. Provincial air quality objectives for particulate matter are listed in Table 2-1.

Particulate matter is often defined in terms of size fractions. Particles less than 40 µm in diameter typically remain suspended in the air for some time. Suspended PM less than 10 µm in diameter is termed PM_{10} and PM less than 2.5 µm in diameter is termed $PM_{2.5}$. Exposure to PM aggravates a number of respiratory illnesses and may even cause premature death in people with existing heart and lung disease. The smaller particles are generally thought to be of greater concern to human health than the larger particles. Due to this greater concern for PM_{10} and $PM_{2.5}$, air quality objectives for total suspended particulate (TSP) are not often used.

In consideration of the threat to human health, the BC Ministry of Environment (MOE) set a provincial objective for PM_{10}. The objective of 50 µg/m^3 is averaged over a 24-hour period. The MOE does not currently have objectives for $PM_{2.5}$, but has recently proposed a 24-hour objective of 25 µg/m^3 and an annual objective of 8 µg/m^3. The MOE is also proposing a long-term continuous improvement target of 6 µg/m^3. There are currently no one-hour objectives or standards for particulate matter.

Table 2-1: Provincial Ambient Air Quality Objectives and Standards for Particulate Matter

Contaminant	Averaging Period	Objective/Standard (µg/m^3)
PM_{10}	24-hour	50
$PM_{2.5}$*	24-hour	25
	Annual	8

** Proposed objectives as of January 2008.*

2.2 PRINCE GEORGE ZONING BYLAWS

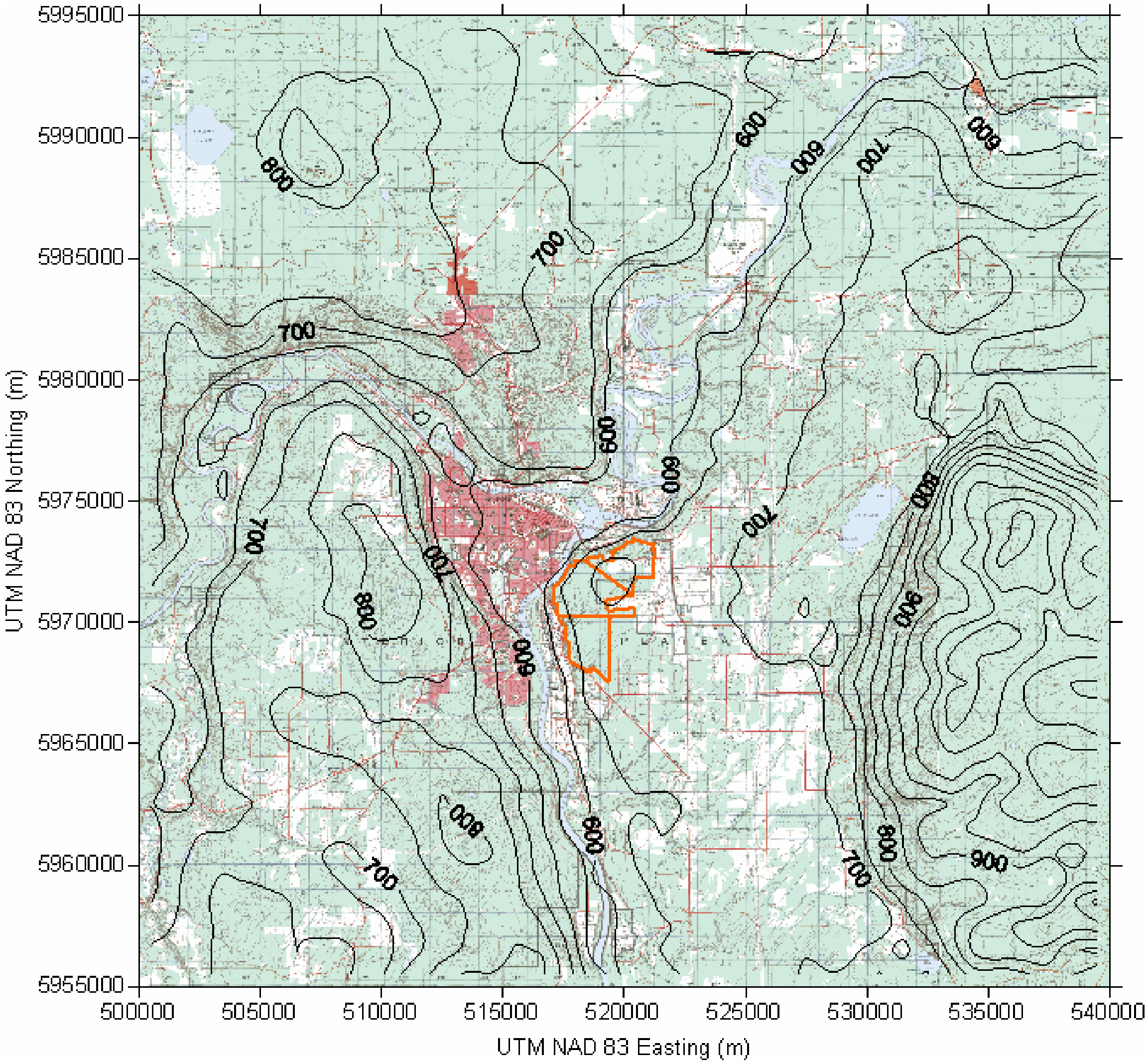
After reviewing the Prince George zoning bylaws there appears to be two relevant bylaws that apply to this study (Table 2-2). Bylaw 7850 in section 7 on page 52 speaks directly to the fact that in the light industrial (M1 and M2) land-use zone all off-street parking and loading areas must be paved. Bylaw 7721 in Part 4 on page 4 states the requirement that all off-street parking, loading and storage areas and highways must be maintained so that dust does not escape that contributes to the degradation of human, plant or animal health.

Table 2-2: Bylaws Applicable to this Study

Bylaw 7850, Section 7 – Parking and Loading, p. 52
Every off-street parking or loading area, and every access to such required parking or loading area, shall have a durable, dust-free, hard surface of concrete, asphalt or similar material, except in AG, AF, AR, RS, RT, C9, M5, M6, and M7 zones, provided that these required parking or loading areas are gravelled, compacted, and treated to suppress dust and kept free of plant growth.
Bylaw 7721, Part 4 – Fugitive Dust Control, p. 4
All off street parking, loading and storage areas, demolition sites, construction sites and highways must be maintained so that dust does not escape in such a manner as to cause or significantly contribute to the cause of injury or damage to human health, plant or animal life or property, or so as to unreasonably interfere with the enjoyment of life or property.

3.0 STUDY AREA

Figure 3-1 shows the topography of the region along with the relative location of the proposed light industrial land-use zone, which has been subdivided into three areas for assessment purposes. The proposed light industrial land-use zone is located in an area north and west of the Prince George Airport situated on a bench approximately 650 m above sea level to the east of the Fraser River. The proposed area occupies approximately 1180 hectares and is situated between the Prince George Airport and downtown Prince George. The net developable area is expected to be 856 hectares. Of this area, 25% is expected to be paved road and parking lot, 30% paved storage area, 30% buildings and 15% undeveloped and landscaped area.



Contour interval is 50 m.

Figure 3-1: Topography of Prince George Region. Location of Proposed Industrial Land-Use Zone in Prince George is Outlined in Orange

4.0 METHODOLOGY

Modelling PM_{10} and $PM_{2.5}$ is done with a dispersion model, which is a computer program that uses emissions and meteorological information to simulate the behaviour and movement of air pollutants in the atmosphere. In this study the CALMET/CALPUFF modelling suite was used to predict concentrations of PM_{10} and $PM_{2.5}$. The CALMET meteorological model was run for five years to provide input to the CALPUFF dispersion model and also to serve as a resource for a meteorological analysis of the proposed site.

4.1 CALMET

The CALMET meteorological model assimilates observations from multiple meteorological stations and simulates the changes in mixing height and boundary layer mechanics that result from variable land use and terrain within the study area of interest.

The input files from UNBC's CALMET modelling were obtained. These input files consisted of a geo.dat and surf.dat file along with CALMET input files. These files were checked to ensure that they were consistent with the Model Guidelines and also to ensure that the CALMET results were realistic.

CALMET was initialized using five full years of surface and upper air meteorological data between 2001 and 2006. Observations from six surface stations, one precipitation station and one upper-air station were used. The CALMET model domain of 40 km by 40 km was centred on the City of Prince George. The extent of the model domain is illustrated in Figure 3-1. The domain resolution assumed by UNBC was 1 km, giving 40 cells in each horizontal direction. In the vertical, 10 layers were chosen by UNBC, with the top of each layer set as 20, 50, 80, 100, 200, 400, 800, 1400, 2000, and 3000 m above ground level. Terrain and land-use data given in the geo.dat file were also at one-kilometre spacing (Figure 4-2).

During the review of the input files it became evident that changes were needed so that the CALMET modelling was consistent with the Model Guidelines. The changes to the files are given in Table 4-1. These changes were discussed with Dennis Fudge at the BC Ministry of Environment and he agreed with the proposed changes to the inputs.

The values for parameters IFRADJ and IKINE specified in the Model Guidelines are 1 and 0, respectively. The parameter IKINE, used to calculate kinematic effects, should be switched off otherwise the predicted second-level wind field typically has erroneously high wind speeds. Therefore, kinematic effects were not used in this study. The parameter IFRADJ is used to evaluate thermodynamic blocking effects of the terrain on the wind flow and are described using the critical Froude number.

Surface, mid-level and upper-level wind fields produced by CALMET were plotted for a calm, stable night in the winter. When BIAS was set to zero for all layers, the predicted surface-level wind field did not appear to follow the terrain and the upper-level wind field was not uniform. Assigning an equal weighting (with BIAS) of surface and upper air data is not appropriate at the surface layer and upper layers. When the bias is changed to values described in Table 3-1 both the surface-level and upper-level wind fields are more realistic. With a BIAS of -1 for the surface layer, the wind field closely follows terrain features and a BIAS of 1 aloft produces a strong and uniform wind field in the upper level. Therefore, the BIAS values given in the right-hand column of Table 3-1 were used for this study.

Table 4-1: Changes made to CALMET Input Files

Parameter	UNBC Study	Current Study
IFRADJ	0	1*
IKINE	1	0*
BIAS	0, 0, 0, 0, 0, 0, 0, 0, 0, 0	-1, -1, -1, -1, -1, -1, -0.5, 0, 0.5, 1

**Required value given in the Model Guidelines.*

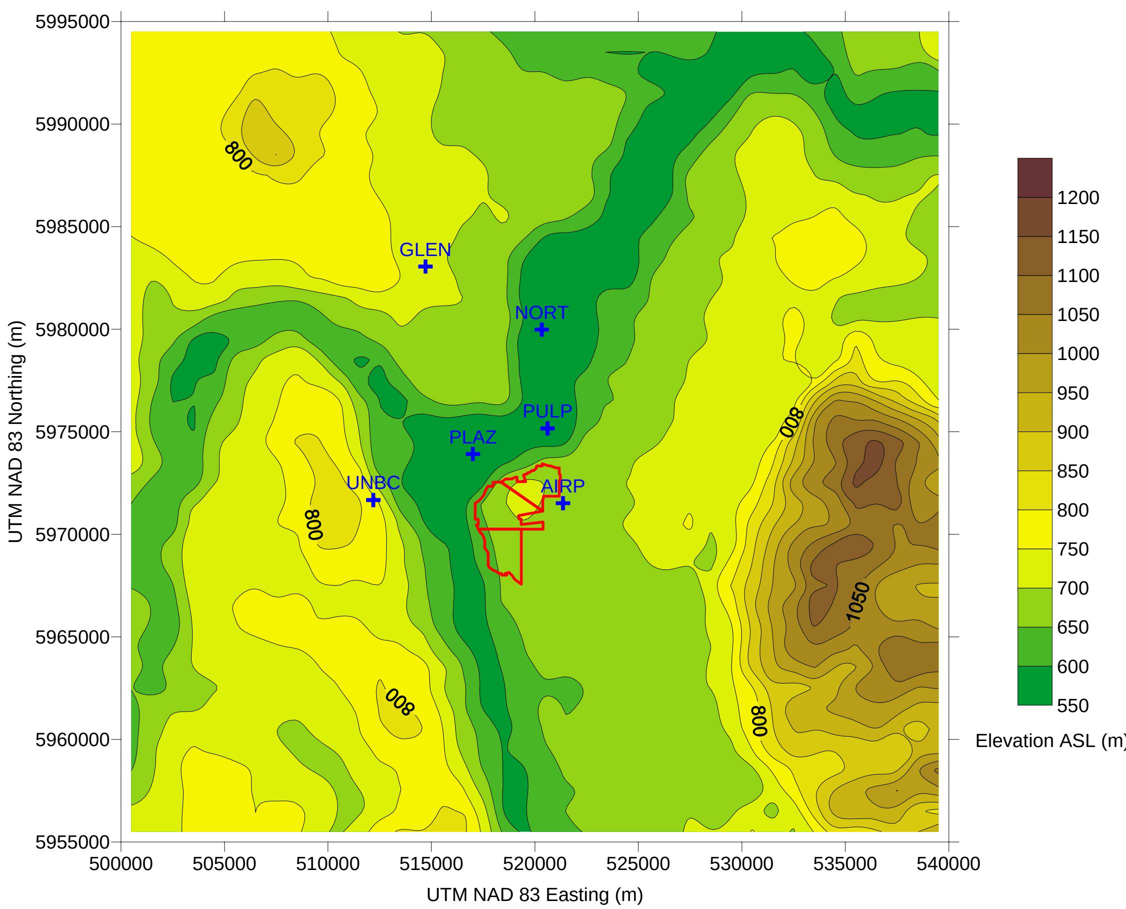


Figure 4-1: Terrain elevations and meteorological stations (shown as a blue cross) used in CALMET. The three sub-areas of the proposed industrial land-use zone are shown in red.

4.2 CALPUFF

CALPUFF is a multi-layer, multi-species, non-steady-state puff dispersion model. It simulates the effects of time- and space-varying meteorological conditions on pollutant transport, transformation and deposition. The CALPUFF model was used to gain an understanding of fugitive dust emissions originating from different man-made surfaces possible in a light industrial land-use zone.

The focus of the modelling is on particulate matter, specifically PM_{10} and $PM_{2.5}$. Given that there are currently no specific facilities planned for the study area, the surface types assumed for this study are based on roads and storage areas only.

The proposed light industrial land use zone was divided into three sub-areas to assess the impact of emissions from various locations within the zone (shown in red in Figure 4-2). Since the proposed zone is relatively large, emissions from one end may have considerably different air quality effects on sensitive receptors such as downtown Prince George as compared to emissions from the opposite end. The subdivision of the proposed zone was done in discussion with the water quality consultant to ensure that the division was feasible from a water quality perspective.

Three source areas were defined for modelling that closely matched the area of the three sub-areas. See Figure 4-3 for the locations of each area source in the modelling domain. To simulate the release characteristics of a dust cloud, each area source was given an effective height of five metres and an initial Sigma Z of five metres. Dry deposition was modelled using the size parameters for dry deposition of PM_{10} and $PM_{2.5}$ as defined by UNBC.

The CALPUFF input file that was obtained from UNBC was also checked to ensure consistency with the Model Guidelines. The changes made to the file are given in Table 4-2. These changes were discussed with Dennis Fudge at the BC Ministry of Environment and he agreed with the proposed changes to the inputs.

The method used to compute dispersion coefficients is set by the values MDISP and MDISP2. A value of 2 was used so that the method is based on a near-field domain (i.e., a domain of less than 50 km). Typically a value of 3 is used for a long-range model domain (i.e., a domain greater than 50 km).

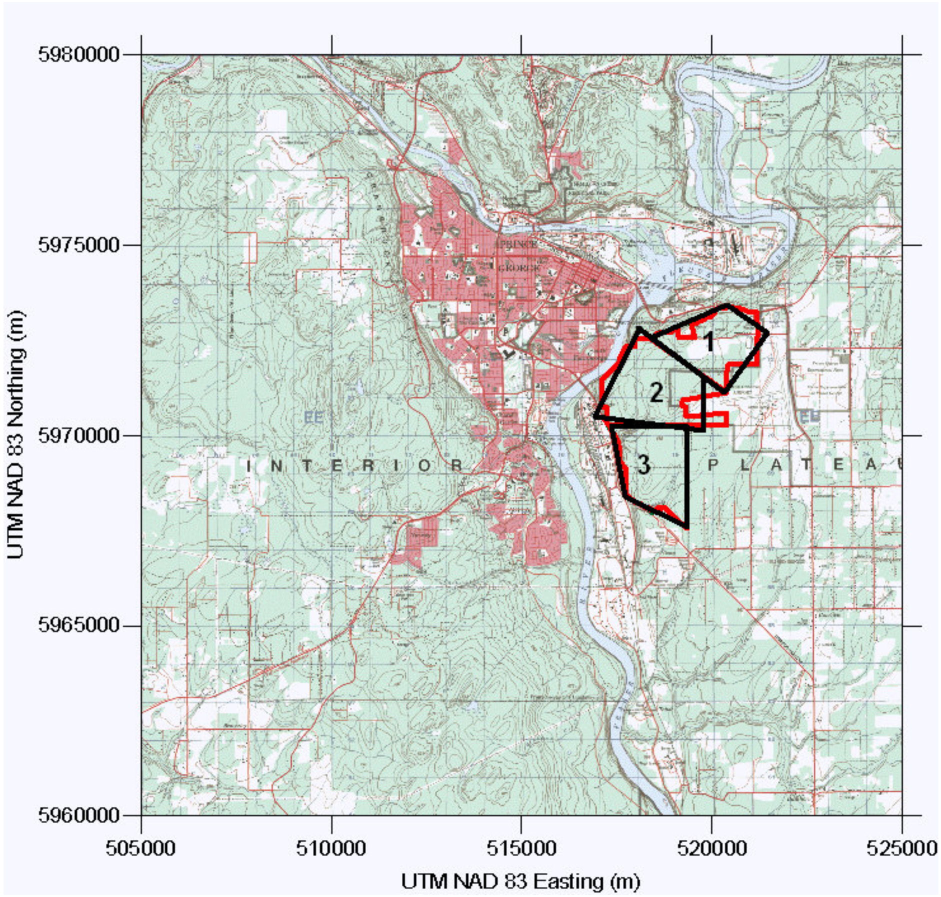


Figure 4-2: Three Source Areas Used in CALPUFF Shown in Black.

Table 4-2: Changes made to CALPUFF input file

Parameter	UNBC Study	Current Study
MDISP	3	2
MPDF	0	1
LSAMP	T	F
NREC	8	11029

It was determined that the one-kilometre gridded receptors used by UNBC could be improved upon by adding a finer grid of receptors over the City of Prince George. Therefore a fine grid of discrete receptors was applied to the model domain with a 200-m spacing centred on the proposed land-use zone out to 10 km. This fine grid of receptors encompasses downtown Prince George. A one-kilometre receptor spacing was used beyond 10 km. Since a nested receptor grid of 11,029 receptors (i.e., NREC = 11,029) was used, the uniform, one-kilometre gridded receptors were turned off (i.e., LSAMP = F). The receptor grid is shown in Figure 4-4.

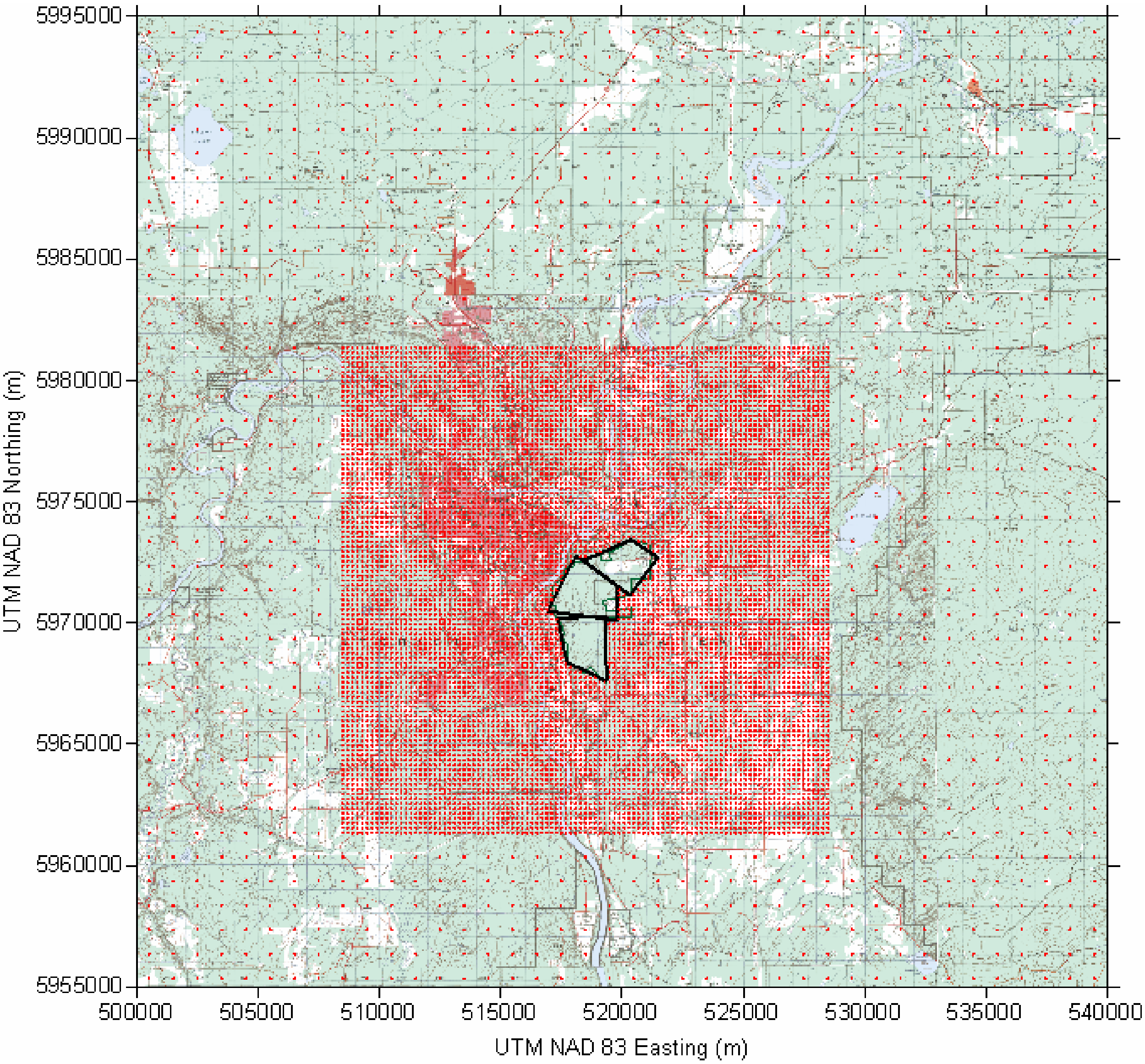


Figure 4-3: Receptor Grid Applied in CALPUFF Modelling.

4.3 EMISSION ESTIMATION

Vehicle and fugitive dust emissions of PM were estimated for two different source types: (1) paved roads and parking lots and (2) paved storage areas. The latest development plan does not include any unpaved surfaces, and thus emissions from these surfaces were not estimated. Since all parking lots in the development plan will be paved, the emission estimation for paved roads is also applicable to parking lots and the two emission sources were grouped together. The emission estimate for each of the two source types was used to determine the individual and cumulative source contributions to ambient PM_{10} and $PM_{2.5}$ concentrations in the study area. This section describes the emission methodology used.

4.3.1 Paved Road Vehicle and Fugitive Emissions

When employee and other vehicles operate on paved roads and parking lots in the proposed zone, they emit PM from combustion of fuel and road dust particles may be re-suspended. Particulate emissions from the use of paved roads and parking lots were calculated following the methodology described in Section 13.2.1 of the United States Environmental Protection Agency (US EPA) Compilation of Air Pollutant Emission Factors known as AP-42 (2006a) and summarized by the following equation:

$$E = k\left(\frac{sL}{2}\right)^{0.65}\left(\frac{W}{2.72}\right)^{1.5} - C$$

where:

E = emission factor in g/vehicle-kilometre-travelled

k = empirical constant (Table 4-3)

sL = road surface silt loading (g/m^2)

W = mean vehicle weight (tonnes)

C = emission factor for 1980s vehicle fleet exhaust, brake wear and tire wear (Table 4-3)

Table 4-3: Empirical Constants for Paved Road Dust Emissions

	PM_{10}	$PM_{2.5}$
k	4.6	0.66
C	0.1317	0.1005

Based on this equation, the magnitude of paved road dust depends on the mean vehicle weight, road surface silt loading, and total vehicle-kilometres-travelled (calculated as traffic volume multiplied by travel distance). A road surface silt loading of 0.2 g/m^2 was assumed, based on the silt loading value used by most states in the 2002 US EPA National Emission Inventory (2006b) for urban local paved roads. A mean vehicle weight of 3.06 tonnes was estimated assuming that the vehicle mix in the light industrial area will consist of 70% passenger cars with an average weight of 1,588 kg (3,500 lbs), 20% light-duty trucks with an average weight of 2,948 kg (6,500 lbs) and 10% heavy-duty trucks with an average weight of 13,608 kg (30,000 lbs). Traffic volumes and trip generation statistics were provided by L&M Engineering. These traffic statistics match the traffic impact study and equate to approximately 16.1 vehicles/1000 m^2/d (1.5 vehicles/1000 ft^2-d) based on the area occupied by buildings (30% of 856 ha). Twice this vehicle density (i.e., 32.3 vehicles/1000 m^2/d) was also evaluated for comparison purposes. A one-way travel distance of 1.5 km was assumed, corresponding to the approximate road distance from one end of a sub-area to the centre.

The constant C is used when vehicle fleet exhaust, brake wear and tire wear are estimated using the US EPA MOBILE model for a more representative fleet than the default 1980s fleet. PM_{10} and $PM_{2.5}$ emissions were estimated for passenger cars, light-duty trucks and heavy-duty trucks travelling on arterial roads using the Canadian version of the US EPA MOBILE6.2 model (known as MOBILE6.2C). Since no speed limits have been defined for the proposed light industrial zone, default speeds in MOBILE6.2C were applied.

4.3.2 Paved Storage Areas

When loading equipment and other vehicles operate on paved storage areas in the proposed zone, road dust particles may be suspended. Vehicle and fugitive dust emissions associated with paved storage areas were estimated using the same methodology as for paved roads. The road surface material, and thus silt content, as well as the mean vehicle weight typical of light industrial areas used to estimate paved road dust emissions were assumed to be representative of paved storage areas. The main difference between the methodology for paved roads and paves storage areas is the assumed traffic volume and travel distance. A lighter traffic volume of 10 vehicles/d and a shorter one-way travel distance of 15 m were assumed for each 10 m by 10 m parcel of paved storage area.

4.3.3 Natural Mitigation

Fugitive dust emissions are suppressed by rainfall. To account for the natural mitigation of fugitive dust emissions in the proposed light industrial zone due to rainfall, an AP-42 correction term was applied to emissions from the re-entrainment of road surface material:

$$CT = 1 - \frac{P}{4N}$$ for paved roads and areas

where:

CT = correction term multiplied to estimated emissions

P = number of days with measurable (> 0.254 mm) rainfall

N = number of days in period

These correction terms are based on a simplifying assumption that average emissions are inversely proportional to the frequency of measurable rainfall. A factor of 4 is introduced to the denominator to account for the fact that paved roads tend to dry quickly, and precipitation may not occur over the complete 24-hour day. Since particulate emissions estimated using MOBILE6.2C represent direct emissions from vehicles rather than re-entrained fugitive dust emissions, the rainfall correction terms were not applied to vehicle PM emissions.

The average annual frequency of measurable rainfall during the model period, as recorded by Environment Canada at the Prince George Airport, was used to evaluate the correction term. The Prince George Airport observed an average of 53 days of measurable rainfall each year between 2001 and 2006.

4.4 BACKGROUND CONTRIBUTION

To understand the contribution of the proposed light industrial zone to existing air quality in the Prince George area, historical PM monitoring data collected at the Plaza 400 station in downtown were reviewed. A summary of the ambient 24-hr PM_{10} and $PM_{2.5}$ concentrations observed at Plaza 400 during the 2001 to 2005 model period is shown in Table 4-4. Annual average PM_{10} and $PM_{2.5}$ concentrations are summarized in Table 4-5. The existing PM_{10} and $PM_{2.5}$ concentrations are relatively high, exceeding the 24-hour MOE objectives 3.7% and 5.1% of the time, respectively. Annual average concentrations of $PM_{2.5}$ at Plaza 400 exceed the proposed objective of 8 µg/m^3 during four of the five years considered. The long-term continuous improvement target for $PM_{2.5}$ of 6 µg/m^3 was exceeded all five years.

Table 4-4: Summary of 24-Hour PM_{10} and $PM_{2.5}$ Concentrations at Plaza 400

	PM_{10}	**$PM_{2.5}$**
Selected Percentile Concentrations (µg/m^3)		
100th	**109.6**	**66.0**
98th	**58.2**	**33.8**
95th	46.2	**25.3**
90th	37.1	19.6
75th	27.3	12.3
50th	15.5	7.3
Frequency of Exceedance of MOE Objective (%)	3.7	5.1
Frequency Greater than Half the Objective (%)	23.6	24.1

Note: Exceedances of the provincial objectives are shown in bold

Table 4-5: Summary of Annual PM_{10} and $PM_{2.5}$ Concentrations (µg/m^3) at Plaza 400

Year	**PM_{10}**	**$PM_{2.5}$**
2001	18.1	**9.4**
2002	18.3	**9.2**
2003	19.5	**10.8**
2004	20.3	**10.6**
2005	20.6	7.9

Note: Exceedances of the proposed provincial $PM_{2.5}$ objective are shown in bold

5.0 RESULTS

The results of the meteorological analysis and dispersion modelling are provided in this section.

5.1 CALMET ANALYSIS

The CALMET model simulation was analyzed by reviewing various model outputs and, where possible, comparing to observations. These outputs include: surface wind roses for various locations, CALMET-derived stability classes and mixing heights, and wind vector plots under various stability and flow regimes. The CALMET output was extracted at four locations, one within each sub-division and one in downtown at Plaza 400. In the remainder of the study area, CALMET-derived wind vectors follow the expected terrain flows under various stability and flow regimes.

5.1.1 Surface Winds

Figure 5-1 shows the CALMET derived wind roses for the four extracted points in the CALMET domain. The three points, extracted from each of the sub-areas show a strong south orientation approximately 20% of time. The predominant wind direction is from the south with a smaller component coming from south-southwest and north. Considering these wind patterns, the eastern part of downtown may be impacted by particulate matter emissions blown from the western-most part of the proposed zone when a south wind is experienced. However, since the dispersion of pollutants in the air is determined by several other factors one cannot only look at the prevailing winds to determine the effects of a source on local air quality. The wind rose extracted from downtown shows a different wind regime. While downtown also shows a dominant south wind, there are several other components including south-southwest, southwest, and west- southwest winds that are dominant.

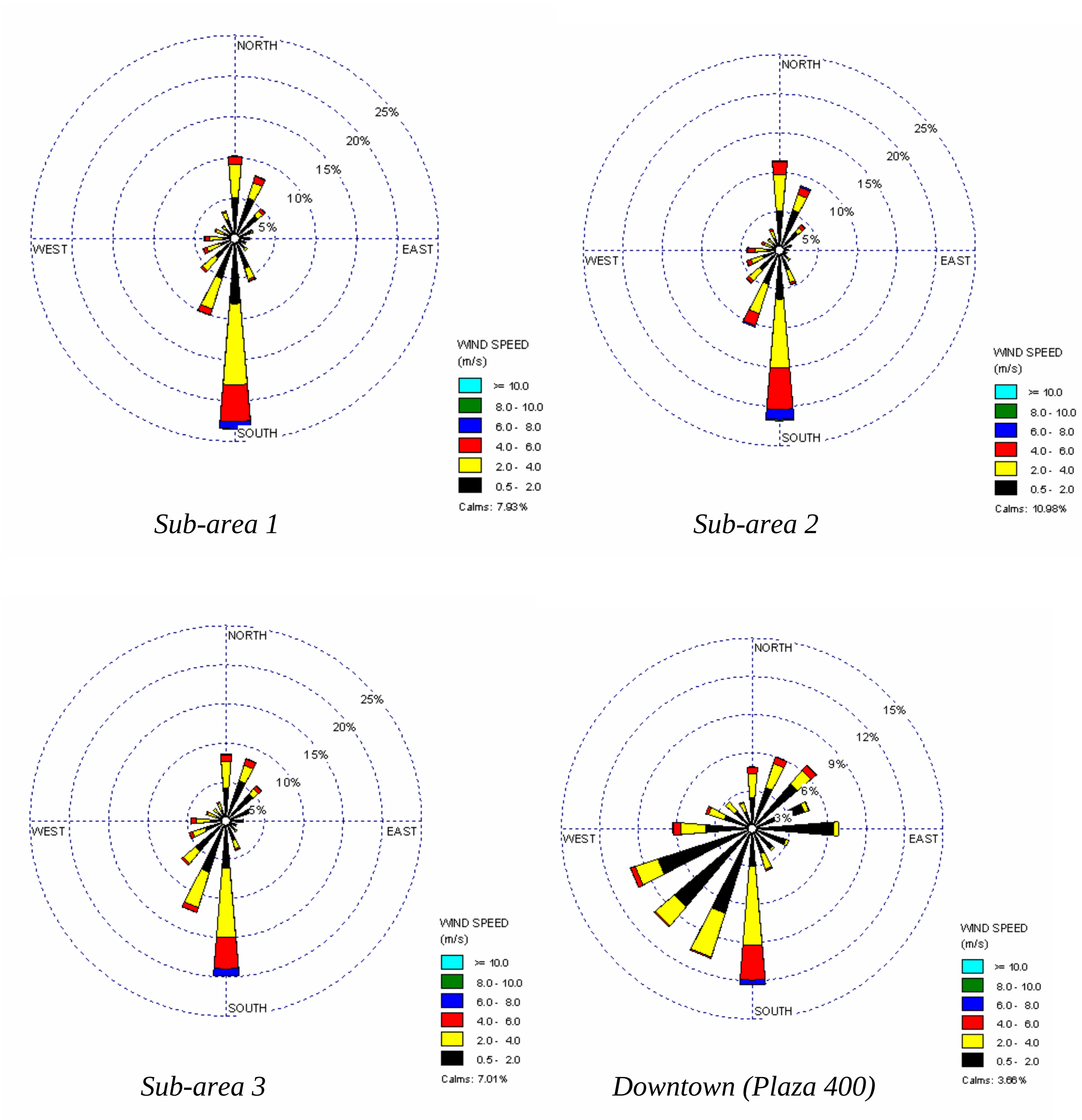


Figure 5-1: Surface wind roses extracted from four locations in the model domain, one for each sub-division and one at the Plaza 400 downtown

5.1.2 Stability Classes

In CALMET, the Pasquill-Gifford-Turner (PGT) stability scheme is used to classify atmospheric stratifications in the boundary layer. These classes range from unstable (Classes 1, 2 and 3), through neutral (Class 4) to stable (Classes 5 and 6). Normally, unstable conditions are associated with daytime, ground-level heating, which results in thermal turbulence activity in the boundary layer. Stable conditions are primarily associated with night-time cooling, which results in the suppression of the turbulence levels and temperature inversion at lower levels. Neutral conditions are mostly associated with high wind speeds or overcast sky conditions.

CALMET derived PGT stability classes were extracted from four locations in the model domain. The results are shown in Table 5-1. At all four locations the predominant PGT stability is Class 4 or neutral. This is expected for an area that often experiences overcast skies.

Table 5-1: CALMET Derived PGT Stability Classes

Location	**Relative Frequency of Occurrence by PGT Stability Class**					
CALMET Extracted						
	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
Sub-area 1	1.1 %	9.7 %	17.4 %	38.9 %	6.1 %	26.8 %
Sub-area 2	1.3 %	10.4 %	17.9 %	36.2 %	5.4 %	28.7 %
Sub-area 3	1.4 %	10.3 %	17.7 %	36.7 %	5.7 %	28.1 %
Downtown (Plaza 400)	0.5 %	11.6 %	19.1 %	33.6 %	3.8 %	31.4 %

There are lower frequencies for moderately unstable Classes 2 and 3, corresponding to the moderate solar insolation and wind speeds typical at this latitude. Stability Class 1 (very unstable) occurs least frequently. At almost 54 degrees latitude, the insolation is not intense enough to establish stability Class 1. The large frequency of Class 6 is a direct result of the large percentages of low (<3 m/s) wind speeds experienced at night. These results are what one would expect in the Prince George region and are important because they show that CALMET is predicting realistic stability classes.

5.1.3 Mixing Heights

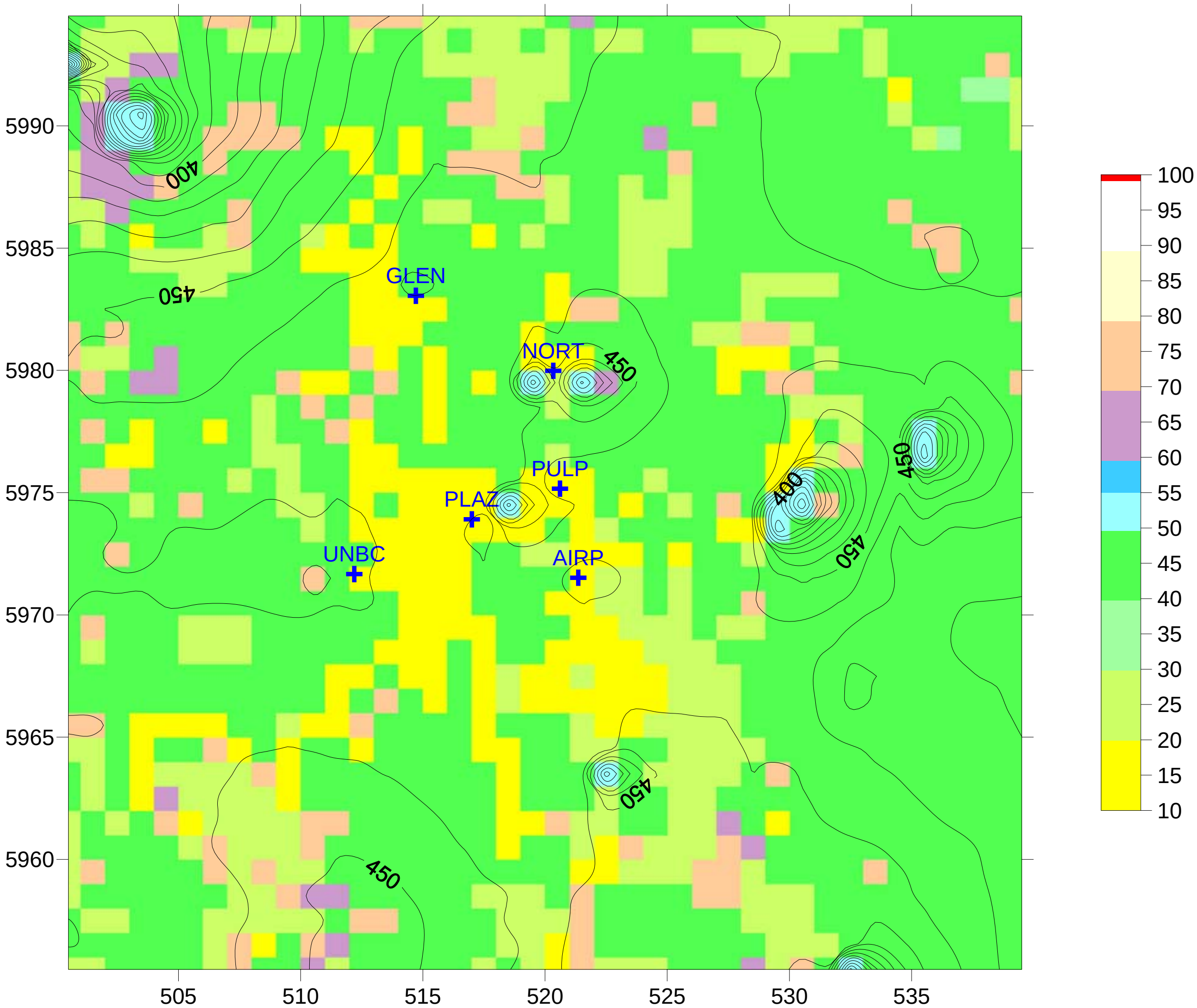
Mixing height is defined as the height of the atmospheric layer adjacent to the ground over which an emitted or entrained non-buoyant tracer will be mixed (by turbulence) within a time scale of about one hour or less. The mixing heights under different stability conditions are estimated through methods that are based on either surface heat flux (thermal turbulence) and vertical temperature profile, or the friction velocity (mechanical turbulence).

Table 5-2 summarizes the average mixing height associated with each PGT stability class for four locations. As expected, deepest mixing heights are associated with the unstable Classes 1 and 2. Lowest mixing heights are for stable Classes 5 and 6. Mixing heights for neutral conditions (Class 4) include night-time hours when mixing heights are more similar to the values shown for Classes 5 and 6. Therefore, average daytime mixing heights for neutral conditions will be higher than indicated in Table 5-2.

Table 5-2: CALMET Mixing Heights Above Ground by PGT Stability Class

Location	**Average Mixing Height (m) by PGT Stability Class**					
	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
Sub-area 1	1024 m	905 m	527 m	549 m	288 m	67 m
Sub-area 2	982 m	909 m	521 m	573 m	395 m	81 m
Sub-area 3	1017 m	919 m	519 m	562 m	380 m	80 m
Downtown (Plaza 400)	630 m	906 m	498 m	526 m	469 m	94 m

Figure 5-2 shows the CALMET-derived mixing heights for a typical afternoon in summer (July 8, 2004 at 16:00 LST). Generally, the mixing height is low (~300 to 400 m) over water (shown in blue) and increases over land (all other colours) as a result of greater sensible heat flux and increased surface roughness. The mixing height increases with distance from water more quickly in areas where surface roughness is greater (i.e., where surface elements are larger). Mixing heights will be much lower under stable conditions, i.e. on clear nights with low (<3 m/s) wind speeds, typically on the order of 50 to 100 m. Daytime mixing heights may also be suppressed for PGT stability Class 1. These results show mixing heights that are typical for this region and that CALMET is realistically estimating the height of the atmospheric surface layer in which emissions are mixed.



Note: The land uses given are: 10 urban, 20 agricultural, 30 rangeland, 40 forest, 50 water, 60 wetlands, 70 barren land, and 80 tundra.

Figure 5-2: Mixing Heights on a Typical Summer Afternoon (July 8, 2004 at 16:00 LST) Plotted on Land Use Data

5.1.4 Wind Vector Plots

Wind vector plots representing all stability classes including stable, neutral and unstable conditions are presented to provide an overview of different wind flow patterns (Figure 5-3 to 5-8). These figures show wind fields extracted from the CALMET modelling at the surface layer.

An example surface wind regime during very unstable conditions (Class 1) is shown in Figure 5-3 where the wind field shows winds from the east in the top left of the domain, northeast winds in the top right of the domain and an area of calms winds near the airport.

Figure 5-4 shows an example of a uniform south wind field during unstable conditions (Class 2). It can be seen that the most western part of the proposed study area is upwind of downtown during this hour.

A surface wind regime during slightly unstable (Class 3) conditions is shown in Figure 5-5 where the wind field is uniform across the entire domain blowing from the west-southwest. This plot shows that for higher winds speeds, terrain in the model domain will be insufficient to influence flow pattern and synoptic-scale winds will dominate.

High wind speeds are displayed in Figure 5-6 plotted during neutral (Class 4) conditions where the wind regime blowing from the south is fairly uniform except for around the mountains in the east. In this case, the mountainous terrain is shown to slightly influence winds.

Slightly stable (Class 5) conditions are shown in Figure 5-7 where the south wind flow appears to closely follow terrain features. The prominent flow in this night-time example is derived from the topography of the region.

Finally, Figure 5-8 shows an example of northwest winds during stable night-time conditions (Class 6). In this example the winds flow down slope following terrain features.

Based on this meteorological analysis one would expect the greatest impact on downtown from the fugitive dust emission emitted from the proposed site associated with stable conditions when the wind direction is from the south. However, these stable conditions, namely Class 5 and 6, only occur at night when traffic volumes typically tend to be lowest (i.e., less fugitive emissions released).

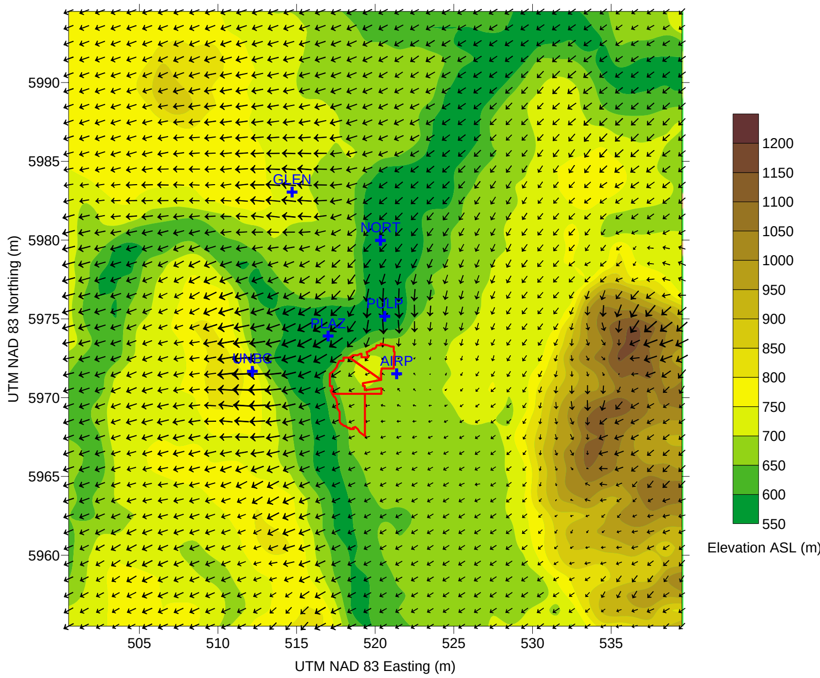


Figure 5-3: Surface Vector Wind Fields during PG Stability Class 1 (Very Unstable) on *June 4, 2005 at 13:00 LST*. Arrow lengths give relative wind speed from 0 to 1.8 m/s.

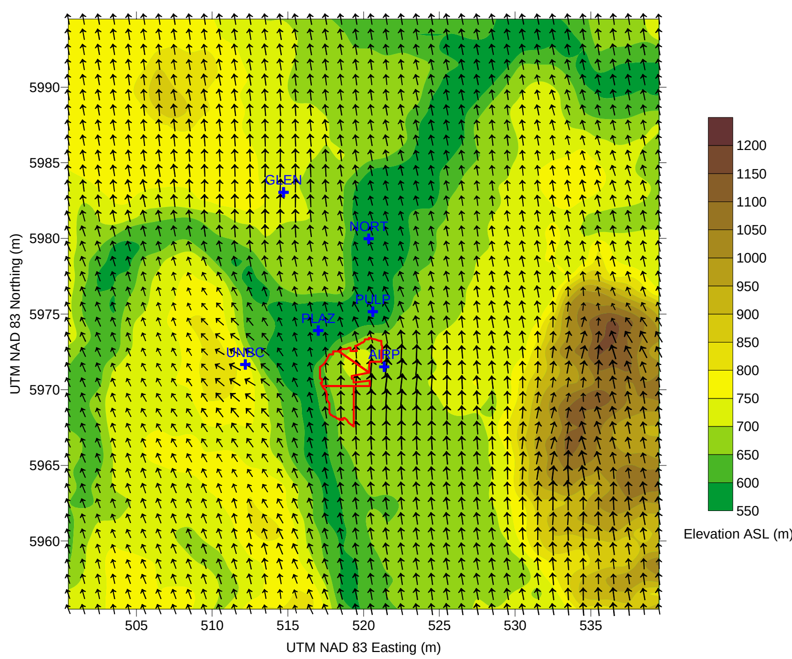


Figure 5-4: Surface Vector Wind Fields during PG Stability Class 2 (Unstable) on *May 6, 2001 at 11:00 LST*. Arrow lengths give relative wind speed from 0 to 1.4 m/s.

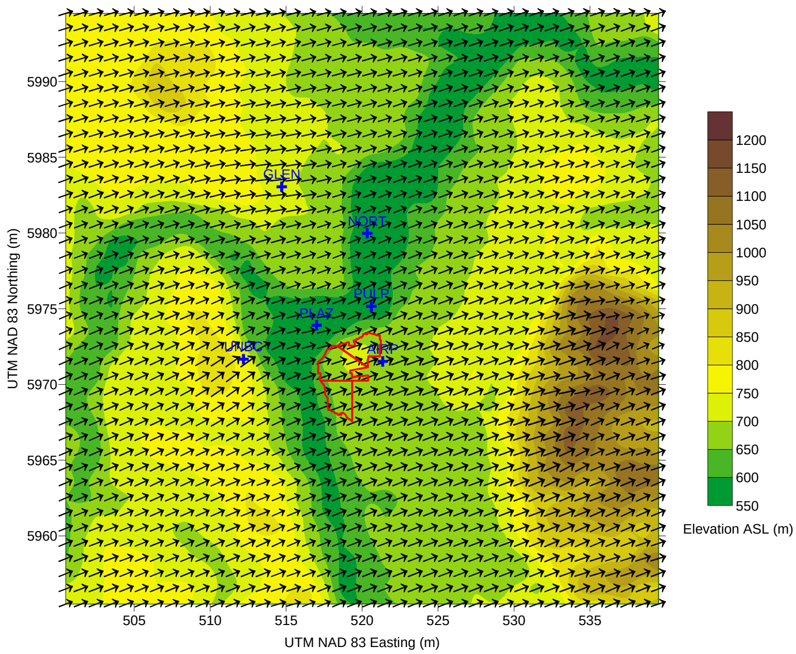


Figure 5-5: Surface Vector Wind Fields during PG Stability Class 3 (Slightly Unstable) on *January 29, 2001 at 13:00 LST*. Arrow lengths give relative wind speed from 0 to 4.0 m/s.

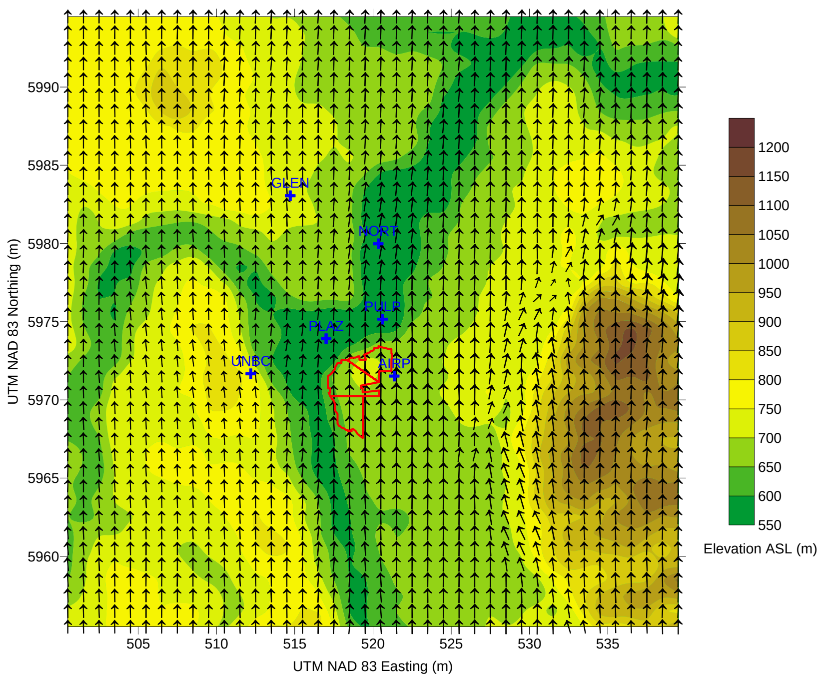


Figure 5-6: Surface Vector Wind Fields during PG Stability Class 4 (Neutral) on *March 30, 2002 at 20:00 LST*. Arrow lengths give relative wind speed from 0 to 6.5 m/s.

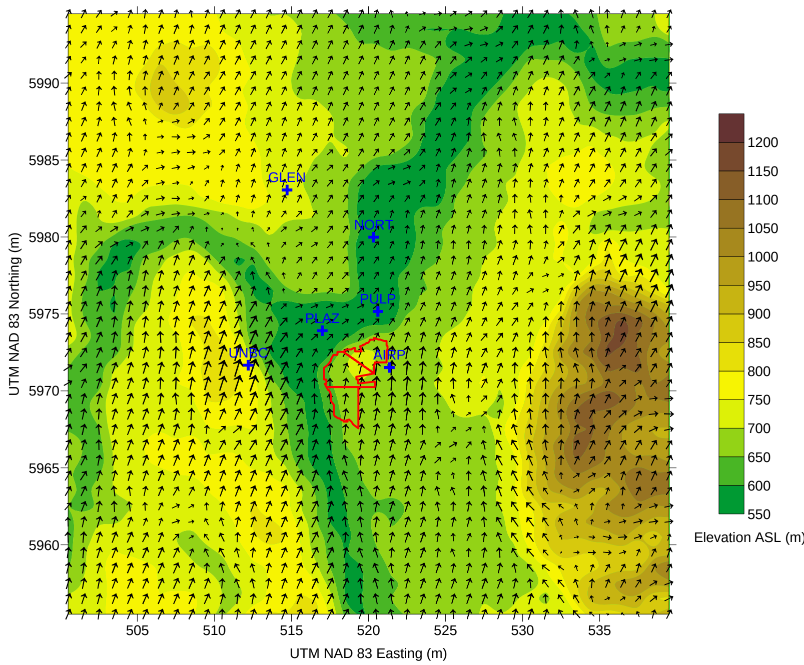


Figure 5-7: Surface Vector Wind Fields during PG Stability Class 5 (Slightly Stable) on *November 30, 2004 at 01:00 LST.* Arrow lengths give relative wind speed from 0 to 4.2 m/s.

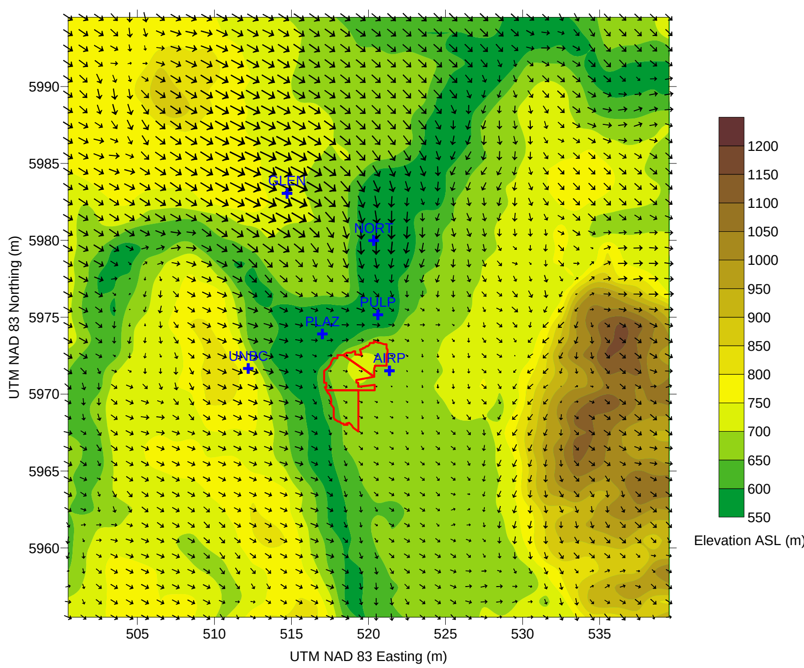


Figure 5-8: Surface Vector Wind Fields during PG Stability Class 6 (Stable) on *January 11, 2001 at 04:00 LST.* Arrow lengths give relative wind speed from 0 to 1.2 m/s.

5.2 MODELLING RESULTS AND DISCUSSION

Maximum concentrations of PM_{10} and $PM_{2.5}$ were predicted within the study area but outside the proposed light industrial zone. The individual contributions of each source type in each sub-area to 24-hour PM_{10} and $PM_{2.5}$ concentrations are summarized in Table 5-3 for the entire study area and in Table 5-4 for downtown Prince George. In all three sub-areas, the paved roads contribute considerably higher particulate concentrations than the paved storage areas. It appears that Sub-area 2 results in the highest particulate concentrations, partially due to its larger size in comparison to Sub-areas 1 and 3. It can also be seen that PM_{10} concentrations are estimated to be approximately nine times the $PM_{2.5}$ concentrations.

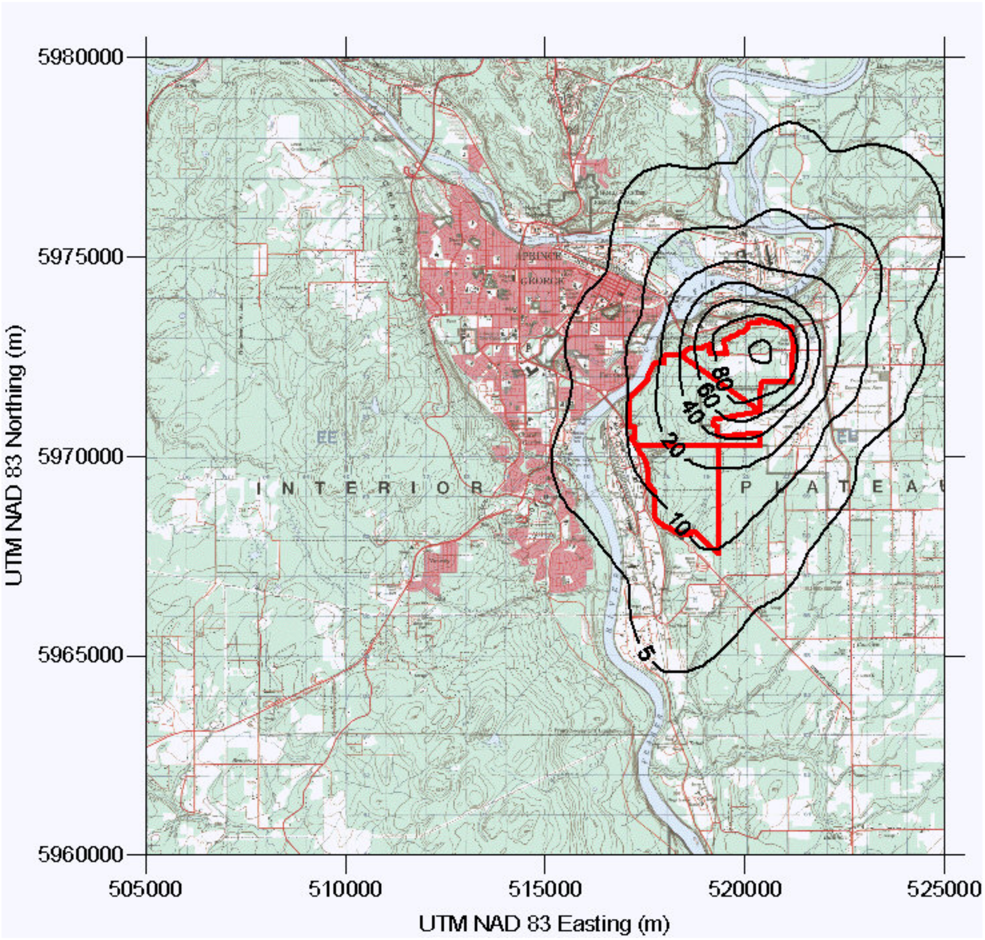
Plots of maximum predicted 24-hour PM_{10} concentrations associated with each sub-area are given in Figure 5-9 to 5-11 when modelled with a unit emission flux (1 mg/s/m^2). While the absolute numbers are meaningless, the plots show the relative location of where the 24-hour maximums will occur and their proximity to downtown Prince George. It is interesting to note that Sub-area 2 results in larger areas of impact and maximum concentrations that occur much closer to downtown than Sub-areas 1 and 3. This is largely due to Sub-area 2 being located further west than Sub-areas 1 and 3 and its slightly larger surface area.

Table 5-3: Maximum Predicted 24-Hour PM_{10} and $PM_{2.5}$ Concentrations (µg/m^3) in the Study Area by Source Type and Sub-Area

	Paved Road + Parking		Paved Storage Areas	
	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Sub-area 1	11.0	1.2	0.7	0.07
Sub-area 2	13.2	1.4	0.8	0.09
Sub-area 3	11.7	1.3	0.7	0.08

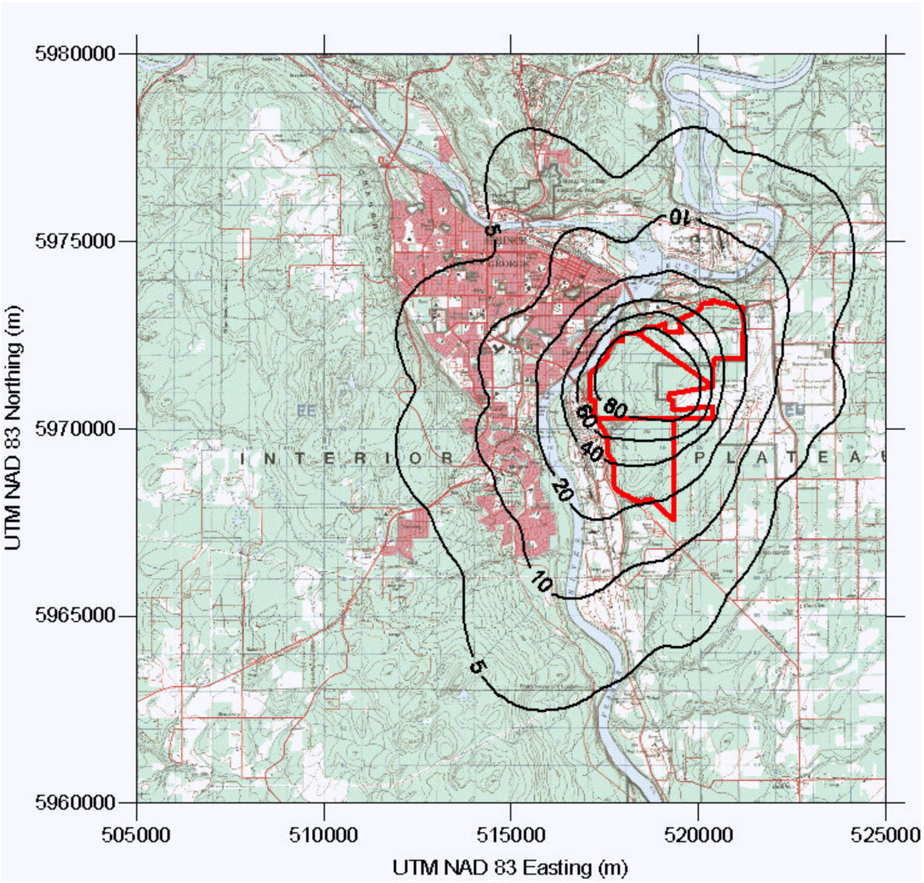
Table 5-4: Maximum Predicted 24-Hour PM_{10} and $PM_{2.5}$ Concentrations (µg/m^3) in Downtown Prince George by Source Type and Sub-Area

	Paved Road + Parking		Paved Storage Areas	
	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Sub-area 1	2.6	0.3	0.2	0.02
Sub-area 2	9.6	1.0	0.6	0.06
Sub-area 3	3.5	0.4	0.2	0.03



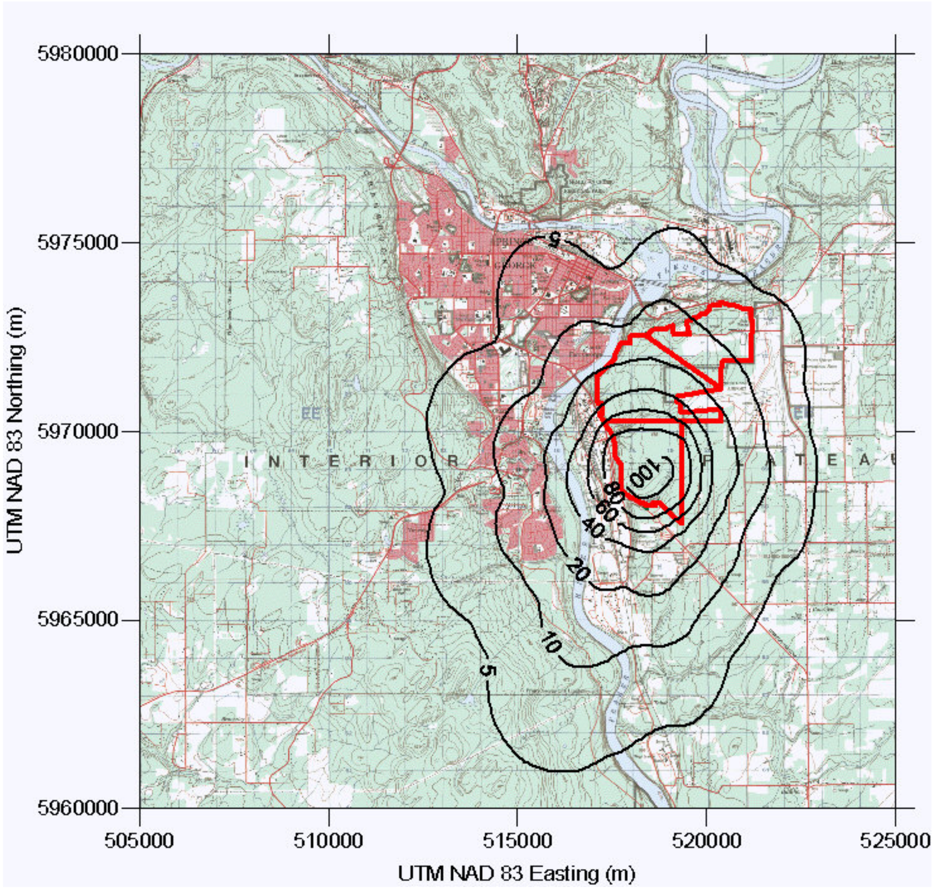
Contour Intervals are: 5, 10, 20, 40, 60, 80, and 100 unitless.

Figure 5-9: Contour Plot of 24-hour Averaged Unitless PM_{10} for Sub-area 1 Modelled with a Unit Emission Flux



Contour Intervals are: 5, 10, 20, 40, 60, 80, and 100 unitless.

Figure 5-10: Contour Plot of 24-hour Averaged Unitless PM_{10} for Sub-area 2 Modelled with a Unit Emission Flux



Contour Intervals are: 5, 10, 20, 40, 60, 80, and 100 unitless.

Figure 5-11: Contour Plot of 24-hour Averaged Unitless PM_{10} for Sub-area 3 Modelled with a Unit Emission Flux

5.2.1 Combined Results

The combined maximum predicted concentrations of PM_{10} and $PM_{2.5}$ for the three sub-areas are shown in Table 5-5 and Table 5-6 for daily and annual averaging periods, respectively. Results based on traffic generation rates of 16.1 and 32.3 vehicles/1000 m^2/d (1.5 and 3 vehicles/1000 ft^2/d) are shown for comparison purposes. For both traffic generation rates, the maximum 24-hour PM_{10} concentration predicted anywhere in the study area is less than the MOE objective of 50 µg/m^3. The maximum 24-hour PM_{10} concentration predicted in downtown Prince George is approximately half the MOE objective for the higher traffic generation rate of 32.3 vehicles/1000 m^2/d. The maximum predicted 24-hour and annual $PM_{2.5}$ concentrations both in the study area and in downtown Prince George are considerably less than the MOE proposed objectives of 25 and 8 µg/m^3, respectively.

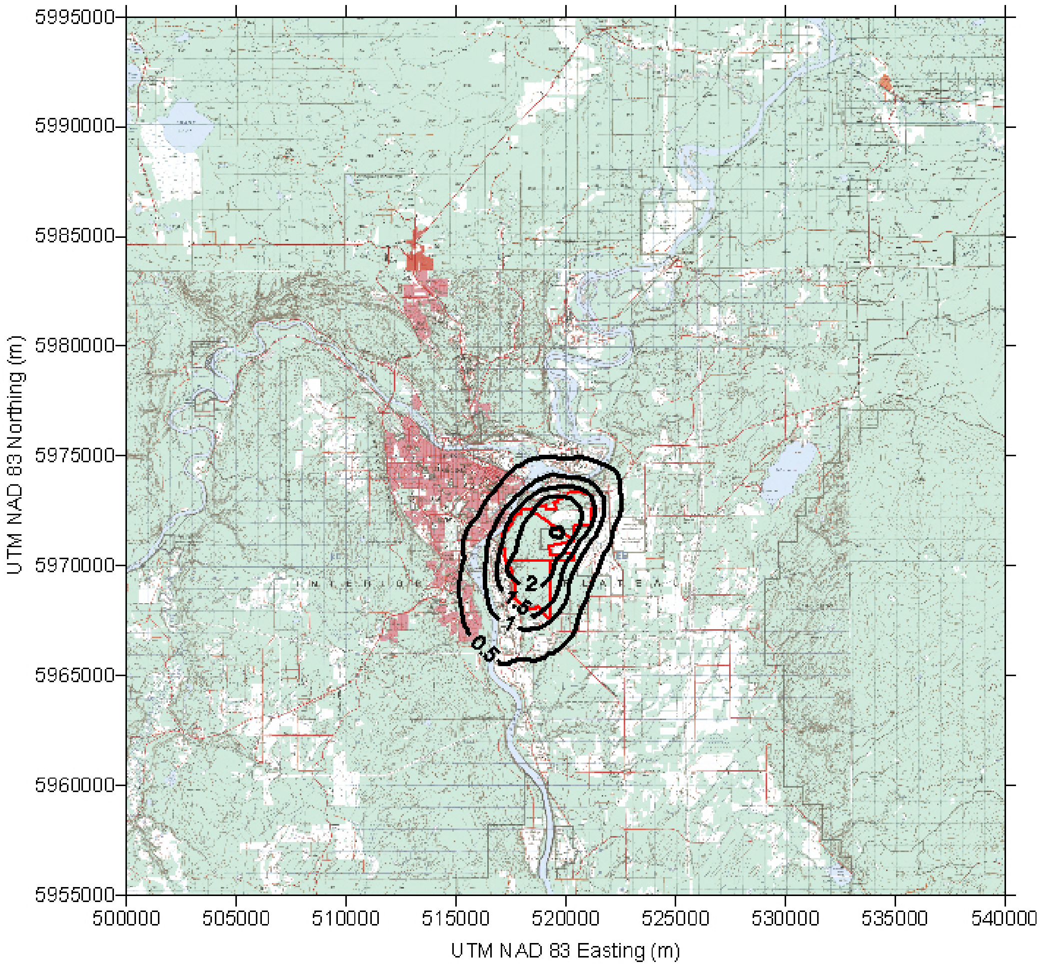
Table 5-5: Maximum Predicted 24-Hour PM_{10} and $PM_{2.5}$ Concentrations for All Source Types and All Sub-areas

Average Daily Traffic Volume (per 1000 m^2 of buildings)	Maximum Predicted Concentrations in Study Area (μg/m^3)		Maximum Predicted Concentrations in Downtown Prince George (μg/m^3)	
	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
16.1	23	2.6	13	1.5
32.3	45	5.0	25	2.8

Table 5-6: Maximum Predicted Annual PM_{10} and $PM_{2.5}$ Concentrations for All Source Types and All Sub-areas

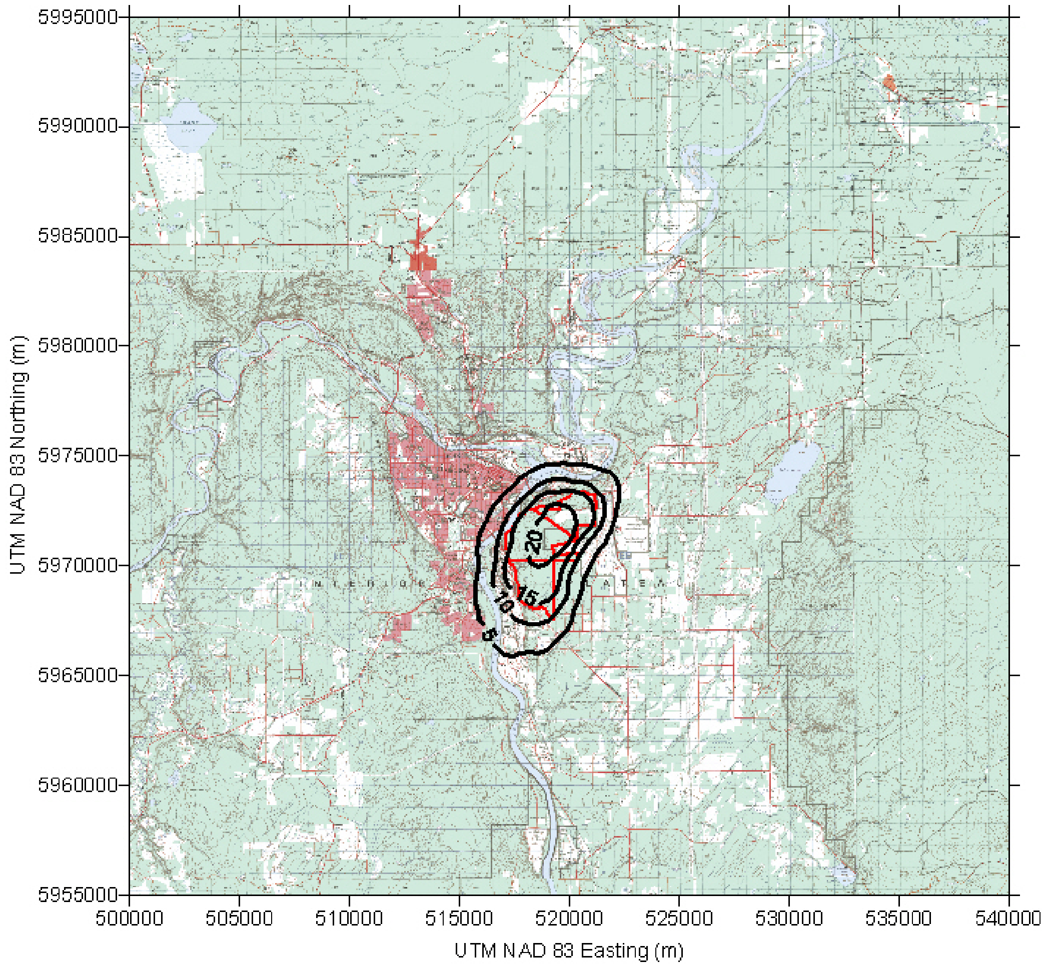
Average Daily Traffic Volume (per 1000 m^2 of buildings)	Maximum Predicted Concentrations in Study Area (μg/m^3)		Maximum Predicted Concentrations in Downtown Prince George (μg/m^3)	
	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
16.1	9.0	0.9	3.0	0.3
32.3	17.4	1.8	5.8	0.6

Contour plots of combined results for the expected traffic generation rate (16.1 vehicles/1000m^2/d) for $PM_{2.5}$ and PM_{10} are illustrated in Figure 5-12 and Figure 5-13, respectively. These figures illustrate that the expected contribution of PM emissions from the proposed land use area to the downtown area is low. When the expected traffic generation rate is doubled, the contribution of predicted PM emissions to ambient concentrations in the downtown area is still low (see Figure 5-14 and Figure 5-15). Concentrations greater than half the provincial objective are only predicted for the high traffic generation rate and PM_{10}. Figure 5-15 illustrates that concentrations greater than half the PM_{10} objective are predicted to occur within and in the vicinity of the proposed land use zone, out to a maximum of 720 m from the edge of the zone. Predicted concentrations are greater than half the PM_{10} objective up to 18% of the time in this area.



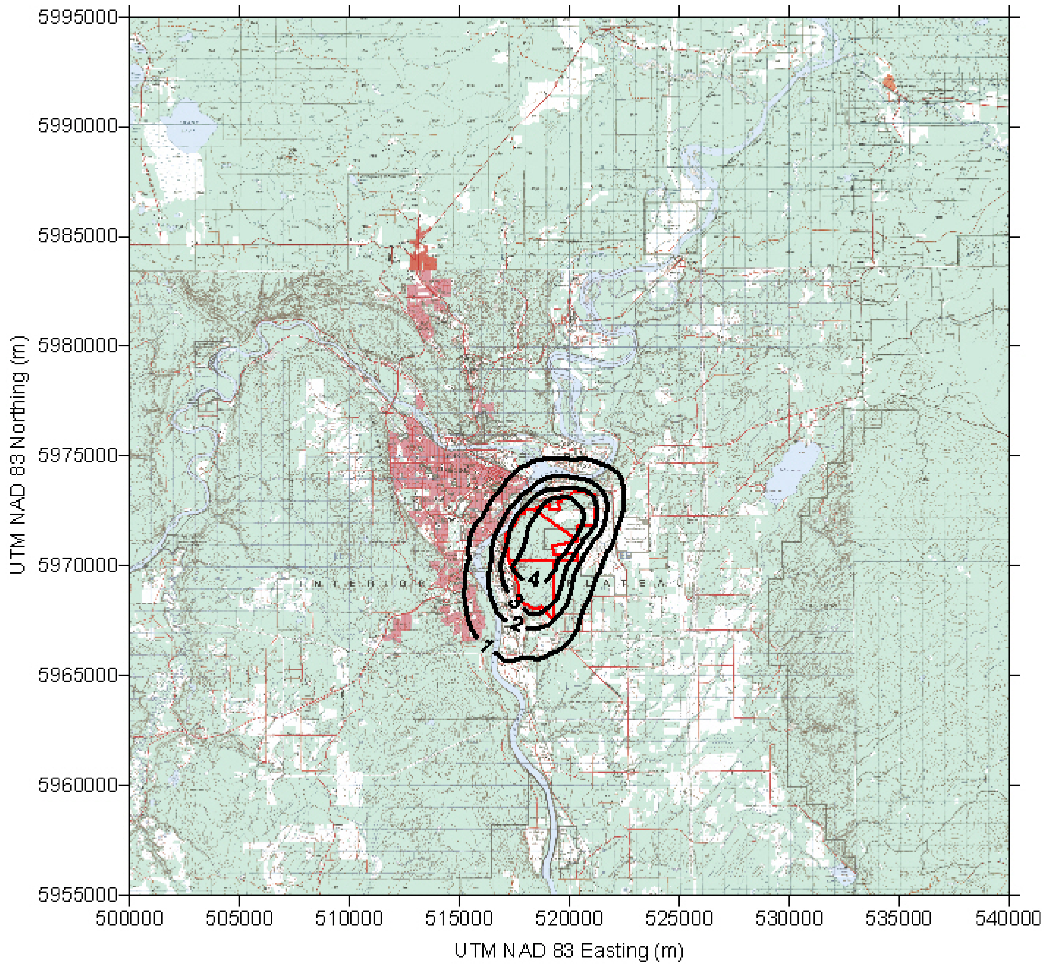
Contour Intervals are: 5, 10 and 25 µg/m³.

Figure 5-12: Contour Plot of Maximum Predicted 24-Hour $PM_{2.5}$ Concentrations from all Three Sub-areas for Expected Traffic Generation Rate (16.1 vehicles/1000 m^2/d)



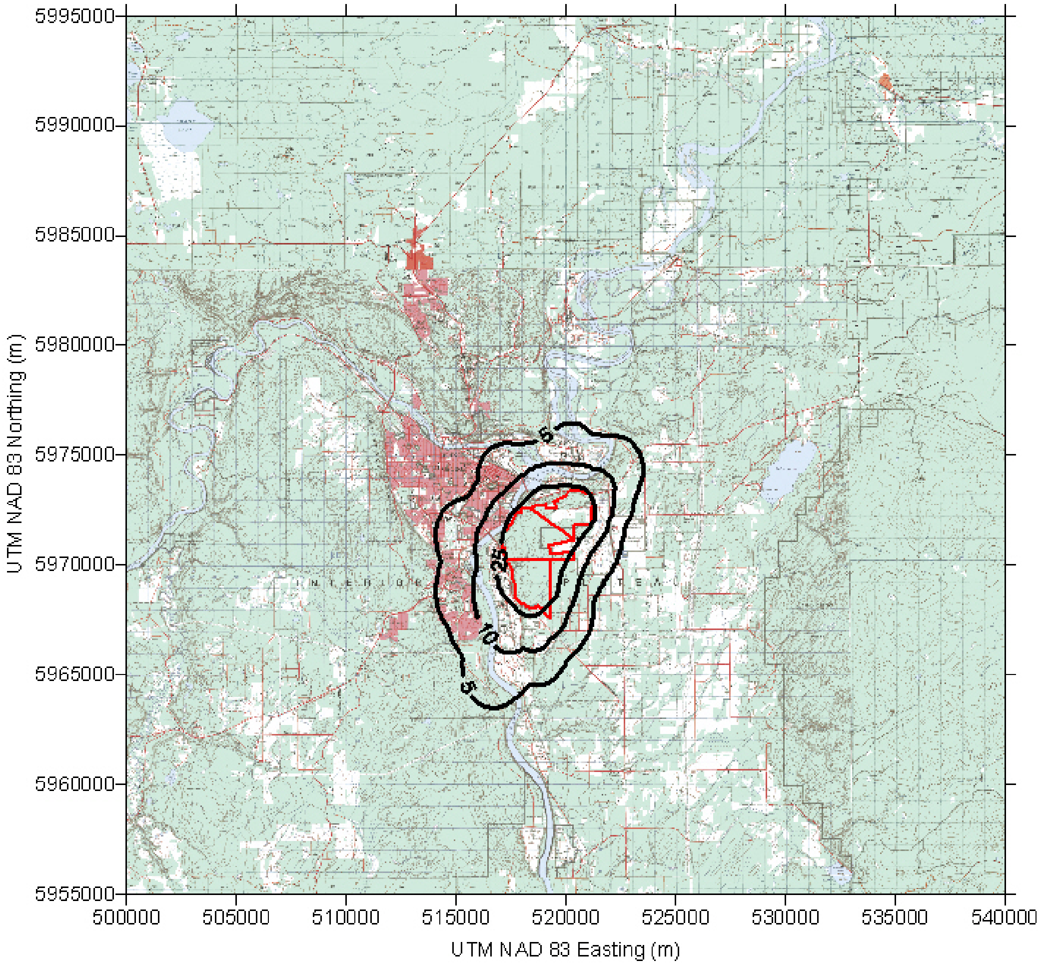
Contour Intervals are: 5, 10 and 25 µg/m^3.

Figure 5-13: Contour Plot of Maximum Predicted 24-Hour PM_{10} Concentrations from all Three Sub-areas for Expected Traffic Generation Rate (16.1 vehicles/1000 m^2/d)



Contour Intervals are: 5, 10 and 25 µg/m³.

Figure 5-14: Contour Plot of Maximum Predicted 24-Hour $PM_{2.5}$ Concentrations from all Three Sub-areas for Higher Traffic Generation Rate (32.3 vehicles/1000 m^2/d)



Contour Intervals are: 5, 10 and 25 µg/m³.

Figure 5-15: Contour Plot of Maximum Predicted 24-Hour PM_{10} Concentrations from all Three Sub-areas for Higher Traffic Generation Rate (32.3 vehicles/1000 m^2/d)

As stated in Section 4.4, exceedances of the 24-hour $PM_{2.5}$ and PM_{10} provincial objectives have been observed 3.7% (13.5 days/year) and 5.1% (18.6 days/year) of the time at the Plaza 400 monitoring station. To assess the increase in the frequency of exceedances of particulate matter objectives, different percentiles of predicted concentrations were added to PM_{10} and $PM_{2.5}$ concentrations observed at the Plaza 400 monitoring station. The frequencies of resulting concentrations greater than the corresponding objective or half the objective are summarized in Table 5-7 and Table 5-8 for traffic generation rates of 16.1 and 32.3 vehicles/1000 m^2/d, respectively.

The proposed light industrial zone with the expected traffic generation rate (16.1 vehicles/1000 m^2/d) may increase the frequency of exceedance of the PM_{10} and $PM_{2.5}$ objectives in the study area by up to a maximum of 17% and 2%, respectively. In downtown Prince George, the frequency of exceedance of the PM_{10} and $PM_{2.5}$ objectives may be increased by up to a maximum of 6 and 1%, respectively. These percentages are based on the assumption that the worst-case predicted concentrations would occur at the same time and the same location as the worst-case observed concentrations, which is unlikely. Therefore, percentiles other than the maximum predicted concentration (or 100^{th} percentile) were also assessed. To assess a more likely scenario, the median (50^{th} percentile) PM_{10} concentration predicted for the downtown area and associated with the expected traffic generation rate were added to concentrations observed at Plaza 400. The resultant increase in frequency of exceedance of the PM_{10} objective was 0.7% (2.6 days/year) in the downtown area. Similarly, when the 50^{th} percentile predicted $PM_{2.5}$ concentration associated with the expected traffic generation rate was added to observed concentrations, the increase in the frequency of exceedance in downtown was 0.2% (0.7 days/year).

From 2001 to 2005 the proposed annual $PM_{2.5}$ objective (8 µg/m^3) was exceeded four out of five years or 80% of the time. In the one year that it was not exceeded, the observed value was 7.9 µg/m^3, which is only slightly less than the annual objective. Although the predicted annual $PM_{2.5}$ concentrations are low, especially in downtown Prince George (see Table 5-6), when added to the observed concentrations, they would result in an additional exceedance of the annual $PM_{2.5}$ objective and therefore the annual objective would be exceeded 100% of the time.

Table 5-7: Predicted Project Contribution Plus Background Greater than Objective or Half the Objective – Traffic Generation Rate of 16.1 vehicles/m^2/d

Location	Pollutant		Percentile of Predicted Concentrations					
			100th	98th	95th	90th	75th	50th
Entire Study Area	PM_{10}	Count of Predicted + Background > 25 µg/m^3	42,538	40,284	37,436	32,756	25,336	18,826
		Frequency of Predicted + Background > 25 µg/m^3	100.0%	94.7%	88.0%	77.0%	59.6%	44.3%
		Increase Relative to Background	76.4%	71.1%	64.4%	53.4%	36.0%	20.7%
		Count of Predicted + Background > 50 µg/m^3	8,920	6,420	5,722	4,924	3,839	2,957
		Frequency of Predicted + Background > 50 µg/m^3	21.0%	15.1%	13.5%	11.6%	9.0%	7.0%
		Increase Relative to Background	17.2%	11.3%	9.7%	7.8%	5.3%	3.2%
	$PM_{2.5}$	Count of Predicted + Background > 12.5 µg/m^3	14,638	13,556	13,165	12,726	12,036	11,375
		Frequency of Predicted + Background > 12.5 µg/m^3	34.8%	32.2%	31.3%	30.2%	28.6%	27.0%
		Increase Relative to Background	10.6%	8.1%	7.1%	6.1%	4.5%	2.9%
		Count of Predicted + Background > 25 µg/m^3	3,022	2,836	2,759	2,655	2,537	2,398
		Frequency of Predicted + Background > 25 µg/m^3	7.2%	6.7%	6.6%	6.3%	6.0%	5.7%
		Increase Relative to Background	2.1%	1.6%	1.4%	1.2%	0.9%	0.6%
Downtown	PM_{10}	Count of Predicted + Background > 25 µg/m^3	27,738	20,372	17,400	15,612	13,632	11,944
		Frequency of Predicted + Background > 25 µg/m^3	65.2%	47.9%	40.9%	36.7%	32.0%	28.1%
		Increase Relative to Background	41.6%	24.3%	17.3%	13.1%	8.4%	4.5%
		Count of Predicted + Background > 50 µg/m^3	4,212	3,175	2,721	2,432	2,138	1,893
		Frequency of Predicted + Background > 50 µg/m^3	9.9%	7.5%	6.4%	5.7%	5.0%	4.5%
		Increase Relative to Background	6.2%	3.7%	2.6%	2.0%	1.3%	0.7%
	$PM_{2.5}$	Count of Predicted + Background > 12.5 µg/m^3	12,586	11,831	11,438	11,158	10,831	10,548
		Frequency of Predicted + Background > 12.5 µg/m^3	29.9%	28.1%	27.2%	26.5%	25.7%	25.0%
		Increase Relative to Background	5.8%	4.0%	3.0%	2.4%	1.6%	0.9%
		Count of Predicted + Background > 25 µg/m^3	2,628	2,496	2,417	2,363	2,297	2,229
		Frequency of Predicted + Background > 25 µg/m^3	6.2%	5.9%	5.7%	5.6%	5.5%	5.3%
		Increase Relative to Background	1.1%	0.8%	0.6%	0.5%	0.3%	0.2%

Table 5-8: Predicted Project Contribution Plus Background Greater than Objective or Half the Objective – Traffic Generation Rate of 32.3 vehicles/m²/d

Location	Pollutant		100th	98th	95th	90th	75th	50th
Entire Study Area	PM_{10}	Count of Predicted + Background > 25 µg/m³	42,538	42,538	42,538	42,538	42,512	34,285
		Frequency of Predicted + Background > 25 µg/m³	100.0%	100.0%	100.0%	100.0%	99.9%	80.6%
		Increase Relative to Background	76.4%	76.4%	76.4%	76.4%	76.3%	57.0%
		Count of Predicted + Background > 50 µg/m³	41,859	24,999	18,826	13,728	8,363	5,168
		Frequency of Predicted + Background > 50 µg/m³	98.4%	58.8%	44.3%	32.3%	19.7%	12.1%
		Increase Relative to Background	94.7%	55.0%	40.5%	28.5%	15.9%	8.4%
	$PM_{2.5}$	Count of Predicted + Background > 12.5 µg/m³	20,435	17,587	16,594	15,556	14,049	12,669
		Frequency of Predicted + Background > 12.5 µg/m³	48.5%	41.8%	39.4%	36.9%	33.4%	30.1%
		Increase Relative to Background	24.4%	17.6%	15.3%	12.8%	9.2%	6.0%
		Count of Predicted + Background > 25 µg/m³	4,049	3,600	3,408	3,183	2,919	2,643
		Frequency of Predicted + Background > 25 µg/m³	9.6%	8.5%	8.1%	7.6%	6.9%	6.3%
		Increase Relative to Background	4.5%	3.4%	3.0%	2.4%	1.8%	1.2%
Downtown	PM_{10}	Count of Predicted + Background > 25 µg/m³	42,538	38,274	30,099	24,340	18,108	14,040
		Frequency of Predicted + Background > 25 µg/m³	100.0%	90.0%	70.8%	57.2%	42.6%	33.0%
		Increase Relative to Background	76.4%	66.4%	47.2%	33.6%	19.0%	9.4%
		Count of Predicted + Background > 50 µg/m³	9,842	5,879	4,558	3,697	2,830	2,198
		Frequency of Predicted + Background > 50 µg/m³	23.1%	13.8%	10.7%	8.7%	6.7%	5.2%
		Increase Relative to Background	19.4%	10.1%	7.0%	4.9%	2.9%	1.4%
	$PM_{2.5}$	Count of Predicted + Background > 12.5 µg/m³	15,170	13,544	12,790	12,201	11,491	10,833
		Frequency of Predicted + Background > 12.5 µg/m³	36.0%	32.2%	30.4%	29.0%	27.3%	25.7%
		Increase Relative to Background	11.9%	8.0%	6.3%	4.9%	3.2%	1.6%
		Count of Predicted + Background > 25 µg/m³	3,119	2,836	2,680	2,558	2,432	2,298
		Frequency of Predicted + Background > 25 µg/m³	7.4%	6.7%	6.4%	6.1%	5.8%	5.5%
		Increase Relative to Background	2.3%	1.6%	1.2%	1.0%	0.7%	0.3%

5.3 CONCLUSIONS

An initial meteorological analysis was performed based on five years of CALMET modelling of the Prince George region. Based on this meteorological analysis one would expect the greatest impact on downtown from the PM emissions from the proposed land use zone to be associated with stable conditions when the wind direction is from the south. However, these stable conditions, namely Class 5 and 6, only occur at night when activity in the light industrial will be reduced (i.e., less fugitive emissions released). This is important because when the meteorological conditions are the worst in terms of air quality the emissions from the proposed light industrial area will be at their lowest.

Dispersion modelling was performed with three area sources representing the three sub-areas of the proposed zone. Results from the three sub-areas show that Sub-area 2 results in slightly higher maximum 24-hour concentrations of particulate than Sub-areas 1 or 3. Also, emissions originating from Sub-area 2 result in maximum concentrations that are closer to downtown. This would indicate that PM emissions should be more closely scrutinized in Sub-area 2 or efforts to locate emission sources further east within Sub-area 2 may have merit.

Particulate matter emissions were estimated for paved public roads and parking lots and paved storage areas. Emission estimation was based on results of a traffic impact study provided by L&M Engineering Ltd. Results show that traffic on paved roads and parking lots are expected to emit the most PM. The paved storage areas represent a very minor source of PM emissions. It can also be seen that PM_{10} concentrations are estimated to be about nine times the $PM_{2.5}$ concentrations.

Results were predicted for the most likely land-use plan where all roads and storage areas are paved, made up of 25% paved roads and parking lots, 30% paved storage areas, 30% buildings and 15% undeveloped or landscaped areas. The maximum predicted 24-hour PM_{10} and $PM_{2.5}$ concentrations as well as the annual $PM_{2.5}$ concentration are less than half the provincial objectives when the expected traffic generation is assumed.

From 2001 to 2005, exceedances of the 24-hour PM_{10} and $PM_{2.5}$ objectives were observed 3.7% (13.5 days/year) and 5.1% (18.6 days/year) of the time, respectively, at the Plaza 400 monitoring station in downtown Prince George. The proposed annual $PM_{2.5}$ objective was exceeded 80% of the time during this period. When the maximum predicted concentrations were combined with the observed concentrations, it was found that the proposed land use development plan may increase the frequency of exceedance of the 24-hour PM_{10} and $PM_{2.5}$ objectives by a maximum of 17% and 2% in the study area, or 6% and 1% in downtown Prince George. However, these increases are based on the assumption that the worst case predicted concentrations would occur at the same time and the same place as the worst case observed concentrations. This is unlikely. Therefore more realistic combinations of predicted and observed concentrations were also assessed and the increases in the frequency of exceedance are less for such scenarios. For example, when the median (50^{th} percentile) PM_{10} concentration predicted for the downtown area and associated with the expected traffic generation rate is added to concentrations observed at Plaza 400, the resultant increase in frequency of exceedance of the PM_{10} objective is 0.7% (2.6 days/year) in the downtown area. Similarly, when the 50^{th} percentile predicted $PM_{2.5}$ concentration associated with the expected traffic generation rate is added to observed concentrations, the increase in the frequency of exceedance in downtown is 0.2% (0.7 days/year).

To minimize the project contribution to particulate concentrations in the study domain, all roads and storage areas should be paved, and the best management practices discussed in the next section should be followed.

6.0 BEST MANAGEMENT PRACTICES AND DESIGN

Dust emissions on paved roads should be managed. Factors affecting paved road dust emissions include the road surface silt loading, mean vehicle weight, and traffic volumes. The use of tracked vehicles and heavy trucks should be restricted to prevent damage to road surface and base.

Loose material on paved road surfaces (i.e. silt loading) originates from spillage of material from vehicles and carryout from nearby areas. Therefore, best management practices to minimize road dust emissions include covering loads in trucks with heavy tarpaulins to prevent spillage of material and removing any material that has deposited on the travel lanes via vacuum sweeping or water flushing. Note that street sweeping of gutters and curb areas may increase silt loading on the travel lanes. Application of coarser winter traction material as opposed to finer sands that would contribute to heavier silt loadings would also reduce dust emissions. Excess salt and sand applied to the roads during winter should be removed at the end of the season. Minimizing activities during PM episodes is another mitigation strategy.

Storm-water drainage should be addressed such that curbing or ditching is constructed to prevent water erosion onto paved roads and road shoulders should be either paved or stabilized with gravel or vegetation.

7.0 RECOMMENDATIONS FOR FURTHER INVESTIGATION

This study provides a good initial investigation into fugitive dust and vehicle emissions from several different surface types based on several assumptions about activities and infrastructure in a light industrial land-use zone. To further improve upon this study it would be prudent to scrutinize the underlying assumptions and obtain actual industrial land-use plans of the development to better define them.

If development plans are known, further refinement of the dispersion modelling could be done such that the proposed site could be further subdivided into smaller areas. For example, plans containing the locations of water quality setbacks, roads, parking lots, storage areas and buildings could be considered in the modelling so that a more realistic prediction of concentrations could occur.

This study only considers fugitive dust emissions from the land surface on which the industrial development will be built and vehicle exhaust emissions in the area, but not the development itself. Since the development will be designated as a light industrial zone it will likely not contain large particulate emission sources; however, there may be some small particulate emission sources including stacks, vents, and stockpiles. Understanding the PM emission contribution from these small sources and potentially modelling them may help determine the best location within the entire light industrial land-use zone to locate them.

8.0 REFERENCES

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