WILLIAMS LAKE AIRSHED MANAGEMENT PLANNING
BACKGROUND AIR QUALITY REPORT
(FOR DATA COLLECTED 1990 – 2002)

Prepared for:

Ministry of Environment
Cariboo Region
Williams Lake, BC

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Abbreviations

$\mu g/m^3$	micrograms (of contaminant) per cubic metre of air
ACE	Air Contaminant Emission (Model)
agl	above ground level
AQMP	Air Quality Management Plan
asl	above mean sea level
atm	atmosphere
AWMA	Air and Waste Management Association
BC	British Columbia
CAC	Criteria Air Contaminants
CDN	Canadian
CEAA	Canadian Environmental Assessment Act
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CWS	Canada-wide Standards
d	day
E	east direction
EC	Environment Canada
EPA	Environmental Protection Agency (U.S.)
g	gram
g/s	grams per second
h	hour
H_2S	hydrogen sulphide
K	temperature in Kelvin
km	kilometre
km/hr	kilometre per hour
kPa(g)	pressure in units of thousands of pascals above 101.3 kPa
L	litre
m	metre
m/sec	metres/second
mg	milligram
MOE	Ministry of Environment
MSC	Meteorological Service of Canada
N	north direction
N_2O	nitrous oxide
NAPS	National Air Pollution Surveillance
NO_2	nitrogen dioxide
NO_X	oxides of nitrogen reported as NO_2
O_3	Ozone
^oC	degrees Celsius
^oF	degrees Fahrenheit
Pa	pascal
PDF	Adobe Acrobat Format of document
PM	Particulate Matter
PM_{10}	Particulate Matter with an aerodynamic diameter less than or equal to 10microns
$PM_{2.5}$	Particulate Matter with an aerodynamic diameter less than or equal to 2.5microns
ppb	parts per billion
ppm	parts per million
ppmv	parts per million by volume
ppmvd	parts per million by volume, dry
RH	relative humidity

s	second
S	south direction
SO_2	sulphur dioxide
SO_x	sulphur oxides
t	metric tonne
t/y	tonnes/year
U	horizontal wind speed (m/s)
U.S. EPA	U.S. Environmental Protection Agency
US EPA	United States Environmental Protection Agency
US	United States
UTM	Universal Transverse Mercator co-ordinates
VOC	volatile organic compounds, excluding methane and ethane
W	west direction
yr	year

Definitions

Air Pollutant: Any pollution agent or combination of such agents, including any physical, chemical, biological, radioactive (including source material, special nuclear material, and byproduct material) substance or matter that is emitted into or otherwise enters the ambient air.

Ambient Air: The portion of the atmosphere, external to buildings, to which the general public has access; Outdoor or open air.

Anthropogenic: Resulting from the presence or activities of humans.

Area Source: Small stationary emissions sources that are inventoried as a group such as residential, governmental, institutional, commercial, industrial fuel combustion or fugitive emissions, small solid waste disposal facilities, agricultural, and natural sources.

Carbon Monoxide (CO): Also known as carbonic oxide, CO is a colourless, odourless, toxic gas at standard conditions. CO is a product of incomplete combustion of fossil fuels. It is also an effective reducing agent in various metal-smelting operations and is also encountered for the production of several synthesis gases.

Criteria Air Contaminant (CAC): There are seven air pollutants that are considered Criteria Air Contaminants (CAC) that are emitted predominantly to the air. The seven contaminants are Total Particulate Matter (PM), Inhalable Particulate Matter (PM_{10}), Fine Particulate Matter ($PM_{2.5}$), Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2), and Volatile Organic Compounds (VOC). A brief description of each CAC is provided in this glossary.

Diagnostic Model: A diagnostic model uses interpolation schemes to produce gridded meteorological fields from irregularly spaced observation data. It is unable to predict how the meteorological fields will change in the future.

Detection Limit: The minimum concentration of a compound that can be determined by a specific analytical method.

Diurnal: Having a daily (24 hour) cycle.

Emission Factor: An estimate or statistical average of the rate at which a contaminant is released to the atmosphere as a result of some activity, such as combustion or industrial production, divided by the level of that activity. The emission factor, therefore, relates the average quantity of each contaminant emitted according to an appropriate base quantity. Emission factors are usually expressed as a weight of contaminant divided by a unit weight, volume, distance or duration of associated activity that emits the pollutant (e.g., kg of SO_2 emitted per kilometre traveled). Emission factors are usually obtained from data of varying

degrees of accuracy and may be presented for either uncontrolled sources or facilities having air pollution control devices in place.

Emission Inventory: An emission inventory is a comprehensive account of air pollutant emissions and associated data from sources within the inventory area over a specified time frame that can be used to determine the effect of emission on ambient air quality.

Emission: The act of releasing or discharging air pollutants into the ambient air from any source.

Fugitive Emissions: Air pollution derived from human activities that do not emanate from a particular point, such as an exhaust pipe or stack. Road dust and VOCs from refinery valves are examples of fugitive emissions.

Greenhouse Gas: Greenhouse gases are gases in the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds. For the purposes of this report greenhouse gases include carbon dioxide, nitrous oxide and methane.

Heavy-Duty Vehicle: A motor vehicle that is rated at more than 3856 kg (8500 lbs.) Gross Vehicle Weight Rating [includes Heavy-Duty Gasoline Trucks and Heavy-Duty Diesel Vehicles].

Hebdomadal: Having a weekly (7 day) cycle.

Inversion: A meteorological condition in which a layer of warm air resides over a layer of cold air. Pollution can be trapped below the warm air potentially resulting in poor air quality over an area.

Levels A, B and C Ambient Air Quality Objectives:

Level A Objectives are established to provide the basis for an anti-degradation policy for undeveloped areas with an adequate safety margin. For some contaminants, the provincial Level A Objectives are equal to the national Maximum Desirable Level which is the long-term goal for air quality and provides the basis for an anti-degradation policy for unpolluted parts of the country, and for the continuing development of control technology.

Level B Objectives are established to provide adequate protection against adverse effects on human health, animals, vegetation, soil, water, materials and visibility. Comparable to the national Maximum Acceptable Level.

Level C Objectives are established to provide protection against health effects that are specific to each contaminant. No common definition is used.

Light-Duty Truck: A vehicle that is rated at less than 3856 kg (8500 lbs.) Gross Vehicle Weight Rating, that has a curb weight of 2722 kg (6000 lbs.) or less and a basic vehicle frontal area of 4.2 m^2 (45 square feet) or less and that is available with special features that enables it to be operated and used off-road [includes Light-Duty Gasoline Trucks and Light-Duty Diesel Trucks].

Light-Duty Vehicle: A motor vehicle that is designed primarily for transportation of persons and has a designated seating capacity of not more than 12 persons [includes Light-Duty Gasoline Vehicles and Light-Duty Diesel Vehicles].

Mesoscale: The scale of meteorological phenomena that range in size from a few kilometres to about 100 kilometres. It includes local winds, thunderstorms, and tornadoes.

Micron or Micrometre: $1/1000^{th}$ of a millimetre, or $1/1{,}000{,}000^{th}$ of a metre.

MIS: Meteorological Information System. A meteorological station that generally measures wind speed, wind direction and temperature.

Mobile Source: Mobile emission sources normally including road and off-road sources, motor vehicles, aircraft, marine vessels, and locomotives.

NAPS: National Air Pollution Surveillance. A federal schedule in which pollutants are monitored for a 24-hour period (midnight to midnight) once every 6 days.

Nitrogen Oxides (NO_X): Consists of nitric oxide (NO) and nitrogen dioxide (NO_2) and are reported as equivalent NO_2.

Particulate Matter: Any aerosol that is released to the atmosphere in either solid or liquid form. **PM_{10}**: Fine particulate matter 10 micrometers or less in diameter. **$PM_{2.5}$**: Fine particulate matter 2.5 micrometers or less in diameter. $PM_{2.5}$ is considered the ultra-fine subset of PM_{10} and is generally made up of combustion source emissions (e.g. wood smoke, vehicle emissions).

Primary Pollutant: A contaminant which is emitted directly to the atmosphere.

Point Source: Major stationary emission sources discharging from a stack.

Prognostic Model: A prognostic model relies on the fundamental equations of atmospheric motion to provide predictions of how meteorological conditions will behave between observing stations. It can also be used for projecting existing conditions into the future.

Sulphur Oxides (SO_X): Gaseous sulphur dioxide (SO_2) for which national and provincial air quality objectives and regulations have been promulgated. Particulate or aerosol sulphate is excluded from emissions totals and is included under particulate matter. SO_X is reported on a SO_2-equivalent basis.

Synoptic Scale: The typical weather map scale that shows features such as high- and low-pressure areas and fronts over a distance spanning a continent.

Secondary Pollutant:: A contaminant that is formed through chemical reactions involving other pollutants in the atmosphere.

TRS: Total reduced sulphur. TRS is a colorless gas that is considered to be a nuisance odour pollutant. At detectable concentrations, TRS is characterized by an offensive odour similar to rotten eggs. TRS includes hydrogen sulphide, dimethly sulphide, dmethyl disulphide, and methly mercaptan.

TSP: "Total suspended particulate". This term refers to the portion of particulate matter containing particles less than 100 μm.

VOC: Volatile Organic Compounds (VOC) refer to photochemically reactive hydrocarbons, excluding methane, ethane, acetone, methylene chloride, methyl chloroform and several chlorinated organics, because of their low reactivity in the atmosphere. This is the same definition as the one used by U.S. EPA.

These are gases that form when hydrocarbons are released to the atmosphere from such things as trees & grasses, decomposition of vegetative matter, combustion, industrial processes, and evaporation from liquid petroleum fuel. Natural biological sources are responsible for the majority of VOC releases, however, man-made sources may dominate in urban airsheds. Some VOC have direct health and environmental effects while others react with other gases in the atmosphere to promote ground-level ozone formation.

Williams Lake Airshed: The mass of air contained in Williams Lake and the immediate surrounding communities of the Cariboo Regional District, and particularly that air mass contained and affected by the natural topographical features of the Williams Lake Valley.

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Executive Summary

Introduction

In the 1970s and 1980s air quality issues in Williams Lake had been a focus of the community primarily due to the practice of disposing wood waste by burning it in bee-hive burners at local sawmills, and/or open burning log yard debris on site (MOE 1981, MELP 1997). This practice produced large amounts of smoke and flyash in the community and generated many public complaints. In the late 1970s there were ten burners, and ambient air measurements indicated that air quality was unacceptable at the time (MOE 1981). Monitoring was primarily conducted in the form of dustfall measurements, and in 1987, particulate matter monitoring started at the firehall site (MELP 1997). In the early to mid1990's, the burner operations were phased out and a burning bylaw was passed prohibiting open burning anywhere within city limits. However the ambient air quality monitoring network continued as levels of fine particulate air pollution indicated the need for their presence. Air quality has improved in the Airshed as a result of burner phase-out and the burning bylaw, however, fine particulate levels still remain a concern.

The emphasis on air quality in Williams Lake is primarily related to fine particulate matter (PM_{10} and $PM_{2.5}$) and their impact on public health and visibility. Recent health studies have found that fine particulate air pollution has a substantial impact on human health. Various studies have indicated that exposure to increases in PM_{10} concentration is associated with increased incidences of respiratory illness (e.g. coughing, runny nose, bronchitis, asthma, pneumonia, emphysema) and mortality from lung and heart disease (Vedal, 1993, 1995; Pope, 1991; Pope et al., 1992; Koenig et al., 1993; CEPA/FPAC, 1999).

In December of 1999 a community driven Airshed Management Planning (AMP) process was initiated to study the air quality levels and make recommendations to improve air quality in the community (Zirnhelt and Plain, 1999). This report has been prepared for the Williams Lake Air Quality Roundtable in accordance with Section 3.0 C. of the Air Monitoring and Assessment Strategy for Williams Lake BC, 2000 – 2005 (Plain and Zirnhelt, 2000). This report was developed to collate all pertinent ambient air quality information in the last twelve years for the Williams Lake Airshed into one comprehensive document. This information will provide a basis for determining the direction of air quality assessment work in the airshed that will assist with the development of recommendations for the Airshed Management Plan. The report covers the following main areas:

- a review of sources of PM_{10}, $PM_{2.5}$, VOCs and NO_X in the Williams Lake Airshed based on the previous emission inventories, what's known about the area, as well as, pictures;
- a review of the local meteorology, specifically as it relates to air quality in the airshed;
- the status of ambient air quality in Williams Lake from 1990 to 2002;

The following parameters were analyzed in detail and a brief summary of the analysis is provided in the rest of this section, followed by the conclusions and recommendations:

- Local meteorology
- Suspended particulate less than 10 microns in diameter (PM_{10}),
- Suspended particulate less than 2.5 microns in diameter ($PM_{2.5}$),
- Oxides of Nitrogen and Ozone
- Polycyclic Aromatic Hydrocarbons (PAHs)
- Metals data from fine particulate matter filters

Sources of Pollutants

Historically wood waste burning was known to be a source of air pollution that led to periods of unacceptable air quality, as these burners phased out of operation air quality improved. The air pollution sources in the airshed in the late 1990s and early 2002 are diverse.

The latest Williams Lake emission inventory was used to identify sources that may influence ambient concentrations of PM_{10}, $PM_{2.5}$, PAHs, metals, NO_X and ozone, in the Williams Lake Airshed. Local knowledge of the area along with picture examples illustrated the sources that affect the airshed.

The most significant sources of pollution in the airshed were identified as the permitted sources, however, the ambient analysis indicates that road dust, fugitive emissions, mobile sources, and residential wood burning all play a very important role, in influencing ambient concentrations.

Air Quality Meteorology

The air quality meteorology of the area is conducive to inhibiting the dispersion of pollutants. Measured data in the region shows that the MOE Glendale School Station is representative of the meteorology at the northwest end of the airshed. Initial data from the Canadian Tire meteorological station indicates that it is well situated to represent air quality meteorology at the south end of the airshed. Wind speeds and wind directions at the MSC Williams Lake Airport data do not correspond as well to the two stations that are situated within the valley. The Airport site has a significantly higher frequency of calms than the Glendale site due to the anemometer threshold and location. The MOE data is the more accurate data to represent valley flow regimes.

Based on the frequency of calm winds, one might expect that air quality would be worse in 1995 and 2000, than in other years (using both sites as indicators). The year 2002 indicated relatively higher frequencies of calms at Canadian Tire which could be a contributing factor to reduced dispersion for that year.

On average, the lowest total precipitation occurs during the late winter/early spring months (February through April) while the highest total precipitation occurs in June, July and the late fall. The driest periods from February to April generally correspond to the months with some of the highest average wind speeds. These conditions are conducive to producing dust events following spring thaw.

Non-Continuous PM_{10}

The PM_{10} results were compared to the British Columbia Air Quality Objective for PM_{10} of 50 $\mu g/m^3$ and the CEPA health reference level for PM_{10} of 25 $\mu g/m^3$. From 1990-2001, PM_{10} concentrations were observed using a HiVol sensor at the Firehall site. In 2001 and 2002, PM_{10} concentrations were also observed using a Partisol sampler at this site. The highest annual mean concentration occurred in 1991 and the data showed a definite downward trend from then until 2001. On average, the months of February and March had the highest concentrations.

Both the average monthly concentrations and the exceedance frequencies at the Firehall site improved after the phase out of the burner operations. The average 24-hour concentration was 27.92 $\mu g/m^3$ from 1991-1995, and 24.3 $\mu g/m^3$ from 1996-2001. The health reference level was exceeded on average 43.73% from 1991-1995 and 37.14% from 1996-2001. The 24-hour Level B Objective of 50 $\mu g/m^3$ was exceeded 13.37% from 1991-1995 and 6.18% from 1996-2001.

Non-continuous PM_{10} concentrations were observed using a HiVol sensor at the Skyline site. The second full year of observations, 1994 had the highest annual mean concentration and the data showed a definite downward trend from then until 2001 when the HiVol was

decommissioned. On a monthly basis the data fluctuated somewhat erratically, but in general concentrations were higher in summer and lower in winter.

The frequency of concentrations above 25 $\mu g/m^3$ and 50 $\mu g/m^3$ was higher at Skyline when compared with the other sites. For the period of data collected, Skyline did show a downward trend of the frequency of exceeding the 24-hour objective, however, similar to Firehall, there was no distinct improvement in the frequency above 25 $\mu g/m^3$. Prior to 1995, the frequency above 50 $\mu g/m^3$ was 15.1% and post 1995 it was 7.2%.

PM_{10} concentrations were observed using a HiVol sensor at the Watertower site. The third full year of observations, 1998, had the highest annual mean concentration, and the data showed a definite downward trend from then through 2002. Each year, concentrations at the Watertower site were lower than at any other site. On a monthly basis, the concentrations were fairly constant, and were consistently lower than at any other Williams Lake site.

From 1997-2002, PM_{10} concentrations were observed using a HiVol sensor at the 168 Mile Road site. 1998 had the highest annual mean concentration and the data showed a definite downward trend from then through 2002. The 168 Mile Road data showed essentially the same annual pattern as the Watertower data, but with absolute values about 5 $\mu g/m^3$ higher than the Watertower site. Each year, concentrations at the 168 Mile Road site were lower than those at the Skyline and Firehall sites.

Continuous PM_{10} Results

Continuous data collected at Skyline showed that the annual average PM_{10} concentration ranged from 27.0 to 29.3 $\mu g/m^3$ from 2001-2002. The month during which concentrations were most often above 50 $\mu g/m^3$ was August 2001, when stable, warm conditions, which are conducive to dust generation, prevailed. Generally, February, March and April have been observed to be primarily associated with dust episodes, which are exacerbated by stagnant meteorological conditions. The months of January and February had the fewest frequencies above the reference levels. Frozen ground during these months reduces the amount of available dust for lift into the atmosphere. On average Skyline PM_{10} levels were above the health reference levels 44.1% of the time in 2001, and 44.3% of the time in 2002.

The 1992-2002 continuous PM_{10} results collected at the Columneetza site showed annual average PM_{10} concentrations ranging from 16.5 to 22.8 $\mu g/m^3$. These concentrations are much lower than the Skyline site. The impacts of spring time road dust at this site were clearly evident, and most years showed a second PM_{10} peak in late summer/early fall (e.g. August-October), often in September. From 1993 to 1995 the average annual concentration was 21.8 $\mu g/m^3$ while from 1996-2002 annual average concentrations were lower at 18.1 $\mu g/m^3$, with the lowest observed in 2001, 16.5 $\mu g/m^3$. The health effects level of 25 $\mu g/m^3$ was exceeded from 14.3% to 34.8% of the time from 1993-2002. In terms of block averages, the health effects level was exceeded on average 30.4% from 1993 to 1995 compared with an average of 19.6% from 1996-2002. This strongly indicates that the phase-out of the burners improved air quality in the airshed.

In January and February 2002, the health effects level was exceeded about as frequently at Skyline as at Columneetza. For every other month in 2002, the health effects level was exceeded about twice as often at Skyline as at Columneetza. This is not entirely unexpected because Skyline is surrounded by a large portion of anthropogenic sources of fine particulate matter.

During the short continuous monitoring period at the Skyline site, months with higher precipitation did not necessarily correspond with the lowest PM_{10} frequencies above 50 $\mu g/m^3$. At the Columneetza site, the months of March in years with more precipitation had fewer

concentrations exceeding the objectives. Several instances of high precipitation coinciding with low PM_{10} frequencies above 50 $\mu g/m^3$ were observed for all months but most frequently before 1996.

Calm winds did not correlate strongly with more frequent values above the objective, although in some instances, months with more calms tended to have more PM_{10} concentrations above the objective.

It was noticed that the month of October 2002 at Skyline had particularly calm wind speeds with no exceedances of the Level B objective. The mean wind speeds at all of the meteorological stations were lower than normal. This potentially indicates that sources that are affected by winds (e.g. road and fugitive dust) could be significant contributors to that site.

Log yards thaw slower than roadways, therefore, spring-time road dust, and dust from other ground level sources (e.g. cyclones) was likely the main cause of elevated PM_{10} during the months of February and March. Ice and snow pack likely had a stronger influence on spring-time PM_{10} concentrations than did calm wind conditions.

Annual Continuous PM_{10} Monitoring Trends

The peak annual average PM_{10} concentrations at Columneetza occurred in 1993 and 1995; 1999 and 2001 had the lowest 24-hour maximum concentrations. The 95th and 75th percentiles did not fluctuate significantly from year to year, but a decline was noticeable from when the wood waste burners were phased out by 1996.

Monthly Variations in Continuous PM_{10} Data

Seasonal trends were apparent at Columneetza, with the highest concentrations typically occurring in the spring and the lowest concentrations occurring in summer and winter. A secondary peak was observed during fall. The approximately 1.5 years of continuous data from the Skyline site did not exhibit the same trends as the 11 years of data from the Columneetza site, although as at Columneetza, there was a minimum at Skyline during winter. The phase out of the burners in the early 1990's may have influenced the Columneetza station seasonal trends. If a comparison of the two stations is to be made when more data is available from Skyline (i.e. continuous monitoring seasonal trends can be established for the station) they should be compared to data after 1995 from Columneetza.

With the 1.5 years of data available from Skyline, the non-winter months at Skyline showed no distinct PM_{10} trend; concentrations fluctuated somewhat, but essentially they were slightly but consistently higher than those in the winter months. The low winter values recorded at the sites occur when the coarse fraction of PM_{10} (e.g. road dust) is bound up in ice and snow and photochemical activity and vegetative emissions are at an annual low. In addition, nights remain cold at this time of the year and home heating contributions add to the total loading in the airshed under stable night time inversion conditions. Because the mean PM_{10} values for December and January are much lower, it can be surmised that it is the coarse fraction material, which becomes available following spring thaw that drives the PM_{10} numbers in the spring.

Diurnal Variations of Continuous PM_{10} Data

At Skyline the plot of the mean PM_{10} concentration described a unimodal curve, increasing gradually from a minimum at 3:00am to a maximum at 4:00pm, and decreasing gradually from then through midnight, to 3:00am. Effectively, the Skyline site is surrounded by anthropogenic PM_{10} sources. The trend of increasing concentrations could be related to the level of activity at each of the nearby industrial sites. The afternoon peak may correspond with the highest industrial, commercial and vehicle activity of the day.

At Columneetza the same plot showed a bimodal curve with maxima at 8:00am and 7:00pm, and with daytime absolute concentrations approximately half their corresponding values at Skyline. At Columneetza the diurnal behaviour of PM_{10} appeared to be driven by the morning and evening rush hours, with peaks at 8:00am and 7:00pm. The time lags of the evening PM_{10} peak occurring slightly later than the evening rush hour, may have been a combined function of atmospheric accumulation of road dust and the beginning of the formation of the nocturnal boundary layer.

Seasonal diurnal patterns for average hourly PM_{10} concentrations at Skyline shows that the spring and fall curves were similar to one another, while the summer curve showed significantly higher absolute concentrations, and the winter curve was lower. The relatively low winter values may have been due to snow and ice cover.

At Columneetza, the rush hour PM_{10} peaks were present in all four seasons, but in winter they were less developed; concentrations did not decrease in the middle of the day, but rather increased steadily from the morning to the evening peak. This was perhaps due to the slower winds and decreased precipitation amounts that characterize winters in Williams Lake; the absence of wind and precipitation would reduce the flushing of particulate matter from the atmosphere. This line of reasoning is tenuous, however, because generally anthropogenic atmospheric phenomena, such as urban heat islands, are most distinct in the absence of precipitation and strong winds. Another possible explanation for the relatively high midday PM_{10} concentrations in winter is that the mixing layer was shallower and less vigorous than in other seasons, reducing the midday dilution of pollutants.

Hebdomadal Analysis of Continuous PM_{10} Data

PM_{10} concentrations at both Columneetza and Skyline are influenced by human activity. Weekdays were on average higher than weekends showing that there is an influence of anthropogenic activity at the site. The Skyline values showed more variation than the Columneetza values, presumably because of the longer observation period at Columneetza.

Non-Continuous $PM_{2.5}$

In most years, the peak $PM_{2.5}$ concentration occurred during winter. $PM_{2.5}$ accounted for roughly 30-45% of the PM_{10} mass during spring, but up to 74% of the mass in winter. $PM_{2.5}$ from wood burning makes a much larger portion of PM_{10}, and therefore, these values are somewhat expected and was likely associated with increases in home heating emissions (particularly wood stoves) and mobile emissions (running longer) combined with poor dispersion meteorology that traps industrial emissions. In each year, fall $PM_{2.5}$ concentrations were higher than summertime concentrations. The winter $PM_{2.5}$ peak and the increase from summer to fall that were observed at Columneetza were also seen in the Firehall data. The health reference levels were exceeded on average 13.5% between 1994 and 2000 at Columneetza and 8.7% between 2001 and 2002 at the Firehall site. The Canada Wide Standard was not exceeded in any year at either site.

Continuous $PM_{2.5}$

Continuous $PM_{2.5}$ data from 2001-2002 at Skyline and Columneetza showed concentrations at both sites were above 30 $\mu g/m^3$ in each year with greater than 75% data capture. The Canada Wide Standard could not be calculated because only one year of data were available, however, the 98^{th} percentile of midnight-midnight block averages was 23 $\mu g/m^3$ for Columneetza and 20 $\mu g/m^3$ for Skyline in 2002. Columneetza had higher maximum rolling 24-hour average values of $PM_{2.5}$ than Skyline. At Skyline and Columneetza, the annual average $PM_{2.5}$ concentrations were similar, ranging from 5.76 $\mu g/m^3$ to 6.71 $\mu g/m^3$ from 2001-2002. The health reference level of 15 $\mu g/m^3$ was exceeded on average 6.15% of the time from 2001-2002 at Columneetza and 5.25% of the time at the Skyline site for 2001 and 2002.

Monthly, Diurnal and Hebdomadal Variations of Continuous $PM_{2.5}$

The highest mean monthly values of $PM_{2.5}$ at Skyline and Columneetza occurred in November of 2002. These peaks correspond with the PM_{10} episodes that occurred in Williams Lake (and in Quesnel) during November 2002. The monthly variations show higher peaks in winter when home heating becomes a factor. This pattern is significantly more distinct at Columneetza than at Skyline, and is not unexpected as Columneetza is more influenced by residential areas.

Diurnal variations in $PM_{2.5}$ concentrations at the Skyline and Columneetza sites were analysed. The diurnal patterns at Columneetza show a slight morning peak and an similar slight evening peak. The highest maximum hourly concentrations occur at Columneetza during the morning. A number of factors could contribute to the maximums at these times, including the break-up of the morning inversion, as well as the increase in particulate matter emissions from vehicles and mobile sources, and contributions from road dust kicked up by morning traffic. At Skyline a muted peak occurs at 8am, but essentially concentrations are constant throughout the day and night. The influence of industry and mobile sources near Skyline is likely the reason for higher concentrations at that site.

Seasonal analysis of diurnal mean average $PM_{2.5}$ concentrations show that both sites experienced a morning peak in average concentrations in all seasons, although the peak was more pronounced (and consistent from season to season) at the Skyline site. The pattern suggests that the seasonal peak morning concentrations occurred after the dispersal of the nocturnal inversion. At Skyline, there was little diurnal or seasonal variation in $PM_{2.5}$, with all four seasons essentially the same, and aside from the morning peak, all hours were similar. This also suggests that a continuous source is influencing this site, or conversely no single source is influencing the site over another. The overall patterns at Columneetza indicate that ground level sources such as traffic (fuel combustion and road dust) likely contribute to the variations.

Weekday (hebdomadal) variations in $PM_{2.5}$ for both of the stations experienced different weekly variations in $PM_{2.5}$ than for PM_{10}. For both sites the highest mean and 75^{th}, 95^{th}, and 99^{th} percentile values all occurred on Friday. Generally the $PM_{2.5}$ concentrations showed an increasing trend from Monday to Friday. This was unexpected to a degree, it is hypothesized that the close down or cleaning of particular sources on weekends, may result in the weekend, and start of week low, with a Friday high resulting from emissions building up over the five day period.

Ratios of PM_{10} to $PM_{2.5}$ from Continuous Data

At both sites, the data showed that $PM_{2.5}$ constituted a larger portion of the PM_{10} data in winter than in other seasons, with the minimum percentages occurring in summer. This pattern was more consistent at Columneetza than at Skyline. At Skyline there was a peak in May-June as well as in winter. The winter highs could again indicate that wood burning, which compared to other sources of particulate matter produces a large portion of $PM_{2.5}$ relative to PM_{10}, was the main contributor to elevated $PM_{2.5}$ concentrations. At Skyline, another source is likely the cause of the May-June peak.

NO_X and Ozone

Continuous NO_2 and NO observations were initiated in April 1992 and ended in May 2000 at the Columneetza site and ozone has been measured from 1992 to 2002. Ozone is one of the main concerns in urban smog because of the adverse effects on human health that can arise from both short-term and long-term exposure to elevated concentrations. Ozone is not usually emitted from processes, but may form near ground level as a result of photochemical reactions involving ozone precursors. Ozone is normally present in the troposphere as a result of naturally occurring photochemical and meteorological processes.

In the absence of VOCs, NO will react with the produced ozone, converting to NO_2 via the reaction. In the presence of VOCs, higher ozone concentrations can occur because VOCs react with NO to form NO_2 without destroying ozone. This upsets the equilibrium associated with the NO_X reactions discussed above and can lead to ozone accumulation under favourable meteorological conditions.

Ozone measurements were compared to the federal 1-hour desirable objective of 100 $\mu g/m^3$ and 160 $\mu g/m^3$ as well as the Canada Wide Standard (CWS), 98th percentile 8-hour rolling average, based on a 3-year metric of 65 ppb. Of the measured ozone data maximum 8-hour rolling average concentrations ranged from 51.4 to 59.1ppb. The 98th percentile concentrations ranged from 40.5 to 44 ppb. All of these concentrations are below the CWS. Ozone was above the federal desirable objective from 0.48% to 1.98% of the time from 1990-2002.

A hebdamodal analysis was conducted to determine if there was any anthropogenic influence on measured ozone values. Mean ozone concentrations were observed to be lower in the weekdays than on the weekend. The reverse was true for NO_x and NO_2. This is strong evidence that the anthropogenic NO_X that is emitted to atmosphere from vehicles (or other predominantly weekday sources) are acting to consume ozone. Put another way, the NO is reacting with O_3 to produce NO_2 and oxygen (O_2). This indicates that the airshed is limited by the VOCs that can react to form photochemical smog.

The NO_2 results were compared to the Canadian Federal Objectives of: 60 $\mu g/m^3$ and 100 $\mu g/m^3$ for the annual mean (maximum desirable and maximum acceptable, respectively), 200 $\mu g/m^3$ for the maximum acceptable 24-hour average, and 400 $\mu g/m^3$ for the maximum acceptable hourly average. The annual average NO_2 concentration ranged from 14.4 to 18.3 $\mu g/m^3$ from 1993-1999. From 1995-1999, the annual average NO_2 concentration increased steadily, but none of the Objectives were exceeded. The block averages of NOx concentrations also increased after the burners were phased out. Generally the maximum observed concentrations were 25%-30% of the value of the objectives.

A seasonal trend was apparent, with the highest concentrations occurring in winter and the lowest concentrations occurring in summer. This seasonal variation is typical, and is due to the temperature dependance of the series of chemical reactions that occur in the atmosphere to form ozone from NO_2. On a daily basis, the NO_2 data described a bimodal curve, with maxima at 7:00am and 9:00pm and a minimum at midday. The midday minimum was due to two main factors: scavenging of NO_x by reactions that produce ozone, and dilution by atmospheric mixing. Meteorological patterns and human activity, especially variation in traffic volumes, were both likely to have affected the diurnal variations of NO_2 and NO_X.

Polycyclic Aromatic Hydrocarbons

PAHs were measured at the Anne Stevenson School site every six days from 1992 to 1994, and from time to time throughout this same period at various sites across the airshed. The maximum concentrations were higher in 1993 and 1994 than in 1992. The maximums occurred during February of 1993 and November of 1994. It was noted that these two months were particularly dry, with very little precipitation. For all levels, the maximum PAHs occurred during the winter months while the minimums occurred in summer.

The highest PAHs occurred on the coldest and calm days in winter. In general, during higher periods of PAHs the PM_{10} and NO_X values were higher for the daily periods indicating that residential wood combustion, as well as gas combustion from home heating and vehicles is the likely source. The highest PAH concentrations also occurred on weekends, when the burners were not likely operational. Maximum concentrations of Acenaphthene, Phenanene, Pyrene, and Benzo(a)pyrene were 3.7%, 22%, 24%, and 30.7% of the Effects Screening Levels (ESLs) and

represented the closest PAHs to the respective ESLs. All short-term and long-term predicted concentrations were well below their applicable ESLs.

Metals

Metals are considered toxic, and can exist in the atmosphere in either "elemental" or "oxidized" form. They can bind to particles or stay volatile at various temperatures depending on each metal's properties. Metals can be a natural constituent of particulate matter, and can also result in increased levels due to combustion of fossil fuels, as well as other sources of particulate matter.

Metals data were collected at each of the HiVol PM_{10} air quality monitoring locations in the Williams Lake airshed for certain periods from 1996 to 2001. The particulate matter filters were analysed on the NAPS cycle (once every six days) for the metal constituents. For 2001, the raw data that was available at the time this report was written had not yet been corrected for the analytical techniques that were used, and the filter components of the data had not been subtracted out of the measured constituents. Therefore, a complete analysis of the data was not possible.

All of the measured concentrations at each of the sites are below the pertinent ESL, and in most cases, below even 10% of the short-term ESL. Seasonal variations indicated that highest average concentrations occurred generally in summer. The highest observed concentrations were situated at the Skyline site, while the lowest were at the Watertower site. On occasion the Firehall had higher averages than the other two stations. Average concentrations in 1999 were higher than average concentrations in 1996.

PM_{10} Episode Analysis

PM_{10} episodes were analyzed for the Skyline and Columneetza sites. A Type 1 episode is defined as a period of time during which levels above 50 $\mu g/m^3$ occur for at least 24 hours but less than 48 hours in duration. A Type 2 episode lasts 48 hours or more.

At the Columneetza School monitoring location, the number of episode days per year decreased significantly after 1996, subsequent to wood waste burner phase out. The longest continuous period of high concentrations occurred in 1996, when the rolling 24-hour average was greater than 50 $\mu g/m^3$ for 125 hours. The Type 2 episode in November 2002 was the first since February 1996. Episode days from 1993 to 1996 accounted for a significant fraction of the total number of times concentrations were above the Level B Objective, with 74% to 89% of the year's total number of rolling 24-hour averages that were above the Objective occurring during episodes. From 1997 to 2002, episode days accounted for markedly fewer of the total number of times concentrations were above the Objective, with 41% to 65% of the year's total number of rolling 24-hour averages that were above the Objective occurring during episodes. This improvement reflects that sources other than the burners were also influencing the site.

At the Skyline School monitoring location, in less than five months (August 8-December 31) in 2001, there were more episode days (15.46) than during any entire year at Columneetza from 1993-2002. In contrast, in 2001 at Columneetza, there were no episodes at all. Episodes occurred at Skyline 11% of the time in August-December 2001, and 7% of the time in 2002. The longest Type 2 episode at Skyline occurred in August 2001, when the rolling 24-hour average was greater than 50 $\mu g/m^3$ for 121 hours. Episode periods accounted for 77% and 67% of the total exceeding PM_{10} levels experienced at Skyline in 2001 and 2002 respectively. Over the period, episodes occurred in August and November of both years. The higher amount of episodes at Skyline reflect the presence of sources from all directions.

Air Quality Index

In Williams Lake, both Ozone and PM_{10} are used for calculating the Air Quality Index (AQI) at Columneetza while PM_{10} is used for Skyline. In 2002 at Skyline the AQI was less frequently in the GOOD range (55.66%) and more frequently in the POOR range (9.87%) than during any year from 1993 to 2002 at Columneetza. The AQI at Columneetza was rated GOOD from 65.15 to 85.70% of the time, and from 1996 to 2002, after the burners were phased out the AQI was rated GOOD significantly more often than it was during 1993-1995. The AQI at Columneetza was never rated VERY POOR except in 1996, when it was rated VERY POOR for 0.54% of the time; the corresponding value was 0.17% for Skyline in 2002.

Conclusions and Recommendations

1. The valley setting of Williams Lake is conducive to inhibiting dispersion of pollutants, particularly when meteorological conditions are calm and dry, or with the presence of a nocturnal or winter time inversion.

2. An Airshed specific emissions inventory indicates that in terms of total loading, the Permitted and Road Dust source categories (paved and unpaved) emit the most fine particulate matter (PM_{10} and $PM_{2.5}$) to the Williams Lake Airshed.

3. The largest single change in emission sources prior to 1996 was the phase-out of all beehive burners in the airshed between December 1992 and December of 1995. An improvement in fine particulate levels is indicated by a statistically significant decline in annual averages, a decline in the number of exceedances of the B.C. Ambient Air Quality Objective for PM_{10}, and a decline in monthly average concentrations at all of the PM_{10} monitoring stations in Williams Lake since burner phase out. The block averages presented in the report further support this change. In addition, the City of Williams Lake instituted a back yard burning policy in the spring of 1998 (but possibly as early as 1997) that eliminated backyard burning within city limits. Other factors such as changes in residential heating practices in the vicinity of the monitoring stations and variability in meteorology (wind speed, direction, precipitation, etc.) also may have influenced these trends.

4. Anthropogenic activities have an influence on PM_{10} levels in Williams Lake. This is reflected in the hebdomadal analysis (day of the week) in that both continuous monitoring sites show a weekend minimum and a weekday maximum concentration. The difference between the midweek maximum PM_{10} and the weekend minimum PM_{10} at Skyline for the 75^{th}, 95^{th} and 98^{th} percentile concentrations were 55%, 61% and 60%. Differences between the minimum and maximum values at Columneetza were 36%, 40% and 47% respectively.

5. Anthropogenic activities have a larger influence on PM_{10} values at the Skyline site than at the Columneetza site. This is supported by the diurnal analysis at both sites. At Columneetza the bimodal diurnal behavior of PM_{10} appeared to be driven by the morning and evening rush hours, with peaks at 8:00am and 7:00pm. Residential heating would also add to particulate loading at these times. At Skyline, PM_{10} concentrations increased during the daytime period indicating that the many sources surrounding the site have a significant localized effect - concentrations continue to increase even though atmospheric mixing conditions are the best during the afternoon hours and concentrations should be decreasing as a result.

6. On average, Skyline continuous PM_{10} levels were above the health reference levels 44.1% of the time in 2001, and 44.3% of the time in 2002. There was not a single observed month when a 25 $\mu g/m^3$ 24-hour level was not exceeded. In January and February 2002, the health effects level was exceeded about as frequently at Skyline as at Columneetza. For

every other month in 2002, the PM_{10} health effects level was exceeded about twice as often at Skyline as at Columneetza.

7. Based on six months of meteorological data, high hourly average PM_{10} concentrations at the Skyline monitoring location were recorded in association with winds from all directions as there are numerous sources (permitted, commercial and mobile) surrounding the site. However, the highest frequency of values over 50 µg/m3 occurred when winds were either from the east or from the west to northwest sector. High frequencies of lower concentrations come from the south and southeast of the site.

8. The highest frequency of elevated hourly PM_{10} values at Columneetza occurred when winds were from the west-northwest, where the Glendale industrial area is located. Other high values were experienced when winds were from the east-southeast (residential/mobile).

9. From 1990-1996 the data at the Williams Lake Firehall site showed distinct peaks in late winter and late summer/early fall, but from 1997-2002 no meaningful pattern was evident aside from the February/March peak and wintertime minimums. The late winter/early spring peaks correlate well with observations of road dust impacts throughout the community prior to street sweeping activities.

10. In the Williams Lake Airshed road dust, dust from log yards and traction material, and permitted source emissions appear to have a significant influence on measured ambient PM_{10} data. Based on seasonal variations, the highest PM_{10} values are generally recorded in the spring and are largely associated with re-entrainment of road dust.

11. A significant portion of PM_{10} concentrations exceeding provincial objectives occurs during air quality episodes. Management efforts focused at those sources that contribute most significantly to episodes should reduce the overall number of exceedances, reduce the annual average PM_{10} value and result in improved air quality. Management efforts need to be aimed at reducing the total loading of fine particulate to the airshed from all sources in order to control episodes during stagnant meteorological conditions.

12. $PM_{2.5}$ from the non-continuous monitoring location at Columneetza accounted for between 53.6% and 73.5% of the PM10 mass in winter and roughly 30% of the mass during the spring from 1994 to 2000. In 2001 and 2002, $PM_{2.5}$ accounted for roughly 40-50% of the PM_{10} mass in winter (relatively dry winters) at both continuous monitoring sites and roughly 20% of the mass in the spring. The dominant coarse component in the early spring and through the summer months is largely attributable to road dust being re-entrained by passing vehicles although permitted sources will also contribute depending on dispersion. It is evident that effective control of dust will improve ambient PM_{10} values throughout the community.

13. The Canada Wide Standard for $PM_{2.5}$ was not exceeded during the 7-year record of non-continuous measurements from Columneetza. However, not enough data is available to calculate the Canada Wide Standard for the continuous monitoring sites. The 98^{th} percentile of midnight-midnight block averages in 2002 was 23 $\mu g/m^3$ for Columneetza and 20 $\mu g/m^3$ for Skyline giving initial indications that the CWS will not be exceeded. Twenty-four hour values of $PM_{2.5}$ were above the health reference level of 15 $\mu g/m^3$ an average of 5.25% of the time at Skyline and 6.15% of the time at Columneetza from 2001 to 2002.

14. Diurnal patterns of continuous $PM_{2.5}$ at Columneetza show a slight morning peak in mean through 99th percentile concentrations at 0700 hours, and a slight evening peak at 2000 hours. The highest maximum hourly concentrations occur at Columneetza during the morning. A number of factors could contribute to the maximums at these times, including the break-up of the morning inversion, the increase in particulate matter emissions from

mobile sources (primarily vehicles) and residential/commercial heating, and contributions from road dust kicked up by morning traffic. At Skyline a muted peak occurs at 0800 hours, but essentially concentrations are constant throughout the day and night, with absolute values similar to those at Columneetza. Influences from nearby industrial/commercial sources and the major traffic corridors near Skyline produce the higher daytime and more constant patterns in $PM_{2.5}$ concentrations measured at this site.

15. Seasonal diurnal patterns of continuous $PM_{2.5}$ indicate that residential wood burning, mobile sources, and possibly open burning in the fall, have an influence on measured ambient $PM_{2.5}$ data at both continuous monitoring sites. Permitted sources also contribute to $PM_{2.5}$ impacts depending on meteorology and source location in relation to receptors.

16. It is evident that traffic patterns and emissions from industrial/commercial activity during the week have an influence on ambient concentrations of $PM_{2.5}$. Weekday (hebdomadal) variations in mean $PM_{2.5}$ concentrations at both Skyline and Columneetza exhibit a weekend minimum (Saturday or Sunday) and a late weekday maximum (Thursday or Friday) at both stations. On average, mean and 75^{th} percentile $PM_{2.5}$ concentrations during the weekday maximum are 20% and 29% higher respectively than the weekend/early weekday low. The weekend and early weekday (Monday/Tuesday) lows at Skyline are associated with reduced activity on Sunday. Emissions are allowed to flush out/settle out during this reduced activity period. Home heating emissions on their own do not appear to be able to sustain the $PM_{2.5}$ levels through the weekend.

17. The Air Quality Index (AQI) indicates that, at times, poor air quality still exists in Williams Lake and that there is room for improvement in reducing fine particulate matter concentrations.

18. Ambient NO_X data shows that NO_2 levels were well below federal objectives for the duration of the monitoring period.

19. Ambient NO_x concentrations were influenced by human activity, with higher values on weekdays than during the weekend. The block averages (before and after burner phase out) show that NO_x was higher in 1996-2000 than in the early 1990s. This may in part be due to the TransCanada boiler emissions having an impact at this location although other sources such as vehicle emissions and home heating also play a significant role.

20. Ozone concentrations have not exceeded the Canada Wide Standard, however values have been close to the standard on occasion, and data should continue to be tracked.

21. Seasonally, ozone concentrations in Williams Lake peak in the spring time when ozone has the greatest chance of being transported to ground level from the troposphere where it naturally occurs in higher concentrations.

22. The data from the hebdomadal analysis provides strong evidence that the anthropogenic NOx that is emitted to atmosphere from vehicles (or other predominantly weekday sources) are acting to consume ozone. This indicates that the airshed is likely limited to the VOCs that are present (the mixture of VOCs and NOx was not conducive to ozone formation), and that photochemical ozone episodes are not likely to occur with current emissions from Williams Lake.

23. In examining ozone trends before and after burner phase out and the subsequent start-up of the TransCanada energy facility, there is very little difference between the two periods in terms of concentration. This could indicate that historically, anthropogenic emissions have not strongly influenced ozone concentrations.

24. PAHs were all below the Texas Effects Screening Levels (ESLs) previously from 1992 to 1994, and they would likely be below the ESLs today. Maximum PAH concentrations occurred during the winter months (home heating) while the minimums occurred in summer.

25. Metals data are all below their respective ESLs, however they appeared to be higher in 1999 when compared to 1996. No significant trend was identified, and further analysis of the 2001 data may provide better insight into the data trends. The most recent data has not been blank corrected at this time, and therefore some parameters may be artificially high due to false positives from the filter media. A more thorough analysis should be conducted once it has been blank corrected.

26. As outlined in the Air Monitoring and Assessment Strategy for Williams Lake BC 2000-2005 (Plain and Zirnhelt, 2000), airshed dispersion modelling should be conducted using CALMET and CALPUFF to help quantify relative source contributions impacts from all source types in the Williams Lake Airshed.

1 INTRODUCTION

In the 1970s and 1980s air quality issues in Williams Lake had been a focus of the community primarily due to the practice of disposing woodwaste by burning it in bee-hive burners at local sawmills, and/or open burning log yard debris on site (MOE 1981, MELP 1997). This practice produced large amounts of smoke and flyash in the community and generated many public complaints. In the late 1970s there were ten burners, and ambient air measurements indicated that air quality was unacceptable at the time (MOE 1981). Monitoring was primarily conducted in the form of dustfall measurements, and in 1987, particulate matter monitoring started at the firehall site (MELP 1997). In the early to mid1990's, the burner operations were phased out and a burning bylaw was passed prohibiting open burning anywhere within city limits. However the ambient air quality monitoring network continued as levels of fine particulate air pollution indicated the need for their presence. Air quality has improved in the Airshed as a result of burner phase-out and the burning bylaw, however, fine particulate levels still remain a concern.

The emphasis on air quality in Williams Lake is primarily related to fine particulate matter (PM_{10} and $PM_{2.5}$) and their impact on public health and visibility. Recent health studies have found that fine particulate air pollution has a substantial impact on human health. Various studies have indicated that exposure to increases in PM_{10} concentration is associated with increased incidences of respiratory illness (e.g. coughing, runny nose, bronchitis, asthma, pneumonia, emphysema) and mortality from lung and heart disease (Vedal, 1993, 1995; Pope, 1991; Pope et al., 1992; Koenig et al., 1993; CEPA/FPAC, 1999).

In December of 1999 a community driven Airshed Management Planning (AMP) process was initiated to study the air quality levels and make recommendations to improve air quality in the community (Zirnhelt and Plain, 1999). This report has been prepared for the Williams Lake Air Quality Roundtable in accordance with Section 3.0 C. of the Air Monitoring and Assessment Strategy for Williams Lake BC, 2000 – 2005 (Plain and Zirnhelt, 2000). This report was developed to collate all pertinent ambient air quality information in the last twelve years for the Williams Lake Airshed into one comprehensive document. This information will provide a basis for determining the direction of air quality assessment work in the airshed that will assist with the development of recommendations for the Airshed Management Plan. The report covers the following main areas:

- a review of sources of PM_{10}, $PM_{2.5}$, VOCs and NO_X in the Williams Lake Airshed based on the previous emission inventories, what's known about the area, as well as, pictures;
- a review of the local meteorology, specifically as it relates to air quality in the airshed;
- the status of ambient air quality in Williams Lake from 1990 to 2002;

The following parameters were analysed in detail and a brief summary of the analysis is provided in the rest of this section, followed by the concludsions and recommendations:

- Local meteorology
- Suspended particulate less than 10 microns in diameter (PM_{10}),
- Suspended particulate less than 2.5 microns in diameter ($PM_{2.5}$),
- Oxides of Nitrogen and Ozone
- Polycyclic Aromatic Hydrocarbons (PAHs)
- Metals data from fine particulate matter filters

In the early 1990's, the ambient air quality monitoring program for PM_{10} consisted of non-continuous monitoring stations at Skyline School and the Williams Lake Firehall, and continuous monitoring at Columneetza School using a TEOM (Tapered Element Oscillating Microbalance) (Figure 2). In 1994, a non-continuous Partisol sampler for measuring $PM_{2.5}$ was also installed at

Columneetza. In 1995, the network was expanded to include a non-continuous PM_{10} HiVol monitor at the Williams Lake Watertower, and again in 1997 with the installation of another PM_{10} Hivol monitor at 168 Mile Road. The Columneetza site was also equipped to monitor for oxides of Nitrogen (1992-2000) and Ozone (1992-2002). From 1992 to 1994 sampling for Polycyclic Aromatic Hydrocarbons (PAHs) was undertaken because of their potential for being bio-accumulative and toxic, and to obtain a baseline measurement during bee-hive burner phase-out which could be used in subsequent years for comparative purposes. Metals present on the PM_{10} filters at each of the non-continuous monitoring stations were analysed in 2001 to quantify concentrations and to determine possible sources, and/or relationships to air quality episodes. Each of these monitoring sites are described in greater detail in Section 4. Further details on these monitoring and meteorological sites are also provided in Table 1.

1.1 PHYSICAL SETTING

The Williams Lake Airshed (Figure 1) is situated in the centre of the Cariboo region. The City of Williams Lake is a community of approximately 11,153 people which has approximately 25,122 people in the census area (2001 Census Data Statistics Canada). It is located 238 kilometres south of Prince George and 540 kilometres north of Vancouver on the interior plateau of British Columbia. The city itself is located in a valley at the west end of Williams Lake (Figure 1). The city of Williams Lake is primarily supported by the wood products industry although agriculture, mining, electrical generation, and tourism are also important to the local economy.

The largest part of the city is situated at the west end of Williams Lake, and is in a northwest – southeast orientation within the valley. There are local plateaus on either side of the valley that rise some 300-400 m from the valley floor. This provides a topographical situation that is conducive to forming night time or winter time temperature inversions which, in the presence of pollution, could inhibit the dispersion of contaminants.

2 SOURCES OF POLLUTANTS IN THE WILLIAMS LAKE AIRSHED

Historically woodwaste burning was known to be a source of air pollution that led to periods of unacceptable air quality (Plate 1 – MOE 1981). Emissions from the five bee-hive burners (1990-1995) had the potential to impact any location in the Williams Lake valley depending on meteorology. These burners were phased out in the early to mid 1990s which represented an improvement in air quality (as well as visibilty) as can be seen in an example of a more recent picture (Plate 2). However, despite the improvements, local meteorology and the remaining emission sources still combine to cause poor air quality at times. The local topography inhibits air circulation which can lead to frequent stagnation periods and the subsequent build-up of air pollutants in the valley bottom causing episodes of poorer air quality (Plate 3). Local sources of air pollution such as industrial/commercial emissions, fossil fuel combustion, wood burning, and road/fugitive dust (Plate 4) can contribute to poor air quality episodes.

An airshed-specific emissions inventory was prepared as part of the background information required to prepare an Airshed Management Plan for the Williams Lake Airshed. Emission estimates were made for permitted sources, commercial sources, mobile sources, residential sources, as well as natural sources. The contaminants included emissions of sulphur dioxide (SO_2), oxides of nitrogen (NO_X), carbon monoxide (CO), Volatile Organic Compounds (VOC), and particulate matter (PM, PM_{10}, and $PM_{2.5}$). SO_2, VOC and NO_X are precursors to fine PM and Ozone for which there are Canada Wide Standards (CWS). The Draft emissions inventory was developed by MOE titled “Inventory of Common Air Contaminants Emitted in the Williams Lake Airshed for the Year 2000” (Plain 2002).

The emissions inventory was calculated using the information from the last B.C. provincial emissions inventory (1995) as a baseline. The title of this document is “1995 British Columbia Emissions Inventory of Common Air Contaminants and Greenhouse Gases (Report and Appendices)” (MELP, 1999). Initially, the provincial estimates were scaled down to Williams Lake using the Air Contaminant Emissions (ACE) model (Glen 2001). The values were then evaluated by MOE staff, and efforts were made to update the information in the database to reflect emissions loading to the Williams Lake Airshed based on the year 2000.

Sources of fine particulate matter in the Williams Lake Airshed are diverse. In general, they can be grouped into five categories: natural sources, permitted sources (permitted by Government), commercial sources, residential sources and mobile sources (e.g. automobiles, trucks, trains, etc.).

Natural examples of PM_{10} include wind blown soil particles, bioaerosols and soot from forest fires. During dry conditions fine soil particles can contribute to ambient fine particulate levels as wind-blown dust. Bioaerosols are composed of living and dead biological or biologically-derived particles, including viruses, bacteria, fungi, pollen, animal allergens and dander, and organic metabolic byproducts. Wild fires and open burning emit both primary particles (soot, flyash) and various gaseous components such as volatile organic compounds (VOCs) that can contribute to ambient particulate levels through secondary chemical reactions.

Anthropogenically, soil related particles can also be released from paved and unpaved roadways (Plate 5), land clearing, construction, quarrying and agricultural activities. Re-suspended road dust from wintertime road sanding is also an issue during the late winter/early spring months (Plain, 2003). Furthermore, material that is attached to wheels of trucks can be transported from unpaved industrial sites (e.g. log yards) and deposited onto paved surfaces (Plate 6). As this material dries, it is kicked up by passing vehicles and can further contribute to particulate matter levels as road dust . Collectively, paved and unpaved road dust contribute up to 44.74% of the PM_{10} and 25.84% of the $PM_{2.5}$ emissions in the airshed. This is even greater if winter sanding is included.

Fugitive dust can also be a significant contributor to high particulate matter levels in the airshed . Fugitive emissions vary in size and release rate depending on the activitiy, for example, loading and unloading of chip trucks could result in fugitive emissions (Plate 7). Other significant sources include wind blown dust from log yards (Plate 8), and fugitive dust from pneumatic conveying systems and chip stockpiles (Plate 9). Fugitive dust emissions tend to have a localized impact but can cover large areas under certain meteorological conditions.

Permitted source contributions to overall fine particulate loading in the Airshed are similar in size to road dust and make up 47.91% of the PM_{10} and 59.62% of the $PM_{2.5}$ emissions. These sources include emissions from the sawmill and planing mill products industry, the value added millwork industry, the softwood veneer and plywood industry, the asphalt Industry, the ready-mix concrete industry, and the electric power systems industry. These sources are located in two main industrial areas of the city. One is situated at the southeast end of the city (at the west end of Williams Lake itself) while the other is located just west of Glendale (Figure 1). Emissions from these sectors impact different parts of the community depending on the buoyancy of the plumes and the dispersion meteorology. Examples of buoyant permitted sources include emissions from the cooling towers and boiler stack at the TransCanada Energy Facility (Plate 10) , veneer dryer and steam plant stack emissions from the Weldwood Plywood facility (Plate 11), and Konus energy system emissions from Lignums. These plumes will likely contribute most significantly to impacts on elevated terrain in all directions. However, these emissions can also be trapped within the valley under inversion conditions and can significantly contribute to degraded air quality. Cyclones and baghouses from the wood products industry (example in Plate 12) are also sources of particulate matter while lumber dry kilns (Plate 13) can contirbute to emissions that may impact the air quality of the region (e.g. primarily VOC emissions).

Residential sources (e.g. home heating, residential wood burning, back-yard burning, etc.) contribute 5.03% of the PM_{10} and 10.99% of the $PM_{2.5}$ emissions to the Airshed as the next most significant sources of particulate matter. Although these sources are not as considerable as road dust or the permitted sources, activities such as residential wood burning can significantly contribute to elevated levels of fine particulate matter ($PM_{2.5}$) as often this type of burning occurs under meteorological conditions not conducive to sufficient dispersion of the pollutants (i.e emissions released during night time). In addition, residential emissions generally impact air quality on the neighbourhood scale as emissions tend to stay localized. As a result, they directly affect the air quality where people live. The main residential areas in Williams Lake (Figure 1) include the City of Williams Lake itself, Commodore Heights and Pine Valley on Highway 97 north, North Lakeside on Highway 97 South, West Ridge and Hodgson Road (elevated terrain to the south west of the city), Dog Creek Road (elevated terrain to the south of the city), Fox Mountain (elevated terrain to the north east of the downtown area), the Sugar Cane Indian Reserve at the east end of Williams Lake, and South Lakeside which runs the length of Williams Lake on the south side. It should be noted that residential activity such as back yard burning in areas of elevated terrain could also have an impact on the valley bottom residents due to night time drainage winds which effectively move air from higher terrain to the valley bottom (see Section 3.0).

Commercial Sources (e.g. restraurants, dry cleaners, gravel pits, etc.) contribute 1.64% of the PM_{10} emissions and 2.2% of the $PM_{2.5}$ emissions to the Airshed. Commercial sources are generally restricted to the downtown core, frontage roads along Highway 97 in and out of the city, and on the west end of South Lakeside near Highway 20. These emissions generally have a localized impact, although more buoyant sources such as the creamatorium would likely have a farther reaching impact under certain meteorological conditions.

Around the Airshed and outside of city limits, other sources can contribute to elevated concentrations of particulate matter. For example, open (slash) burning occurs in the airshed (Plate 14) and open field burning on agricultural and reserve lands (Plate 15) is a common practice in the spring. Other “non-road” sources also contribute to a lessor degree (Plate 16).

The largest emissions of VOCs result from permitted sources (37% of total emissions), however, natural (26.8%), residential (17%), commercial (9.3%), and mobile (9.2%) make up a significant portion of emissions as well. For NO_X emissions, permitted sources make up the majority (74%), with mobile sources (23.5%) contributing the next most emissions. The residential, commercial and natural sources make up the remainder.

From a mobile source perspective, Highway 97 is a major traffic corridor that passes directly through the Williams Lake Airshed. This is a large source of combustion particulate from light and heavy duty vehicles (diesel particulate). Mobile sources are also responsible for emissions of Nitrogen Oxides (NO_X), Volatile Organic Compounds (VOC’s) and fugitive dust from paved and unpaved surfaces. Winter traction material (sand) used on the major traffic arteries and throughout the rest of the City of Williams Lake is also a significant source of fine particulate in the late winter/early spring months (Plain , 2003). This ground up material is re-entrained by traffic once the ice and snow melts. Another mobile source that has the potential to influence PM_{10} levels in the downtown area is the railway. The mainline runs along the south side of Williams Lake and exits the Airshed along the Williams Lake River to the West. The Rail yard is located at the west end of Wiliams Lake itself (behind Candian Tire). Locomotives are a source of diesel particulate, NO_X, and fugitive dust.

Further details on the level of emissions and types of sources of pollution in the Williams Lake Airshed are provided in Plain 2001.

3 AIR QUALITY METEOROLOGY

In order to understand air quality, an understanding of the state of the atmosphere is necessary. For example, elevated ambient particulate levels coincident with calm or very light wind speeds may be indicative of local pollutants accumulating near the point of origin (e.g. wood stove smoke, road dust and automobile exhaust). The same levels of particulate associated with a moderate wind may well indicate transport of pollutants from a source outside of the local area (e.g. forest fires, open burning, industrial emissions, etc.). The likely source of elevated particulate levels during a strong wind event may be wind blown soil particles.

Calm (wind speeds less than 1 meter/second (m/s)) and light wind conditions are generally associated with a stable atmosphere and either elevated (e.g. frontal, etc.) or ground-based inversions. In Williams Lake, as in other interior communities located in river valleys, ground-based nocturnal or radiation inversions occur with the greatest frequency. These temperature inversions (when temperature increases with height above ground) are associated with a climatological process known as radiative cooling. At nightime, the heat energy that the earth receives from the sun during the day is radiated back to space as long-wave radiation. As the ground cools, the air in immediate contact with it also cools and mixing extends this cooling upward, creating the nocturnal inversion. The inversion deepens over the course of the night and may reach its maximum depth just before sunrise. Light winds, cloudless skies and long nights (winter) favor the development of deep, strong radiation inversions (Angle and Sakiyama, 1991).

The topography in the Williams Lake area also influences the local meteorology and the pollution potential in the valley bottom. On clear nights the surface air cools on the surrounding hillside slopes in the same manner as described above, and becomes dense. This heavy air flows downhill to the valley floor (similar to the flow of water) displacing the warm air which is forced aloft. These light winds, termed drainage or katabatic winds, are a regular occurrence during clear nights in most mountainous regions of the world (Angle and Sakiyama, 1991). The nocturnal temperature inversion that would already be forming in the valley bottom due to radiative cooling at the surface is intensified by these cold drainage flows. Pollutants released at ground level would tend to travel with these katabatic flows and accumulate in the valley bottom within the inversion layer. In the presence of pollution, these conditions may lead to degraded air quality in the airshed.

Although the term inversion has come to be synonymous with air pollution problems, this is a misleading generalization. In reality the base height, thickness and strength of the inversion relative to the source of pollutants must be considered. For example, a ground-based inversion a few hundred meters thick certainly creates a potential air pollution situation in an urban area where most sources of pollutants are at or near ground level. However, the plumes from even moderately tall stacks can rise above the inversion and disperse in the less stable air above. The ground-based inversion will then effectively block this industrial pollution from reaching the ground. However, with thick ground-based inversions, the plumes from tall stacks may become embedded. Elevated inversions are responsible for reducing the dispersion of plumes from tall stacks. If the base of the inversion lies slightly above the level of the plume, then the volume of air available for dilution is severly limited. The elevated inversion acts as a lid restricting mixing in the vertical, reducing dilution and increasing ground-level concentrations (Angle and Sakiyama, 1991).

High ground-level concentrations (GLCs) of pollutants can also occur during inversion break-up. This phenomenom is known as “fumigation”. Fumigation occurs when daytime solar heating is sufficient to produce a neutral or unstable layer that reaches the height of a pollutant plume that is trapped within the inversion layer. When this happens, the pollutants within this layer are brought to the ground more or less simultaneously along the full length of the plume. This

condition produces high GLCs but only for a short period of time (roughly 30 minutes to a few hours).

3.1 ANALYSIS OF WINDS

Two Meteorological Information Stations (MIS) were operated by the Ministry of Environment (MOE) in the Williams Lake Airshed (Figure 2). One station labeled the Williams Lake Canadian Tire station (Plate 17) is located at the south end of town on the roof of the Canadian Tire building. The station was placed to be representative of the south end of the airshed, to address conditions particular to the lake and the valley orientation at that point. This station is situated just west of the Skyline ambient monitor, and thus provides valuable information for analysis of the monitor. The station was installed in 2001, and measures wind speed, wind direction and temperature.

The other meteorological monitoring point is the Glendale School station (Plate 18). This station is atop the Glendale school at the northwest end of town. It has been measuring wind speed, direction and temperature since 1990 and is considered to be representative of regional winds within the valley.

The Williams Lake Airport station (Plate 19) is located on the airport premises on the Plateau northeast of the town, and east of Pine Valley. The station is not within the main valley itself and winds have a larger southeast component than the valley stations. A data set including cloud cover, relative humidity and precipitation are measured at this station, and Climate Normals for 1961 – 1990 from Environment Canada (Table 2) are available for comparison to individual years to determine whether a particular year could have had better or worse meteorological conditions.

Figure 4 shows the frequency of unit vector wind direction (degrees) and the average wind speed (m/s) at sixteen compass points for 1990 to 2002 at the Williams Lake Glendale station and Figures 5 through 8 show the windroses by season for 2000-2002 for the same station. Each of the seasons (winter, spring, summer, fall) were defined by three months of the year (e.g. Dec, Feb, Jan for winter). This type of plot is collectively known as a windrose. The direction of a “petal” on the rose indicates the direction “from” which the wind is blowing, while the length of the “petal” on the rose indicates its frequency. For example, winds blew from the east at the Glendale meteorological station approximately 12% of the time from 1990 to 2002.

The windroses at the Glendale station shows the influence that the valley topography has on wind patterns. The windroses also show that there is variation in frequencies in wind direction from season to season. In winters, winds from the east south east are predominant, with very few winds from other directions, whereas in summer, westerly winds are predominant, with more frequent winds from the other directions. Spring and fall are more similar to the annual average conditions. The location of the station indicates that the influence of topography at the northwest end of the valley plays a role in direction, and the Glendale station could be considered representative of this portion of the airshed.

Similarly, Figures 9 through 13 shows the frequency and speed distribution for the Williams Lake Airport station for 1990-2002. The Airport station is highly influenced by winds from the southeast, with very few winds coming from other directions. The topography around the Williams Lake Airport is different than Glendale which is more representative of the conditions at the north end of the valley.

Lastly, Figures 14 through 17 shows the windroses at the Williams Lake Canadian Tire location for 2002. There is not enough data measured at this time to determine specific seasonal trends (station installed in June 2002), however, the data that was measured shows a large southeast to easterly component, without the presence of the westerly component that was observed at

Glendale. The orientation of the valley at this station is slightly different than Glendale, and the lake will also influence winds from the east and southeast. Therefore, it is likely that this station will be representative of the south end of the valley.

Wind speeds recorded at the Glendale site from 1990 to 2002 were similar to the Williams Lake Airport measurements, and slightly higher in some years indicated by the Climate Normals. Particularly, it was noted that the summer months at Glendale on average have higher winds than the Williams Lake Airport. This is not entirely unexpected as the Williams Lake Airport data is measured at the lower 10metre height. In the boundary layer, wind speeds commonly increase with increasing height, as the influence of friction and ground level effects lessen.

It should be noted that airport normals are based on a single observation (approximately 1-2 minutes in duration) for wind speed and direction near the end of each hour. The MIS measurements are made every 2 seconds and the data is retained electronically by a datalogger. Airport wind speed sensors also have a higher starting threshold (approx. 2 m/s) than MIS anemometers (0.5 m/s). At the airport, nighttime observations were frequently not observed during the measurement period. The MIS measurements therefore provide a more accurate representation of meteorological conditions than do airport normals observations.

Figures 18 to 20 shows the average temperatures at each of the monitoring site from 1990-2002 (2002 for Canadian Tire). The mean daily temperatures listed in these figures 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. Overall, temperatures observed at all three stations were similar to each other. It was noted that 2002 was a warmer than normal year, particularly, November 2002.

Monthly average scalar wind speeds for 1990-2002 are presented in Figure 21. The lowest mean wind speeds occur in the summer months, and these wind speeds are much lower at the airport than the Glendale station. Conversely, in the winter the airport experiences higher winds. These two stations are influenced by different topography which is evident in this data. Months with higher wind speeds may be expected to generate more dust from roads and other ground level sources (e.g. log yards).

3.2 METEOROLOGICAL TRENDS

The capability of the atmosphere to disperse air pollutants is closely related to wind speed. Generally, as the wind passes the point of a pollutant release, whether from a stack or at ground-level, the pollutant is diluted proportionally to the wind speed. The years/months with the lowest average wind speeds therefore have the greatest potential to have higher than average air pollutant levels.

Table 3 presents annual average mean wind speeds and the percent valid data for the Glendale MIS site from 1990 to 2002. Annual average mean wind speeds at the Glendale meteorological station ranged from a low of 2.34 m/s in 1994 to a high of 2.78 m/s in 1999. Annual average mean wind speeds at the Williams Lake Airport meteorological station ranged from a low of 2.1 m/s in 1995 to a high of 2.7 m/s in 1999. Based on the annual average wind speed data alone, months and years with lower wind speeds (e.g. 1994 and 1995) one would expect higher concentrations of pollutants during those times.

Table 4 presents monthly average mean wind speed information for the Glendale and Williams Lake Airport sites from 1990 to 2002. At the Glendale site, monthly average wind speeds are lower in winter than in summer, while the highest wind speeds are generally recorded during the spring months of March, April and May. Airport normals follow a similar springtime pattern, but

have much lower summer time winds as previously mentioned. At the valley bottom site, lowest monthly average wind speeds are recorded during September, January and August while the highest average wind speeds are recorded in April, May and March.

Figure 22 presents the percent of time that calm winds (wind speeds < 1 m/s) were experienced on an annual basis at Glendale and the Airport sites from 1990 to 2002. The Airport site has a significantly higher frequency of calms than the Glendale site due to the anemometer threshold and location.

A high frequency of calms limits the dispersal of pollutants and promotes thermal stratification or inversion conditions, which trap pollutants near the ground where they can accumulate to high levels. The highest frequencies of calms at Glendale occurred in 1995 (5.3%), 2000 (5.3%) and in 2002 (7.0%). At the Airport, calms occurred most frequently in 1995 (34.6%), 1996 (31.8%), and 2000 (30.0%). Based on this frequency, one might expect that air quality would be worse in 1995 and 2000, than in other years (using both sites as indicators). 2002 indicated relatively higher frequencies of calms at Canadian Tire, which could be a contributing factor to reduced dispersion. However, the percent calms calculation for this site in 2002 is only based on six months of data so this may not be an accurate representation for this area.

Another meteorological parameter that can have an affect on air quality is precipitation. Precipitation events act as a scrubber for most air pollutants and also binds up soil and organic particles on the ground so that they are not available for re-suspension by wind or vehicle movement (dust). Water droplets can also accelerate chemical reactions of pollutants. Table 5 provides a summary of monthly and annual precipitation records from 1990 to 2002 as obtained from the Williams Lake Airport recording station (courtesy of Environment Canada, Climatic Services).

Over the last the twelve year period, the driest years in terms of total precipitation was 1998 (374.5 mm), while the wettest year was 1996 with 630.3 mm. 2001 and 2002 were also particularly dry years. On average, the lowest total precipitation occurs during the late winter/early spring months (February through April) while the highest total precipitation occurs in June, July and the late fall. The driest periods from February to April generally correspond to the months with some of the highest average wind speeds. These conditions are conducive to producing dust events following spring thaw.

4 AMBIENT AIR QUALITY IN WILLIAMS LAKE

This section examines the ambient air quality data collected in the Williams Lake Airshed to the end of 2002. The following parameters air quality parameters are summarized and interpreted: Suspended particulate less than 10 microns in diameter (PM_{10}), suspended particulate less than 2.5 microns in diameter ($PM_{2.5}$), Oxides of Nitrogen (NO_X), Ozone (O_3). Polycyclic Aromatic Hydrocarbons (PAHs) and Metals have also been measured in the airshed for brief periods in the 1990s and are summarized as well.

4.1 AMBIENT AIR QUALITY CRITERIA

In Canada, the federal and provincial governments have issued ambient air quality objectives to ensure long-term protection of public health and the environment. Federal and provincial committees have established national ambient air quality objectives for a number of common pollutants; these include the pollutants that have been monitored in Williams Lake, namely particulate matter less than 10 microns in diameter (PM_{10}) and particulate matter less than 2.5 microns in diameter ($PM_{2.5}$). For Canada, up to three objective values have been recommended using the categories "desirable", "acceptable", and "tolerable". In B.C., Objectives have been established, and are usually the same or more stringent than the federal desirable objective. The general intent of the federal objectives is described in below:

- Maximum Desirable (most stringent) - Long-term goal for air quality. Provides a basis for anti-degradation policy for unpolluted parts of the country and for continuing development of control technology.
- Maximum Acceptable - Provides adequate protection against adverse effects on soil, water, vegetation, materials, animals, visibility, personal comfort and well being.
- Maximum Tolerable - Indicates appropriate abatement strategies required without delay to avoid further deterioration to air quality to protect the health of the general population. Source (ECO-LOG Canadian Pollution Legislation).

Parameter	British Columbia Objective		Federal Objective	
	Level A* ($\mu g/m^3$)	Level B* ($\mu g/m^3$)	Maximum** Desirable ($\mu g/m^3$)	Maximum** Acceptable ($\mu g/m^3$)
Nitrogen Dioxide (NO_2)	-	-	-	-
1-hour Maximum	-	-	-	400
24-hour Maximum	-	-	-	200
Annual Mean	-	-	60	100
PM_{10}	-	-	-	-
24-hour Maximum	-	50	-	-
Ozone (O_3)	-	-	-	-
1-hour Maximum	-	-	100	160
24-hour Maximum	-	-	30	50
Annual Mean	-	-	-	30

* Concentrations given at 20ºC, 101.3 kPa, dry basis
** Concentrations given at 25ºC, 101.3 kPa, dry basis
Source: British Columbia Ministry of Environment (http://www.env.gov.bc.ca/air/airquality/pdfs/aqotable.pdf)

In June of 2000, the Canadian Council of Ministers of the Environment endorsed new Canada-Wide Standards (CWS) for particulate matter and ozone (CCME 2000). The development of the CWS took place under the auspices of the Canadian Environmental Protection Act (CEPA). These standards supplement and complement the existing air quality objectives described above. The CWS for PM and ozone actually outlines a two-pronged approach to air quality management by setting out both a numeric standard for areas over 100,000 in population and a requirement for Continuous Improvement (CI) and Keeping Clean Areas Clean (KCAC) in areas where ambient levels of PM and ozone fall below the numeric standards.

The numerical standard for particulate matter is for $PM_{2.5}$ (PM_{10} was not specified) and is 30 µg/m^3 based on a 24-hour averaging time (98th percentile averaged over three consecutive years). The Canadian standard for ozone is 65 ppb (127.6 µg/m^3), based on an 8-hour averaging time (4th highest measurement annually averaged over three consecutive years). This compares with the existing acceptable ambient air quality objective for ozone over a 1-hour averaging period of 82 ppb (160 µg/m^3). Both new Canadian standards have a target compliance date of 2010. The latter requirement in the standard is known as Annex A. Definitions, applications, and a common national understanding of the concepts of CI/KCAC are currently being developed at the national level to implement and provided guidance on achieving CI/KCAC.

The Federal and Provincial governments have agreed that the Canada Wide Standards (CWS) are appropriate guidelines from which to base air quality. However, reference Levels have been presented for each of PM_{10}, $PM_{2.5}$ and O_3 to provide a secondary benchmark from which to compare ambient concentrations. The reference levels are based on the Addendum to the Science Assessment Document: National Ambient Air Quality Objectives for Particulate Matter (1999) and for Ozone (1999). The approach taken to identify a comparison level for these pollutants is that of the lowest observed adverse effect level (LOAEL).

The LOAEL's identified for PM_{10} and $PM_{2.5}$ are 25 µg/m^3 and 15 µg/m^3 respectively, based on a 24-hour averaging period. This is a "health based level at which statistically significant adverse effects on human health can be detected". In the case of ozone, two LOAEL's have been identified. For non-accidental mortality, the level is 20 ppb (39.3 µg/m^3), and for respiratory hospitalization it is 25 ppb (49.1 µg/m^3), both based on the daily maximum 1-hour average concentration. Naturally occurring ozone concentrations frequently exceed these levels.

In order to get a sense of the magnitude of the measured ambient concentrations of PAHs and metals, a comparison with guideline values is normally conducted. However, B.C. and Federal ambient air quality objectives and guidelines do not exist for PAHs. Some jurisdictions have developed standards for ambient concentrations of metals and a summary is provided here.

The Texas Natural Resource Commission's (TNRCC) Effects Screening Levels (ESLs) and the Ontario Point-of-Impingement are both jurisdictions that have developed guidelines. The Texas ESLs were developed with the consideration of natural background levels. For short-term periods, they are lower than the Ontario points-of-impingement. The maximum ambient measurements for each of the individual metals and PAHs were compared with the more stringent guideline from these two jurisdictions.

4.2 PARTICULATE MATTER

Total suspended particulate (TSP) matter refers to airborne solid and liquid particles, except pure water, that are microscopic in size, ranging size from 0.005 µm (micrometers) to 100 µm in diameter (CEPA/FPAC, 1999). These particles vary in chemical composition, size and shape, depending on the source. Suspended particles can originate from natural sources such as foliage, which emits pollen; wind, which entrains dust and soil particles; and volcanoes and forest fires, which produce soot. Anthropogenic sources of suspended particulate matter include home

heating devices, automobiles, open-burning, and industrial processes. Particles larger than 10 µm, such as flyash, settle out of the air relatively soon after being emitted. Particles less than 10 µm (PM_{10}) can remain suspended in the atmosphere for long periods of time and can travel great distances from the emission source, depending on the nature of the source and the meteorology.

Large suspended particles may cause a nuisance or irritation problem; however, fine particles (less than PM_{10}) have a greater effect on human health because they are inhaled deep into the lungs. Various health and medical studies have found that exposure to increases in PM_{10} concentration is associated with increased incidence of respiratory illness (e.g. bronchitis, asthma, pneumonia, emphysema), decreased lung function, and mortality from lung and heart disease (Vedal, 1993, 1995; Pope, 1991; Pope et al., 1992; Koenig et al., 1993; CEPA/FPAC, 1999). Individuals with chronic obstructive pulmonary or cardiovascular disease, asthmatics, the elderly, and children are most at risk. The main effects of particulate matter on vegetation are reduced growth and productivity due to interference with photosynthesis, and phototoxic impacts as a result of particle composition.

Fine particulate matter is diverse and includes primary particles (which are emitted directly by a source) and secondary particles (which are formed in the atmosphere by emitted substances). Primary particles do not change significantly after being emitted from a source. Secondary particles can be formed by: reactions between gas molecules to form new particles, coagulation of two particles to form one larger particle, and gas-particle interactions in which gases are adsorbed and absorbed onto existing particles (CEPA/FPAC, 1999). These reactions involve precursor gases such as sulphur dioxide (SO_2), oxides of nitrogen (NO_x), and volatile organic compounds (VOCs).

Fine particulate matter less than 10 microns in diameter (PM_{10}) is divided into a coarse and a fine fraction because particles in each of these fractions generally differ in chemical composition, source, formation process, and behavior in the air. The fine fraction ($PM_{2.5}$) includes particles 2.5 micrometers (µm) in diameter and smaller. In general, this size fraction is composed mainly of primary and secondary combustion source particles (soot), although some mechanical grinding processes can also produce particles in this size range (e.g. road dust). $PM_{2.5}$ particles are thought to have greater impacts on human health than coarser particles because of their ability to reach the deepest regions of the lungs. $PM_{2.5}$ is also very efficient at scattering/absorbing light, which can cause a visible regional haze.

The coarse fraction of PM_{10} includes particles between 2.5 and 10 µm in diameter. This size range is typically associated with particles derived from the earth's crust, and with grinding and mechanical processes; it also includes other natural particles such as spores, fibres and cells (Plain and Carmichael, 1998; CEPA/FPAC, 1999). The chemical and physical composition of PM_{10} varies with location, time of year and meteorology.

4.2.1 Instrumentation

In the Williams Lake Airshed, PM_{10} is measured using both non-continuous and continuous methods. The non-continuous methods involve the use of either a Partisol sampler or a high volume sampler (HiVol). PM_{10} is measured by drawing air (at a rate of 1.13 m^3/minute, in the case of the HiVol instrument) through a size selective inlet prior to collection on a Teflon coated glass fibre filter. The sampler is operated for 24 hours at a time on a 6 day cycle (i.e. once every six days) and the results are available at a later date due to the time required for lab processing and analysis. The minimum detection limit using this method is 2 µg/m^3.

The continuous method involves the use of Tapered Element Oscillating Microbalance (TEOM) technology. This technique involves the measurement of mass collected on a filter which is

seated on one end of a tapered glass element. The instrument calculates mass by monitoring the changes in the oscillating frequency of the element as the filter loads. This method provides more useful data for the purpose of quantifying temporally the air quality of Williams Lake because the gaps of the HiVol PM_{10} sampling schedule are eliminated. In addition, the TEOM allows monitoring of air quality on a real-time basis via modem and personal computer. The minimum detection limit of the TEOM monitor is 5 $\mu g/m^3$.

The results from each of these types of monitoring in the Williams Lake airshed are described in the subsequent sections.

4.2.2 Monitored Parameters

Continuous PM_{10} observations were initiated in December of 1992 at the Columneetza School site (Plate 20, Figure 2) and in August of 2001 at the Skyline site with TEOM samplers (Plate 21). The Columneetza site is situated at the south end of the school field to the east of the Glendale industrial area, where many of the large particulate matter sources are situated. The station can be considered to be representative of a residential area. The Skyline site is situated at the south end of town, just west of the lake, and east of Highway 20. In terms of commercial/industrial sources surrounding the site, Skyline is to the south and south east of the B.C. Rail yard, west of the Jaco chipping operation (intermittent operation in 2002), and east of the Lignum and Riverside sawmill/planer mill operations. Cyclone emissions from Parallel Wood products is to the south of the site and a United Concrete gravel processing and stock pile operation is also to the south and southeast. This site is considered to be representative of a commercial area.

The non-continuous PM_{10} observations were initiated in November of 1990 at the Firehall site (Plate 22) (ending in January of 2002), which is downtown/residential. Also at the Firehall site, non-continuous PM_{10} observations using a Partisol sampler were initiated in April of 2001; thus there was an overlap from April 2001 to January 2002, during which PM_{10} was observed at the Firehall site using both a HiVol and a Partisol sampler. Other non-continuous PM_{10} observations discussed in this report include the period of March of 1992 to January 2002 at the Skyline site, November of 1995 to present at the Watertower site (Plate 23), and December of 1997 to present at the 168 Mile Road site (Plate 24), all with HiVol samplers.

Continuous $PM_{2.5}$ observations were initiated in January of 2001 at the Columneetza site and in August of 2001 at the Skyline site with TEOM samplers. Non-continuous $PM_{2.5}$ observations were initiated in September of 1994 at the Columneetza site (ending in December of 2000, when the TEOM sampler was installed), and in April of 2001 at the Firehall site (Partisol).

4.3 Non-Continuous PM_{10} Data

The PM_{10} results were compared to the British Columbia Air Quality Objective for PM_{10} of 50 $\mu g/m^3$ and the CEPA health reference level for PM_{10} of 25 $\mu g/m^3$.

From 1990-2002, PM_{10} concentrations were observed using a HiVol sensor at the Firehall site. These observations are summarized in Table 6. The first available full year of observations, 1991, had the highest annual mean concentration (34.5 $\mu g/m^3$), and the data showed a definite downward trend from then until 2001, the last full year of observations (Figure 24). On average, February and March had the highest concentrations and the bulk of exceedances occurred during these months. From 1990-1996 (Figure 25), the data at the Williams Lake Firehall site showed distinct peaks in late winter and late summer/early fall, but from 1997-2002 (Figure 25), no meaningful pattern was evident aside from the February/March peak and wintertime minimums. The late winter/early spring peaks correlate well with observations of road dust impacts throughout the community prior to street sweeping activities (Plain, 2003). Street

sweeping generally begins in the community after the threat of snow has passed and new traction material applications won't be required.

Both the average monthly concentrations and the frequencies at the Firehall site improved after the phase out of the burner operations. The average 24-hour concentration was 27.92 $\mu g/m^3$ from 1991-1995, and 24.3 $\mu g/m^3$ from 1996-2001. At the Firehall site, the health reference level was exceeded on average 43.73% from 1993-1995 and 37.14% from 1996-2001. The 24-hour objective was exceeded 13.37% from 1993-1995 and 6.18% from 1996-2001. For the period of data collected, Firehall did show a downward trend of the frequency of exceeding the 24-hour objective (Figure 27), however there was no distinct consistency in improvement in the frequency above 25 $\mu g/m^3$ (See Table 6). In fact, 1998 had the highest frequency above the health reference level at 52.6%.

Also at the Firehall site, PM_{10} was measured using a Partisol sampler (Table 7). These data were compared with the HiVol data (Figure 23). Agreement between the two instruments was quite good, with a linear regression of the scatterplot producing an r^2 value of 0.9. In general, at concentrations from 5 $\mu g/m^3$ to 45 $\mu g/m^3$, the HiVol instrument tended to give slightly lower readings than the Partisol instrument ranging from 1 $\mu g/m^3$ to 4 $\mu g/m^3$.

From March 1992- December 2001, PM_{10} concentrations were observed using a HiVol sensor at the Skyline site. These observations are summarized in Table 8. The second full year of observations, 1994, had the highest annual mean concentration (34.1 $\mu g/m^3$), and the data showed a definite downward trend from then until 2001, the last full year of observations (Figure 24). The negative slope on the trendlines in the figure are indicators of the downward trend. On a monthly basis (Figure 25 and Figure 26), the data fluctuated somewhat erratically, but in general concentrations were higher in summer and lower in winter due to the binding effects of ice and snow on the coarse fraction of PM_{10}. Like the continuous PM_{10} data, the non-continuous data indicated that the Skyline site tended to have higher concentrations than other sites.

The frequency of concentrations above 25 $\mu g/m^3$ (39.8%) and 50 $\mu g/m^3$ (10.4%) was also higher at Skyline when compared with the other sites (Firehall - 36.7%, 168 Mile - 24.6%, and Watertower 10.4%). For the period of data collected, Skyline did show a downward trend of the frequency of exceeding the 24-hour objective (Figure 27), however, similar to Firehall, there was no distinct improvement in the frequency above 25 $\mu g/m^3$ (See Table 8). Prior to 1995, the frequency above 50 $\mu g/m^3$ was 15.1% and post 1995 was 7.2%.

From December 1995-present, PM_{10} concentrations were observed using a HiVol sensor at the Watertower site. These observations are summarized in Table 9. The third full year of observations, 1998, had the highest annual mean concentration (17.1 $\mu g/m^3$), and the data showed a definite downward trend from then through 2002 (Figure 24). Each year, concentrations at the Watertower site were lower than at any other site. On a monthly basis (Figure 26), the concentrations were fairly constant, and were consistently lower than at any other Williams Lake site. This particular site is likely to be "cleaner" than the other PM_{10} monitoring locations in the Airshed, as it is buffered from most residential activity by trees but is open towards the Glendale industrial area. Road dust impacts would be very minimal at this site as evidenced by the lack of a spring peak in PM_{10} levels.

From December 1997-present, PM_{10} concentrations were observed using a HiVol sensor at the 168 Mile Road site. These observations are summarized in Table 10. The first full year of observations, 1998, had the highest annual mean concentration (22.9 $\mu g/m^3$), and the data showed a downward trend from then through 2002 (Figure 24). The 168 Mile Road data showed essentially the same annual pattern as the Watertower data, but with absolute values about 5 $\mu g/m^3$ higher than the Watertower site. Each year, concentrations at the 168 Mile Road site

were lower than at the Skyline and Firehall sites. On a monthly basis (Figure 26), the concentrations varied, with a maximum occurring in February. Monthly average concentrations were usually lower than at the Skyline and Firehall sites.

In summary, the Skyline and Firehall monitoring sites experience the highest annual average PM_{10} values and the highest frequency of exceedances of all the non-continuous monitoring sites in the Williams Lake Airshed (Figure 27) From 1992 to 1995 the 24-hour rolling average concentrations from all non-continuous monitors in the airshed were above 25 $\mu g/m^3$ on average 43.92% of the time, while from 1996-2002, they were above 26.05% of the time on average. A similar pattern was observed for frequencies above the 24-hour objective of 50 $\mu g/m^3$ - from 1992 to 1995, 14.06% of the time, and an average of 4.26% from 1996-2002. Monthly minimum PM_{10} concentrations occurred during the winter months at all monitoring locations.

The largest single change in emission sources prior to 1996 was the phase-out of all beehive burners in the airshed between December 1992 and December of 1995. In addition, the City of Williams Lake instituted a back yard burning policy in the spring of 1998 (but possibly as early as 1997 – Plain, 2003) that eliminated backyard burning within city limits. Other factors such as changes in residential heating practices in the vicinity of the monitoring stations and variability in meteorology (wind speed, direction, precipitation, etc.) also may have influenced these trends.

4.4 CONTINUOUS PM_{10} RESULTS

The continuous PM_{10} results were compared to the British Columbia Air Quality Objective for PM_{10} of 50 $\mu g/m^3$ and the CEPA health reference level for PM_{10} of 25 $\mu g/m^3$. Tables 11, 12, and 13 summarize the 2001-2002 continuous PM_{10} results as collected by TEOMs at Skyline. The following was observed:

- The annual average PM_{10} concentration ranged from 27.0 to 29.3 $\mu g/m^3$ (based on 5 months of data in 2001) from 2001-2002.
- The provincial 24-hour ambient Objective for PM_{10} was exceeded on average 680 times (12.0% of the time) from 2001-2002 based on a rolling 24-hour average.
- 2001 was above the average while 2002 was below the average, at 10.0% of the time. Note that 2001 data are only available from August to December, which could lead to lower observed concentrations, since the highest concentrations of the year are usually observed during the spring months; this expected decrease was not observed in 2001, implying that either August to December of 2001 had particularly high concentrations, or 2002 had particularly low concentrations. One significant source of particulate matter in the area (the Jaco Chipping operation) was operating in 2001 but only operated intermittently in 2002.
- The month during which concentrations were most often above 50 $\mu g/m^3$ was August 2001, when stable, warm conditions, which are conducive to dust generation, prevailed. April 2002 had the second highest frequency of concentrations above 50 $\mu g/m^3$; generally February, March and April have been observed to be primarily associated with dust episodes, which are exacerbated by stagnant meteorological conditions.
- The November percentages show that a secondary peak in concentrations occurred in late fall, both in 2001 and 2002, with concentrations above 50 $\mu g/m^3$ an average of 16.4% of the time. The dry November of 2002 was also noted to have particularly high particulate concentrations across the province.
- 24-hour concentrations were above 100 $\mu g/m^3$ in August and November of 2001, and May 2002.
- On average Skyline continuous PM_{10} levels were above the health reference levels 44.1% of the time in 2001, and 44.3% of the time in 2002.

- There was not a single observed month when a 25 $\mu g/m^3$ 24-hour level was not exceeded.
- The months of January and February had the fewest frequencies above the reference levels. Frozen ground during these months reduces the amount of available dust for lift into the atmosphere.

Tables 14 through 25 summarize the 1992-2002 continuous PM_{10} results as collected by TEOM at the Columneetza School site. The 1992 data were included in the tables for completeness, however, only two weeks of observations were made (in December 1992), and they were excluded from the analysis below.

- The annual average PM_{10} concentration ranged from 16.5 to 22.8 $\mu g/m^3$ from 1993-2002. These concentrations are much lower than the Skyline site.
- From 1993 to 1995 the average annual concentration was 21.8 $\mu g/m^3$ while from 1996-2002 annual average concentrations were lower at 18.1 $\mu g/m^3$, with the lowest observed in 2001, 16.5 $\mu g/m^3$.
- Rolling 24-hour concentrations were above 100 $\mu g/m^3$ only in 1996, during February, March and August.
- From 1993 to 2002, PM_{10} values exceeded the Level B Objective (50 $\mu g/m^3$) in each month of the year.
- The number of occurrences above the Level B Objective ranged from 3 times (0.04%) in 2001 to 351 times (5.7%) in 1996. A dramatic decrease in the percent of time that the ambient objective level was exceeded on an annual basis is evident. From 1993 to 1996 the ambient objective was exceeded between 3.5 and 5 percent of the time while the period from 1997 to 2002 exceeded levels in the range of 0.5 to 1.9 percent of the time. However, it should be noted that even concentrations exceeding guidelines one percent of the time equates to 3.65 days of the year when air quality is considered Poor in the area.
- On a monthly basis the concentrations exceeding ambient objectives experienced during the winter months and into early spring have been reduced significantly since 1996. Again, burner phase-out would have a bearing on exceedances experienced during these periods as dispersion is typically poor during the winter months. It is interesting to note that the fall peak has not changed over the same period. This may be attributable to open burning activities after the first snow fall.
- The impacts of spring time road dust at this site were clearly evident, and most years showed a second PM_{10} peak in late summer/early fall (i.e. August-October), often in September.
- The health effects level of 25 $\mu g/m^3$ was exceeded from 14.3% to 34.8% of the time from 1993-2002. From 1993 to 1995, the health effects levels were exceeded on average 30.4%, compared with an average of 19.6% from 1996-2002. This strongly indicates that the phase-out of the burners improved air quality in the airshed.

In January and February 2002, the health effects level was exceeded about as frequently at Skyline as at Columneetza. For every other month in 2002, the health effects level was exceeded about twice as often at Skyline as at Columneetza. This is not entirely unexpected because Skyline is surrounded by a large number of anthropogenic particulate matter sources.

Figures 28 to 30 show the fraction (%) of available midnight to midnight 24-hour block averages of PM_{10} concentration that were above 50 $\mu g/m^3$ at the Skyline (2002) and Columneetza (1993-2002) sites and the monthly total precipitation at the Williams Lake airport, combined with the fraction of simultaneously available hours of wind speed observations that were below 1 m/s. Wind data for comparison with Skyline PM_{10} were obtained from the Canadian Tire meteorological station; for Columneetza, Glendale meteorological data were used. The data show the following:

- At the Skyline continuous monitoring site, months with higher precipitation did not necessarily correspond with the lowest PM_{10} frequencies above 50 $\mu g/m^3$; however, it is not advisable to draw conclusions about such trends from only six months of data.
- At the Columneetza site, several instances of high precipitation coinciding with low PM_{10} frequencies above 50 $\mu g/m^3$ were observed, Prior to 1996, the highest concentrations were observed during driest conditions, but subsequently the precipitation appeared to play less of a role. With the phase out of the plumes from burners, other ground based sources are likely contributing more significantly, that are not as affected by precipitation.
- At the Columneetza site, the months of March with more precipitation had fewer concentrations exceeding the objectives, although again, counter-examples were numerous, suggesting that, compared with variations in precipitation amounts, the phasing-out of bee-hive burners in 1995 was a more significant factor in reducing PM_{10} concentrations.
- Calm winds did not correlate strongly with more frequent values above the objective, although in some instances, months with more calms tended to have more PM_{10} concentrations above the objective. Calm winds are conducive to local atmospheric accumulation of emitted particulate matter from sources such as combustion, but high wind speeds favour entrainment of dust. These offsetting factors may be a reason for the weak correlation between calm winds and PM_{10} concentration.
- It was noticed that the month of October 2002 at Skyline had particularly calm wind speeds with no exceedances of the Level B objective. The mean wind speeds at all of the meteorological stations were lower than normal (2.09m/s at Glendale – 0.6m/s lower than normal), 1.45m/s at Williams Lake Airport – 1.1 m/s lower than normal, and 1.5m/s at Canadian Tire (no “normal” averages are available for this site yet). This potentially indicates that sources that are affected by winds (e.g. road dust) could be significant contributors to that site.
- Spring-time road dust, and dust from other ground level sources (e.g. log yards) was likely the main cause of elevated PM_{10} during the months of February and March.
- Ice and snow pack during the late winter, early spring months likely had a stronger influence on concentrations than did calm wind conditions.

A pollution rose can show the frequency and direction from which higher ambient concentrations may occur. PM_{10} roses were created for each of the continuous monitoring sites for when concentrations were above 5 $\mu g/m^3$. PM_{10} pollution roses are presented for the Skyline site for 2002, using wind direction data from the Canadian Tire site (Figures 31 to 34). High hourly average PM_{10} concentrations were recorded in association with winds from all directions, because there are numerous sources surrounding the site. However, the highest frequency of values over 50 ug/m3 occurred when winds were either from the east (mobile sources on South Lakeside, B.C. Rail, unpaved truck shop yards (dust and mud tracking to S. Lakeside), Jaco chipping operation (fugitive dust, tracking onto S. Lakeside), residential emissions), or from the west to northwest sector (mobile sources on Hwy 20 and Hodgson Road, Riverside and Lignums operations - mud tracking onto Hwy 20, log yard dust). High frequencies of lower concentrations come from the vicinity of the United concrete gravel/sand stock piles to the southeast of the monitoring site. The Parallel wood products cyclone emissions (located to the south of the site) also have a demonstrated impact.

PM_{10} pollution roses are also presented for the Columneetza site, for 1992-2002, using wind direction data from the Glendale site (Figures 35 to 41). The highest frequency of elevated hourly PM_{10} values occurred when winds were from the west-northwest, where the Glendale industrial area is located. From 1992-1995 the bee-hive burners in this area (Figure 3) would have a significant impact out of this sector, although it is not entirely evident from the pollution roses. Since burner phase-out, the remaining buoyant plumes from this area that would contribute the most to PM_{10} impacts at Columneetza are mainly from the Weldwood Plywood

Plant. Other high values were experienced when winds were from the east-southeast; this may have been due to mesoscale recirculation of pollutants originating to the northwest or south-southeast of Columneetza. A large residential area is located in this sector as are main arterial roads. The local meteorology frequently has winds coming from the east, so this pattern is not entirely unexpected.

4.4.1 Annual Continuous PM_{10} Monitoring Trends

Tables 11 and 14 previously provided annual average statistics for the Skyline and Columneetza monitoring sites, beginning when continuous PM_{10} monitoring began at the respective sites.

Figure 42 shows the annual average concentrations, 24-hour maximum concentrations and the 24-hour 75th and 95th percentiles for the Columneetza site from 1993-2002. A similar figure was not provided for the Skyline site because only one full year of continuous PM_{10} data were available at that location. The peak annual average PM_{10} concentrations at Columneetza occurred in 1993 and 1995; 1999 and 2001 had the lowest 24-hour maximum concentrations. The 95th and 75th percentiles did not fluctuate significantly from year to year, but a decline was noticeable from the phase out of the wood waste burners. It was noted that the 95th percentile increased from 1995 to 1996; the fact that the burners were phased out prior to 1996 gave reason to expect a decrease. Table 14 shows that annual averages remained fairly constant in those years and Figure 35 shows that the 75th percentile values actually decrease from 1995. This could indicate that 1996 experienced poor dispersion for short periods of time that had an effect on the magnitude of the maximum values but little effect on the overall average. Other events that may have had an effect on the 1996 fine particulate levels include large forest fires in the Stein River Valley and in Washington State that resulted in smoke blanketing most interior valleys for periods of time in August. In addition, the snow fall in the winter of 1995 was heavy. This resulted in increased traction material being applied to city streets. Subsequently, an early thaw and very dry conditions in February resulted in large road dust impacts.

Table 26 presents statistical trend analysis for Columneetza. Trends in the annual mean, 75th, 95th and 98th percentile 24-hour average values were calculated and then tested for significance. The trend showed consistent improvement for all four variables (negative slope), and statistical analysis indicated that this downward trend was significant at $p<.05$.

4.4.2 Monthly Variations in Continuous PM_{10} Data

Particulate matter concentrations vary according to season, day of the week (hebdomadal), and time of day (diurnal). Meteorological conditions in combination with variations in emissions on many different time scales contribute to these temporal patterns. In order to discern seasonal trends, continuous PM_{10} measurements are summarized on a monthly basis.

For the Skyline PM_{10} data (2001-2002), Figure 43 shows monthly variations in average concentrations, 24-hour maximum concentrations and the 24-hour 75th and 95th percentiles of concentrations; Figure 44 shows the same for the Columneetza PM_{10} data (1992-2002).

The block averages for 1993-1995 and 1996-2002 in Figures 45 through 47 reflect the improvements in concentrations due to the phase out of the burners in the early 1990s. This is particularly noticeable in the winter and early spring months.

Seasonal trends were apparent at Columneetza, with the highest concentrations typically occurring in the spring and the lowest concentrations occurring in summer and winter. A secondary peak was observed during fall. The approximately 1.5 years of data from the Skyline site did not exhibit the same trends as the 11 years of data from the Columneetza site, although as at Columneetza, there was a minimum at Skyline during winter. The non-winter months at

Skyline showed no distinct PM_{10} pattern owing to the large number of sources in the vicinity of the monitoring site. Monthly concentrations fluctuated somewhat, and were consistently higher in the non-winter months. Throughout the non-winter months values were consistently higher than those recorded at Columneetza.

The low winter values recorded at both sites occur when the coarse fraction of PM_{10} (e.g. road dust) is bound up in ice and snow and photochemical activity and vegetative emissions are at an annual low. In addition, nights remain cold at this time of the year and home heating contributions add to the total loading in the airshed under stable night time inversion conditions. Dispersion meteorology also remains relatively poor at this time of the year and industrial emissions would have a greater impact. However, because the mean PM_{10} values for December and January are much lower, it can be surmised that it is the coarse fraction material, which becomes available following spring thaw that drives the PM_{10} numbers in the spring. As discussed previously, road dust is believed to be an important contributor to coarse fraction PM_{10} concentrations in the late winter/early spring months (Plain, 2003).

4.4.3 Diurnal Variations of Continuous PM_{10} Data

For the Skyline PM_{10} data (2001-2002), Figure 48 shows diurnal variations in average concentrations and the hourly 75th, 95th, and 98th percentiles of concentrations. Figure 49 shows the same for the Columneetza PM_{10} data (1992-2002).

From 7:00pm through midnight to 6:00am, hourly PM_{10} concentrations at Skyline were similar both in variation and absolute magnitude to those at Columneetza. From 7:00am until 6:00pm, however, data from the two sites contrasted sharply. At Skyline the plot of the mean PM_{10} concentration described a unimodal curve, increasing gradually from a minimum at 3:00am to a maximum of 46 $\mu g/m^3$ at 4:00pm, and decreasing gradually from then through midnight, to 3:00am. At Columneetza the same plot was a bimodal curve, with maxima at 8:00am and 7:00pm, and with daytime absolute concentrations approximately half their corresponding values at Skyline.

Meteorological patterns and human activity, especially variation in traffic volumes, were both likely to have affected the diurnal variations of PM_{10}. Effectively, the Skyline site is surrounded by anthropogenic PM_{10} sources. The trend of increasing concentrations during the daytime period indicates that these sources have a significant localized effect - concentrations continue to increase even though atmospheric mixing conditions are the best during the afternoon hours and concentrations should be decreasing as a result. Impacts are likely related to the level of activity at each of the nearby industrial and commercial sites throughout the day. The afternoon peak could occur as a result of when both industrial and local vehicle activity (on Hwy 20 and on South Lakeside) combined to create peak emissions (industrial, dust, mobile, commercial, etc.) at that time. At Columneetza the diurnal behaviour of PM_{10} appeared to be driven by the morning and evening rush hours, with peaks at 8:00am and 7:00pm. The time lags of the evening PM_{10} peak occurring slightly later than the evening rush hour, may have been a combined function of atmospheric accumulation of road dust and the beginning of the formation of the nocturnal boundary layer.

Figure 50 shows the diurnal block averages from 1993-1995 and from 1996-2002 at the Columneetza site. There is a noticeable improvement in the diurnal concentrations between these two periods, particularly during the periods of inversion break-up. This reflects the improvements in air quality due to the burner phase out in the early 1990s.

Seasonal diurnal patterns for average hourly PM_{10} concentrations are presented for the Skyline (2001-2002) and Columneetza (1992-2002) monitoring sites in Figures 51 and 52. At Skyline, the spring and fall curves were similar to one another, while the summer curve showed significantly higher absolute concentrations, and the winter curve was lower. The relatively low

winter values are likely due to snow and ice cover, combined with generally lower wind speeds both of which would have reduced the rate of dust entrainment. Conversely, the relatively high summer values may have been due to the ready availability of particulate matter on paved and unpaved road surfaces, combined with faster winds which are more able to entrain dust during dry periods.

At Columneetza, the rush hour PM_{10} peaks were present in all four seasons, but in winter they were less developed; concentrations did not decrease in the middle of the day, but rather increased steadily from the morning to the evening peak. This was perhaps due to the slower winds and decreased precipitation amounts that characterize winters in Williams Lake; the absence of wind and precipitation would reduce the flushing of particulate matter from the atmosphere. This line of reasoning is tenuous, however, because generally anthropogenic atmospheric phenomena, such as urban heat islands, are most distinct in the absence of precipitation and strong winds. Another possible explanation for the relatively high midday PM_{10} concentrations in winter is that the mixing layer was shallower and less vigorous than in other seasons, reducing the midday dilution of pollutants.

Again, it is evident that sources around the Skyline site have a significant localized impact in all seasons. As expected, summertime PM_{10} levels at Columneetza decline during the day due to surface heating and increased mixing heights. This is not the case at Skyline. Emissions in the vicinity of the monitoring site overwhelm the atmosphere's ability to disperse them even during the best mixing periods of the year.

4.4.4 Hebdomadal Analysis of Continuous PM_{10} Data

Anthropogenic or "man-made" factors affect the cycles of pollutant concentrations on a number of time scales but it is generally difficult to make a direct link between cause and effect. If present, the cycle that can most readily be ascribed to anthropogenic cases is the hebdomadal cycle (CEPA/FPAC, 1999). Given a large enough data set, geophysical conditions such as mixed layer depth, wind speed and humidity levels should be randomly distributed by day of the week (i.e. no geophysical variable "takes the weekend off"), but emissions patterns may be strongly dependent upon the day of the week (Pryor and Steyn, 1995).

For the Skyline PM_{10} data (2001-2002), Figure 53 shows hebdomadal variations in average concentrations and in the 75^{th}, 95^{th}, and 98^{th} percentiles of midnight-midnight block averages of concentrations; Figure 54 shows the same for the Columneetza PM_{10} data (1992-2002). Figure 55 shows the block average comparison for 1993 to 1995, and 1996 to 2002. Again, this shows the improvements reflective of the burner phase out in the mid 1990s.

PM_{10} concentrations at both sites were influenced by human activity. Weekdays were on average higher than weekends showing that there is an influence of anthropogenic activity at the site. The Skyline values showed more variation than the Columneetza values, presumably because of the longer observation period at Columneetza. Absolute values were significantly higher at Skyline than at Columneetza, as discussed earlier in the PM_{10} section of this report.

The difference between the midweek maximum PM_{10} concentration and the weekend minimum PM_{10} concentration at both sites is presented in Table 27. The differences at the Skyline station for the 75^{th}, 95^{th} and 98^{th} percentile were 55%, 61% and 60% respectively. The differences at the Columneetza station for the 75^{th}, 95^{th} and 98^{th} percentile were significantly lower: 36%, 40% and 47% respectively.

4.5 FINE FRACTION PARTICULATE MATTER – $PM_{2.5}$

In 2001, continuous $PM_{2.5}$ samplers (TEOMs) were installed at two existing continuous PM_{10} monitoring locations in Williams Lake, one at Skyline and one at Columneetza. The continuous data from these stations are analyzed and discussed in this section. $PM_{2.5}$ concentrations are compared against the 24-hour average health reference level of 15 $\mu g/m^3$ (CEPA/FPAC, 1999) even though this value has not been formally adopted nationally or by the province of B.C.. $PM_{2.5}$ concentrations are also compared to the Canada-wide Standard (CWS) for $PM_{2.5}$ (30 $\mu g/m^3$, 24-hour averaging time) which was adopted in June of 2000. Achievement of this standard is based on the 98th percentile annual ambient measurement, averaged over 3 consecutive years.

4.5.1 Non-Continuous $PM_{2.5}$ - Results

Table 28 summarizes the non-continuous $PM_{2.5}$ data collected at the Columneetza site from 1994-2000. Figure 56 shows seasonal concentrations of $PM_{2.5}$ and PM_{10} at the Columneetza monitoring location using the non-continuous data from the fall of 1994 to the fall of 2000. Seasons were defined as follows: Winter – December, January, February; Spring – March, April, May; Summer – June, July, August; Fall – September, October, November. All concentrations were based on paired data with PM_{10} concentrations observed with a TEOM sampler, and $PM_{2.5}$ data coming from a Partisol sampler. In most years, the peak $PM_{2.5}$ concentration occurred during winter and was likely associated with increases in home heating emissions (particularly wood stoves) and mobile emissions (running longer) combined with poor dispersion meteorology that traps industrial emissions. In each year, fall $PM_{2.5}$ concentrations were higher than summertime concentrations. The health reference level of 15 $\mu g/m^3$ was exceeded on average 13.5% between 1994 and 2000. 1994 was the highest year at 29.4%. The Canada Wide Standard of 30 $\mu g/m^3$ was not exceeded during the monitoring period at Columneetza.

Figure 57 presents the percentage of PM_{10} that is $PM_{2.5}$ on a seasonal basis at the Columneetza site from 1994-2000. These calculations were based on paired Partisol $PM_{2.5}$ and daily TEOM PM_{10} values. $PM_{2.5}$ accounted for roughly 30-45% of the PM_{10} mass during spring, but up to 74% of the mass in winter. As was previously mentioned, $PM_{2.5}$ from wood burning makes a much larger portion of PM_{10}, and therefore, these values are somewhat expected.

Table 29 summarizes the non-continuous $PM_{2.5}$ data collected at the Firehall site from 2001-2002. Figure 58 shows seasonal concentrations of $PM_{2.5}$ and PM_{10} at the Firehall monitoring location using the non-continuous data from the spring of 2001 to the winter of 2002-03. All concentrations were based on paired PM_{10} and $PM_{2.5}$ concentrations observed with the Partisol. The winter $PM_{2.5}$ peak and the increase from summer to fall that were observed at Columneetza were also seen in the Firehall data. The health reference level of 15 $\mu g/m^3$ was exceeded on average 8.7% at the Firehall Site in 2001 and 2002. The Canada Wide Standard was not exceeded in any year at either site (Tables 28 and 29).

Figure 59 presents the percentage of PM_{10} that is $PM_{2.5}$ on a seasonal basis at the Firehall site from 2001-2002. These calculations were based on paired Partisol $PM_{2.5}$ and PM_{10} values. $PM_{2.5}$ accounted for roughly 30% of the PM_{10} mass during spring, and up to 59% of the mass in winter.

4.5.2 Continuous $PM_{2.5}$ - Results

Tables 32 through 36 present the summary information for the continuous $PM_{2.5}$ data from 2001-2002 at Skyline and Columneetza. The maximum 24-hour concentrations at both sites were above 30 $\mu g/m^3$ in each year with greater than 75% data capture (Tables 32 and 33). The Canada Wide Standard could not be calculated because only one year of data were available,

however, the 98th percentile of midnight-midnight block averages was 23 μg/m^3 for Columneetza and 20 μg/m^3 for Skyline in 2002. Columneetza also had higher maximum rolling 24-hour average values of $PM_{2.5}$ (31.71 μg/m^3 and 43.96 μg/m^3), than Skyline (28.79 μg/m^3 and 38.29 μg/m^3).

At Skyline and Columneetza, the annual average $PM_{2.5}$ concentrations were similar, ranging from 5.76 μg/m^3 to 6.71 μg/m^3 from 2001-2002.

4.5.3 Monthly, Diurnal and Hebdomadal Variations of Continuous $PM_{2.5}$

Continuous $PM_{2.5}$ data from the Skyline and Columneetza locations in Williams Lake were analyzed for 2001 to 2002. The 2001 data do not include the entire year at Skyline. Figures 60 through 68 show the pollution roses for the two sites. The patterns are similar to the PM_{10} roses, however, as the pollution roses only consist of one or two years of data when compared with the PM_{10} pollution roses, the patterns may be evident of annual variation rather than specific trends or relationships between PM_{10} and $PM_{2.5}$.

Figures 69 and 70 show the monthly variation in $PM_{2.5}$ concentrations at Skyline and Columneetza. The highest mean monthly values were 10.64 μg/m^3 at Skyline, and 12.05 μg/m^3 at Columneetza, both in November 2002 (Tables 34 to 36). These peaks correspond with the PM_{10} episodes that occurred in Williams Lake (and in Quesnel) during November 2002. The variations show higher peaks in winter when home heating becomes a factor; this pattern is significantly more distinct at Columneetza than at Skyline, and is not unexpected as Columneetza is more influenced by residential areas.

Figures 71 and 72 present diurnal variations in $PM_{2.5}$ concentrations at the Skyline and Columneetza sites averaged over the 2001-2002 record. Figures 73 and 74 examine diurnal trends on a seasonal basis.

The diurnal patterns at Columneetza show a slight morning peak in mean through 99th percentile concentrations at 0700 hours, and an similar slight evening peak at 2000 hours. The highest maximum hourly concentrations occur at Columneetza during the morning. A number of factors could contribute to the maximums at these times, including the break-up of the morning inversion, as well as the increase in particulate matter emissions from vehicles and mobile sources, and contributions from road dust kicked up by morning traffic. At Skyline a muted peak occurs at 0800 hours, but essentially concentrations are constant throughout the day and night, with absolute values similar to those at Columneetza. The influence of industry and a major traffic corridor near Skyline is likely the reason for higher and more constant pattern in $PM_{2.5}$ concentrations at that site.

The seasonal analysis of diurnal mean average $PM_{2.5}$ concentrations (Figures 73 and 74) show some interesting similarities and differences between the two sites. The following was noted:

- Both sites experienced a morning peak in average concentrations in all seasons, although the peak was more pronounced (and consistent from season to season) at the Skyline site.
- The spring and summer morning peaks (at 0700 hours), occurred slightly before the winter and fall peaks (at 0800 hours). This suggests that the seasonal peak morning concentrations occurred after the dispersal of the nocturnal inversion. In winter time, the break-up happened later than in summer because it is triggered by sunrise and driven by surface heating.
- The evening peak in concentrations, which was significant at Columneetza and almost absent at Skyline, occurred around 1900 hours in fall and winter (shortly after sunset; the evening peak is likely a function of the formation of the nocturnal inversion), while

summer and spring peaks were not observed until later at night. Atmospheric instability is more common at these times of year which could be a contributing factor.

- The low midday values at Columneetza in summer could in part be due to the higher mixing depths that occur in the late afternoon, allowing for greater dispersion. The reverse would be true for nighttime highs in winter.
- At Skyline, there was little diurnal or seasonal variation in $PM_{2.5}$, with all four seasons essentially the same, and aside from the morning peak, all hours were similar. This also suggests that a continuous source(s) is influencing this site, or conversely no single source is influencing the site over another.
- At Columneetza, there was significant diurnal and seasonal variation in $PM_{2.5}$, with all winter concentrations the highest and summer concentrations the lowest, and with pronounced peaks in the morning and evening; the highest peak was the evening peak in winter.
- The overall patterns indicate that ground level sources such as traffic (fuel combustion and road dust) and home heating in winter likely contribute the most to the variations at Columneetza, although industrial emissions also play a role depending on wind direction.

Weekday (hebdomadal) variations in $PM_{2.5}$ are shown in Figures 75 and 76 for both of the continuous $PM_{2.5}$ monitoring stations. The results are summarized in Table 36. Neither station experienced similar weekly variations in $PM_{2.5}$ and in PM_{10}. For both sites the highest mean and 75^{th}, 95^{th}, and 99^{th} percentile values all occurred on Friday. Generally the $PM_{2.5}$ concentrations showed an increasing trend from Monday to Friday. This was unexpected to a degree, it is hypothesized that the close down or cleaning of particular sources on weekends, may result in the weekend, and start of week low, with a Friday high when emissions from all sources have built up to a maximum. It is evident that traffic patterns and industrial/commercial activity emissions during the week have an influence on ambient concentrations of $PM_{2.5}$. The weekend and early weekday (Monday/Tuesday) lows at Skyline are associated with reduced activity in the downtown area. Emissions are allowed to flush out/settle out during this reduced activity period. Home heating emissions on their own do not appear to be able to sustain the $PM_{2.5}$ levels through the weekend.

The difference between the Friday-Saturday maximum $PM_{2.5}$ concentration and the Sunday-Wednesday minimum at both sites is presented in Table 36. On average at the monitoring stations, mean and 75^{th} percentile $PM_{2.5}$ concentrations during the weekday maximum are 20% and 29% higher respectively than the weekend/early weekday low.

4.5.4 Ratios of PM_{10} to $PM_{2.5}$ from Continuous Data

Figures 77 and 78 show the percentage of PM_{10} that was $PM_{2.5}$ on a monthly basis from the Skyline and Columneetza continuous sampling sites between 2001 and 2002. At both sites, the data showed that $PM_{2.5}$ constituted a larger portion of the PM_{10} data in winter than in other seasons, with the minimum percentages occurring in summer. For example, in December, $PM_{2.5}$ constituted 41.8% and 47.0% of the PM_{10} at Skyline and Columneetza, respectively, and in July those values dropped to 18.3% and 22.1%. This pattern was more consistent at Columneetza than at Skyline; at Skyline there was a peak in May-June as well as in winter, but at Columneetza the monthly variation described a unimodal curve with the peak in winter and the trough in summer. The winter highs could again indicate that wood burning, which compared to other sources of particulate matter produces a large portion of $PM_{2.5}$ relative to PM_{10}, was the main contributor to elevated $PM_{2.5}$ concentrations.

4.6 NOX AND OZONE DATA

Oxides of nitrogen (NO_x) are a mixture of nitrogen dioxide (NO_2) and nitric oxide (NO). High-temperature combustion processes typically emit 94-97% NO_x as NO, with the balance as NO_2. Once emitted, NO reacts rapidly with the oxygen in air to form NO_2.

Elevated concentrations of nitrogen dioxide produces a brownish gas that causes irritation of mucous membranes in the respiratory tract and increased risk of respiratory irritation and infection. NO_2 is an important precursor to ground-level ozone formation through photochemical reactions involving volatile organic compounds (VOCs). NO_2 causes a brown colour in the atmosphere at elevated concentrations and reacts in the atmosphere with ammonia to form fine particulate salts, which reduce visibility and increase $PM_{2.5}$ concentrations.

Ozone is a colourless, reactive oxidant gas that is formed at ground-level from photochemical reactions involving principally NO_x, VOCs and, to a lesser degree, CO. Ozone is one of the main concerns in urban smog because of the adverse effects on human health that can arise from both short-term and long-term exposure to elevated concentrations. Elevated concentrations of ozone can cause respiratory and eye irritation to humans and can damage vegetation and building materials.

Ozone is not emitted from fuel combustion processes, but may form near ground level as a result of photochemical reactions involving ozone precursors emitted from combustion, evaporative, process and natural emission sources as they disperse in an airshed under certain climatic and meteorological conditions. The potential for photochemical formation of ground-level ozone increases as ambient temperatures rise above about 27°C and when there is poor atmospheric ventilation. Ground-level ozone is typically a problem in major urban areas during summer months, often as a result of local emissions. Ozone can also be formed during long-range transport of pollutants, which can lead to health and environmental impacts substantial distances away from the source of emissions. The chemical processes leading to ground-level ozone formation can also lead to formation of secondary fine particulate matter that becomes visually evident as haze.

Ozone is normally present in the troposphere as a result of naturally occurring photochemical and meteorological processes. The principal contributors to background ozone concentrations in the troposphere are downward transport of ozone formed in the stratosphere, and photochemical reactions involving NO_x and gaseous organic compounds emitted from ground level sources (EPA 1996). Ozone may be transported in the troposphere over long distances.

Background ozone concentrations are attributed to ozone from natural processes, as well as ozone associated with human activities and subsequently distributed over large areas by long-range transport in the atmosphere. Concentrations of ozone at ground-level can rise above background levels in a polluted atmosphere as a result of photochemical reactions involving NO_x and VOCs emitted from anthropogenic and natural sources. Generation of ozone from these processes is usually only a concern in summer months during periods of high ambient temperature, high solar radiation and poor ventilation of the atmosphere.

The formation of ground-level ozone is a complex process involving many atmospheric chemical reactions, some of which are not well-understood, together with meteorological processes. NO_x and VOCs are considered to be the main precursors of ground-level ozone formation in atmospheres with pollution. The chemical reactions constituting the nitrogen cycle are well-understood. However, the chemical reactions involving VOCs are not fully understood due to the number of compounds involved and the complexity of the reactions.

The basic chemical processes leading to elevated ground-level ozone involve the photolysis of nitrogen dioxide (NO_2) by near ultraviolet solar radiation (hv) to form nitric oxide (NO) and a ground state oxygen atom O (^3P):

$$NO_2 + hv \Rightarrow NO + O(^3P).$$

The oxygen atom then reacts with molecular oxygen to form ozone (O_3):

$$O(^3P) + O_2 + M \Rightarrow O_3 + M.$$

In the absence of VOCs, NO will react with the produced ozone, converting to NO_2 via the reaction:

$$NO + O_3 \Rightarrow NO_2 + O_2.$$

Under steady state conditions, this simplified set of chemical reactions will not result in a significant build up in the ozone concentration at the ambient NO_2 and NO levels that are typically found in urban or rural air.

In the presence of VOCs, higher ozone concentrations can occur because VOCs react with NO to form NO_2 without destroying ozone. This upsets the equilibrium associated with the NO_x reactions discussed above and can lead to ozone accumulation under favourable meteorological conditions. The details of these chemical reactions are discussed at length in EPA, 1996.

4.6.1 Instrumentation

In the Williams Lake Airshed, NO_x and ozone (O_3) are measured continuously using a TECO 42 and a TECO 49 sampler. Ozone was measured in $\mu g/m^3$, but the Canada Wide Standard for ozone (annual 98th percentile of rolling 8-hour averages) is in ppb, hence the concentrations were converted using the following empirical formula:

$$[ppb] = ([\mu g/m^3] \times 22.4 \times T_{standard}) / (48 \times T_a).$$

Where [ppb] is the ozone concentration in parts per billion, [$\mu g/m^3$] is the ozone concentration in micrograms per cubic metre, 22.4 is an empirical constant, $T_{standard}$ is 298.15 K, 48 is the molecular weight of ozone in grams per mole, and T_a is the near-surface air temperature observed at the Glendale site.

Continuous NO_2 and NO observations were initiated in April 1992 and ended in May 2000 at the Columneetza site with TECO samplers.

4.6.2 Ozone Results

Ozone measurements were compared to the federal 1-hour desirable objective of 100 $\mu g/m^3$ and 160 $\mu g/m^3$ as well as the Canada Wide Standard (CWS), 98th percentile 8-hour rolling average, based on a 3-year metric of 65 ppb.

Table 37 shows the annual variations in Ozone concentrations. Maximum 8-hour rolling average concentrations ranged from 51.4 to 59.1ppb. Data in 1992 is artificially high, as monitoring only start in April that year. The 98th percentile concentrations ranged from 40.5 to 44 ppb. All of these concentrations are below the CWS. Ozone was above the federal desirable objective from 0.48% to 1.98% of the time from 1990-2002 (Table 39).

Figure 79 shows the annual trends for the mean, 75th, 95th, and maximum 8-hour concentrations. The concentrations varied from year to year and no particular trend in the data is apparent. This

shows that the phase out of the burners and the subsequent reductions in NOx emissions had little effect on the ozone concentrations.

The monthly variations in ozone concentrations are presented in Table 38. The spring and summer months (when light is abundant) are much higher than the winter averages (when conditions are not conducive for abundant ozone formation), and follow the pattern of that of naturally produced ozone. The hourly variations in ozone presented in Figure 80 shows that ozone is a maximum in the afternoon when ozone production peaks from the heating and light, and lowers after sunset, when ozone formation ceases. Seasonally, Figure 81 shows that ozone in Williams Lake peaks in spring time. In the spring, ozone has the greatest chance of being transported to ground level from the troposphere where it naturally occurs in higher concentrations. Also during the winter, when prolonged periods of darkness NO_X does not get consumed through ozone formation. Excess NO_X that may be present at the onset of spring, could be available for the ozone formation in the lower troposphere.

A hebdamodal analysis was conducted to determine if there was any anthropogenic influence on measured ozone values.(Figure 82). The plot shows that mean ozone concentrations are lower in the weekdays than on the weekend. The reverse is true for NO_x and NO_2, as will be seen in the analysis of their data. On weekdays, NO_x and NO_2 are higher. This is strong evidence that the anthropogenic NOx that is emitted to atmosphere from vehicles (or other predominantly weekday sources) are acting to consume ozone. Put another way, the NO is reacting with O_3 to produce NO_2 and oxygen (O_2). This indicates that the airshed is likely limited to the VOCs that are present, and photochemical ozone episodes are not likely to occur with the current emissions from Williams Lake.

Figure 83 shows the block averages from 1992-1995 and 1996-2002. There is very little difference between the two periods in concentrations, which could indicate that anthropogenic emissions have not historically strongly influenced ozone concentrations. The weekend averages in the more recent years are slightly lower, likely due to the phase out of the burners.

4.6.3 Continuous NO_2 and NO_x Results

The NO_2 results were compared to the Canadian Federal Objectives of: 60 $\mu g/m^3$ and 100 $\mu g/m^3$ for the annual mean (maximum desirable and maximum acceptable, respectively), 200 $\mu g/m^3$ for the maximum acceptable 24-hour average, and 400 $\mu g/m^3$ for the maximum acceptable hourly average.

Tables 41, 42, and 43 summarize the 1992-2000 continuous NO_2 and NO_x results as collected by TECOs at Columneetza (1992 and 2000 are excluded from Table 41 because they do not have data capture of 75% or greater in each quarter). The following was observed:

- The annual average NO_2 concentration ranged from 14.4 to 18.3 $\mu g/m^3$ from 1993-1999 (Table 41).
- The annual average NO_x concentration ranged from 22.4 to 30.1 $\mu g/m^3$ from 1993-1999 (Table 41).
- From 1995-1999, the annual average NO_2 concentration increased steadily (Table 41).
- None of the Objectives was exceeded. Generally the maximum observed concentrations were 25%-30% of the value of the objectives (Table 41).
- The month during which annual and 24-hour average NO_2 and NO_x concentrations were highest was January, when cold temperatures limit their ability to react in the atmosphere to form ozone (Table 42).

- Hebdomadal means and various percentiles of hourly concentrations of NO_2 and NO_x were lowest on Sundays and highest on Tuesdays, Wednesdays, and Thursdays (Table 43).

For the NO_2 data (1992-2002), Figure 84 shows monthly variations in average concentrations and the 24-hour 75^{th}, 95^{th}, and 98^{th} percentiles of concentrations; a similar pattern exists for the NO_x measurements.

A seasonal trend was apparent, with the highest concentrations occurring in winter and the lowest concentrations occurring in summer. This seasonal variation is typical, and is due to the temperature dependence of the series of chemical reactions that occur in the atmosphere to form ozone from NO_2.

For the Columneetza NO_2 data (1992-2002), Figure 85 shows hourly variations in average concentrations and the 75^{th}, 95^{th}, and 98^{th} percentiles of concentrations; a similar pattern was seen for the NO_x data (Figure 86). The NO_2 data described a bimodal curve, with maxima at 7:00am and 9:00pm and a minimum at midday. The midday minimum was due to two main factors: scavenging of NO_x by reactions that produce ozone, and dilution by atmospheric mixing.

Meteorological patterns and human activity, especially variation in traffic volumes, were both likely to have affected the diurnal variations of NO_2 and NO_x. At Columneetza the diurnal behaviour of NO_2 and NO_x appeared to be related to rush hour, and to the morning dissipation and evening formation of the nocturnal atmospheric inversion, with peaks at 6:00am and 9:00pm.

Figure 87 shows the block averages for 1992-1995 and 1996-2002. Unlike the particulate matter patterns, the NO_x measurements have been higher in recent years, than in the early 1990s. This may in part be due to the TransCanada boiler emissions having an impact at this location.

Seasonal diurnal patterns for average hourly NO_2 concentrations are presented for the Columneetza (1992-2002) monitoring site in Figures 88 and 89 for NO_X, as well as the monthly block averages for NO_X in Figure 90. The block averages in Figure 90 show that NO_x was higher 1996-2000 than in the early 1990s. As was noted previously, concentrations were highest in winter and lowest in summer. The morning NO_2 peak was most evident in winter, and essentially absent in summer.

For the Columneetza NO_2 and NO_x data (1992-2002), Figure 91 shows hebdomadal variations in average concentrations and in the 75^{th}, 95^{th}, and 98^{th} percentiles of midnight-midnight block averages of concentrations; Figure 92 shows the same for the NO_x data. NO_2 and NO_x concentrations were influenced by human activity, with higher values on weekdays than during the weekend. The NO_x values showed this pattern more clearly than did the NO_2 data. The block averages in Figure 93 shows that NO_x was higher 1996-2000 than in the early 1990s. The patterns are similar, indicating anthropogenic influence.

The difference between the midweek maximum concentration and the weekend minimum concentrations for both compounds is presented in Table 43. The differences for NO_2 in the 75^{th}, 95^{th} and 98^{th} percentile were 35%, 17% and 15% respectively. The differences for NO_x in the 75^{th}, 95^{th} and 98^{th} percentile were significantly higher: 42%, 37% and 38% respectively.

4.7 PAHs

Polycyclic Aromatic Hydrocarbons (PAHs) are included as a subset of Volatile Organic Compounds. They are typically produced from incomplete combustion and some have been identified to be carcinogenic, or may become toxic at various concentrations. The sources of PAHs have not been explicitly previously estimated in an emission inventory for Williams Lake

however, sources of VOCs are generally good indicators. Combustion of fossil fuels and wood burning are known to be and are likely the main sources of the PAHs that have been monitored in the airshed. Of the VOCs that were estimated in the emissions inventory, permitted, natural, and residential sources make up a significant portion of VOC emissions in the airshed at 81.5%, while mobile sources, which are also known to be sources of PAHs are another 9.2% of the VOC emissions.

The Texas Natural Resource Commission's (TNRCC) Effects Screening Levels (ESLs) and the Ontario Point-of-Impingement were used to compare PAH results. The Texas ESLs were developed with the consideration of natural background levels. For short-term periods, they are lower than the Ontario points-of-impingement. The maximum and annual average ambient measurements for each of the individual PAHs were compared with the more stringent guideline from these two jurisdictions for short and long term averaging periods.

PAHs were measured at the Anne Stevenson School site every six days from 1992 to 1994, and from time to time throughout this same period at various sites across the airshed. These sites are outlined in Figure 3 and include the Glendale Nursery, the Ross Residence, Williams Lake Golf and Country, and the Hodgson Residence. The Figure also shows the location of the burners that were still in operation during this period.

A summary of the total PAH concentrations from 1992 to 1994 from all the sites is provided in Table 44. The maximum concentrations were higher in 1993 and 1994 than in 1992. The maximums occurred during February of 1993 and March of 1994. It was noted that these two months were particularly dry, with very little precipitation. Figure 94 shows the monthly maximum, 98^{th}, 95^{th}, 75^{th}, and mean concentrations of PAHs from 1992 to 1994. For all levels, the maximum PAHs occurred during the winter months while the minimums occurred in summer.

Other pollutants measured during this period were examined to determine if possible relationships existed between PAHs and potential sources. For example, high PAHs in the presence of high NO_X and particulate matter may be related to wood burning, while if only high NO_X is observed, natural gas could be the main contributing factor.

Figures 95 (daily) and 96 (monthly averages) show a time series analysis of the PAHs, PM_{10}, NO_X, Temperature, and NO_2. The highest PAHs occurred on the coldest and calm days in winter. In general, during higher periods of PAHs the PM_{10} and NOx values were higher for the daily periods indicating that wood burning is a likely source, but the monthly averages did not indicate the same pattern. It is notable that NO_2 data on a monthly basis did exhibit a similar pattern, as PAHs concentrations while PM_{10} did not. In 1993 and 1994, the maximum concentrations also occurred on weekends, when beehive burners were not operational. Therefore, residential wood combustion, as well as gas combustion from home heating and vehicles is the likely source. The temperature profile indicates that highest concentrations occurred on the coldest days. In wintertime, residential wood burning and the presence of inversions being more predominant (especially on the coldest days) further indicates that these are the likely conditions that resulted in the higher PAH concentrations.

Table 45 presents the maximum concentrations of each of the individual PAHs. Maximum concentrations of Acenaphthene, Phenanene, Pyrene, and Benzo(a)pyrene were 3.7%, 22%, 24%, and 30.7% of the ESL and represented the closest PAHs to the respective ESLs. All short-term and long-term predicted concentrations were well below their applicable ESLs.

4.8 METALS

Metals are considered toxic, and can exist in the atmosphere in either “elemental” or “oxidized” form. They can bind to particles or stay volatile at various temperatures along with each metal’s

properties. Metals can be a natural constituent of particulate matter, and can also result in increased levels due to combustion of fossil fuels, as well as other sources of particulate matter.

Like PAHs, the Texas Natural Resource Commission's (TNRCC) Effects Screening Levels (ESLs) and the Ontario Point-of-Impingement were used to compare the magnitude of the results. The ESLs are lower than the Ontario points-of-impingement, with the exception of Arsenic. The maximum and mean ambient measurements were compared to these levels.

Metals data were measured at each of the HiVol air quality monitors in the Williams Lake airshed for certain periods from 1996 to 2001. The particulate matter filters were analyzed on the NAPS cycle (once every six days) for the metal constituents. For 2001, the raw data that was available at the time this report was written had not yet been corrected for the analytical techniques that were used, and the filter components of the data had not been subtracted out of the measured constituents. Therefore, a complete analysis of the data is not possible until a thorough QA/QC of the data set is conducted. While some of the metals data examined is in a normal expected range. In 2001, other metals (e.g. aluminum) are above the measured particulate matter values, and are therefore invalid. A discussion of the 2001 data is provided briefly at the end of this section. The 1996 to 2000 data is presented below.

From 1996 to 2000 metals were measured at the Firehall, Watertower and Skyline locations. Tables 46 through 48 show a summary of each station for the metals concentrations for these periods.

At the Skyline station, Arsenic (70%), Cadmium (30%) and Lead (20%) were closest to the short-term ESLs. When the long-term ESLs were compared to the mean concentrations of each metal, concentrations ranged from 0.04% to 68.01% of the long-term ESLs.

At the Firehall station, Arsenic (40%), Cadmium (30%) and Manganese (20%) were closest to the short-term ESLs. When the long-term ESLs were compared to the mean concentrations of each metal, concentrations ranged from 0.04% to 68.71% of the long-term ESLs.

At the Watertower station, Arsenic (40%), Copper (37.2%) and Nickel (26.67%) were closest to the short-term ESLs. When the long-term ESLs were compared to the mean concentrations of each metal, concentrations ranged from 0.04% to 70.92% of the long-term ESLs.

All of the measured concentrations at each of the sites are below the pertinent ESL, and in most cases, below even 10% of the short-term ESL. Seasonal variations for selected metals are provided in Figure 97. These metals were selected based on the range of measured values. The following was observed:

- The Figure shows that on average, the highest observed concentrations were situated at the Skyline site, while the lowest were at the Watertower site.
- On occasion the Firehall had higher averages than the other two stations.
- Average concentrations in 1999 were higher than average concentrations in 1996.
- In general, concentrations were highest in the summer, and lowest in the winter.

For a particular metal (e.g. Zinc) similar patterns of concentrations at all site were observed. Zinc can result from unleaded vehicles as well as incinerators and can be from crustal material. Since the patterns were similar at all sights it is likely crustal in nature. There were exceptions, for example phosphorous exhibited a peak at Skyline that was not measured to the same degree as the other stations. Phosphorous is contained in soil and these peaks may provide additional support that ground level sources such as dust influence this site.

The 2001, uncorrected data are presented here, and initial conclusions are offered where possible. By knowing that actual data will be lower than what is presented here, some thoughts can be offered. Tables 49 through 52 show a summary of the metals concentrations. The most

significant metals are Aluminum, Boron, Magnesium, and Zinc, which all had values higher than the measure PM_{10} data this was not the case in the 1996 to 1999 data. As these metals are also resident on the filter, the correction will likely bring the concentrations much lower. For the remaining metals, all concentrations are below the short-term ESLs. After the correction is applied, these concentrations will be even lower and more like the patterns in the 1996 to 1999 data. The long-term ESLs showed values closer or higher for many of the metals. The required correction will have the greatest effect on the longer term averages, and they will be reduced by the largest margin, likely below all ESLs when completed.

All of the concentrations were similar at each of the sites for all the periods measured indicating that no single source of metals was greatly influencing one site over the others. The highest concentrations did occur at the Firehall site but it is unknown whether this real data or due to the methodology of analysis. Concentrations at Skyline were on average higher than concentrations at 168 Mile Road, in turn which were similar or slightly higher than Watertower concentrations. From time to time, one or two of the metals showed peaks, and usually only at one of the sites. A noted period was in March, when the Firehall showed a significant peak in Cadmium concentration, while Lead reached it's highest at the Skyline location. Once the data has been QA/QCd, further trends may become apparent.

4.9 EPISODE ANALYSIS

PM_{10} episodes were analyzed for the Skyline and Columneetza sites (Table 53 and Table 54 respectively). A PM_{10} episode is defined as a period of at least twenty-four consecutive hours during which the rolling 24-hour average PM_{10} concentration is above 50 $\mu g/m^3$ (the Ambient Air Quality Objective for PM_{10} in B.C.). A Type 1 episode is defined as a period of time during which levels above 50 $\mu g/m^3$ occur for at least 24 hours but less than 48 hours in duration. A Type 2 episode lasts 48 hours or more.

At the Columneetza School monitoring location, the number of episode days per year decreased significantly after 1996, the year after the wood waste (bee hive) burners were phased out. The longest continuous period of high concentrations occurred in 1996, when the rolling 24-hour average was greater than 50 $\mu g/m^3$ for 125 hours. The Type 2 episode in November 2002 was the first since February 1996. Episode days from 1993 to 1996 accounted for a significant fraction of the total number of times concentrations were above the Level B Objective, with 74% to 89% of the year's total number of rolling 24-hour averages that were above the Objective occurring during episodes. From 1997 to 2002, episode days accounted for markedly fewer of the total number of times concentrations were above the Objective, with 41% to 65% of the year's total number of rolling 24-hour averages that were above the Objective occurring during episodes. This improvement reflects that sources other than the burners were also influencing the site.

At the Skyline School monitoring location, in less than five months (August 8-December 31) in 2001, there were more episode days (15.46) than during any entire year at Columneetza from 1993-2002. In contrast, in 2001 at Columneetza, there were no episodes at all. Episodes occurred at Skyline 11% of the time in August-December 2001, and 7% of the time in 2002. At Columneetza the same figures were 0% in 2001 and 1% in 2002. The highest such percentage at Columneetza was 4%, in 1995. The longest Type 2 episode at Skyline occurred in August 2001, when the rolling 24-hour average was greater than 50 $\mu g/m^3$ for 121 hours. Episode periods accounted for 77% and 67% of the total exceeding PM_{10} levels experienced at Skyline in 2001 and 2002 respectively. Over the period, episodes occurred in August and November of both years. The higher number of episodes at Skyline reflect the presence of sources from all directions.

4.10 AIR QUALITY INDEX

The Air Quality Index (AQI) is a way of transforming complex air quality measurements into a numerical value and descriptive term. Its main purpose is to inform the public about the present state of air quality in an area. All AQIs in Canada are calculated using the same federal guidelines and are therefore directly comparable between communities.

The Air Quality Index numbers are interpreted according to the following scale: 0 to 25 is GOOD, 26 to 50 is FAIR, 51 to 100 is POOR, and 100+ is VERY POOR. Air quality information across the province is gathered by a central computer in Victoria and an AQI is calculated based on the highest hourly concentration of any of the pollutants measured at that station. That is, the pollutant with the highest hourly average for that hour is the pollutant that drives the AQI. An AQI of 50 represents the "maximum acceptable" concentration for any pollutant as defined by the MOE ambient air quality criteria documents. In the case of PM_{10}, the AQI is determined based on a rolling 24-hour average compared to the provincial objective of 50 $\mu g/m^3$. In Williams Lake, both Ozone and PM_{10} be used to convert to the AQI for Columneetza and PM_{10} for Skyline. The annual Air Quality Index (AQI) is presented in Table 55 for Skyline (2002) and Columneetza (1993-2002).

The Air Quality Index numbers are interpreted according to the following scale: 0 to 25 is GOOD, 26 to 50 is FAIR, 51 to 100 is POOR, and 100+ is VERY POOR. Table 55 compares the percent of time that the Air Quality Index values fell into each AQI category for both sites.

In 2002 at Skyline the AQI was less frequently in the GOOD range (55.66%) and more frequently in the POOR range (9.87%) than during any year from 1993 to 2002 at Columneetza. The AQI at Columneetza was rated GOOD from 65.15 to 85.70% of the time, and from 1996 to 2002 (i.e. after the bee-hive burners were phased out) the AQI was rated GOOD significantly more often than it was during 1993-1995. The AQI at Columneetza was never rated VERY POOR except in 1996, when it was rated VERY POOR for 0.54% of the time; the corresponding value was 0.17% for Skyline in 2002.

5 CONCLUSIONS AND RECOMMENDATIONS

1. The valley setting of Williams Lake is conducive to inhibiting dispersion of pollutants, particularly when meteorological conditions are calm and dry, or with the presence of a nocturnal or winter time inversion.

2. An airshed specific emissions inventory indicates that in terms of total loading, the Permitted and Road Dust source categories (paved and unpaved) emit the most fine particulate matter (PM_{10} and $PM_{2.5}$) to the Williams Lake Airshed.

3. The largest single change in emission sources prior to 1996 was the phase-out of all beehive burners in the airshed between December 1992 and December of 1995. An improvement in fine particulate levels is indicated by a statistically significant decline in annual averages, a decline in the number of exceedances of the B.C. Ambient Air Quality Objective for PM_{10}, and a decline in monthly average concentrations at all of the PM_{10} monitoring stations in Williams Lake since burner phase out. The block averages presented in the report further support this change. In addition, the City of Williams Lake instituted a back yard burning policy in the spring of 1998 (but possibly as early as 1997) that eliminated backyard burning within city limits. Other factors such as changes in residential heating practices in the vicinity of the monitoring stations and variability in meteorology (wind speed, direction, precipitation, etc.) also may have influenced these trends.

4. Anthropogenic activities have an influence on PM_{10} levels in Williams Lake. This is reflected in the hebdomadal analysis (day of the week) in that both continuous monitoring sites show a weekend minimum and a weekday maximum concentration. The difference between the midweek maximum PM_{10} and the weekend minimum PM_{10} at Skyline for the 75^{th}, 95^{th} and 98^{th} percentile concentrations were 55%, 61% and 60%. Differences between the minimum and maximum values at Columneetza were 36%, 40% and 47% respectively.

6. Anthropogenic activities have a larger influence on PM_{10} values at the Skyline site than at the Columneetza site. This is supported by the diurnal analysis at both sites. At Columneetza the bimodal diurnal behavior of PM_{10} appeared to be driven by the morning and evening rush hours, with peaks at 8:00am and 7:00pm. Residential heating would also add to particulate loading at these times. At Skyline, PM_{10} concentrations increased during the daytime period indicating that the many sources surrounding the site have a significant localized effect - concentrations continue to increase even though atmospheric mixing conditions are the best during the afternoon hours and concentrations should be decreasing as a result.

9. On average, Skyline continuous PM_{10} levels were above the health reference levels 44.1% of the time in 2001, and 44.3% of the time in 2002. There was not a single observed month when a 25 $\mu g/m^3$ 24-hour level was not exceeded. In January and February 2002, the health effects level was exceeded about as frequently at Skyline as at Columneetza. For every other month in 2002, the PM_{10} health effects level was exceeded about twice as often at Skyline as at Columneetza.

10. Based on six months of meteorological data, high hourly average PM_{10} concentrations at the Skyline monitoring location were recorded in association with winds from all directions as there are numerous sources (permitted, commercial and mobile) surrounding the site. However, the highest frequency of values over 50 µg/m3 occurred when winds were either from the east or from the west to northwest sector. High frequencies of lower concentrations come from the south and southeast of the site.

11. The highest frequency of elevated hourly PM_{10} values at Columneetza occurred when winds were from the west-northwest, where the Glendale industrial area is located. Other high values were experienced when winds were from the east-southeast (residential/mobile).

9. From 1990-1996 the data at the Williams Lake Firehall site showed distinct peaks in late winter and late summer/early fall, but from 1997-2002 no meaningful pattern was evident aside from the February/March peak and wintertime minimums. The late winter/early spring peaks correlate well with observations of road dust impacts throughout the community prior to street sweeping activities.

10. In the Williams Lake Airshed road dust, dust from log yards and traction material, and permitted source emissions appear to have a significant influence on measured ambient PM_{10} data. Based on seasonal variations, the highest PM_{10} values are generally recorded in the spring and are largely associated with re-entrainment of road dust.

11. A significant portion of PM_{10} concentrations exceeding provincial objectives occurs during air quality episodes. Management efforts focused at those sources that contribute most significantly to episodes should reduce the overall number of exceedances, reduce the annual average PM_{10} value and result in improved air quality. Management efforts need to be aimed at reducing the total loading of fine particulate to the airshed from all sources in order to control episodes during stagnant meteorological conditions.

12. $PM_{2.5}$ from the non-continuous monitoring location at Columneetza accounted for between 53.6% and 73.5% of the PM10 mass in winter and roughly 30% of the mass during the spring from 1994 to 2000. In 2001 and 2002, $PM_{2.5}$ accounted for roughly 40-50% of the PM_{10} mass in winter (relatively dry winters) at both continuous monitoring sites and roughly 20% of the mass in the spring. The dominant coarse component in the early spring and through the summer months is largely attributable to road dust being re-entrained by passing vehicles although permitted sources will also contribute depending on dispersion. It is evident that effective control of dust will improve ambient PM_{10} values throughout the community.

13. The Canada Wide Standard for $PM_{2.5}$ was not exceeded during the 7-year record of non-continuous measurements from Columneetza. However, not enough data is available to calculate the Canada Wide Standard for the continuous monitoring sites. The 98^{th} percentile of midnight-midnight block averages in 2002 was 23 $\mu g/m^3$ for Columneetza and 20 $\mu g/m^3$ for Skyline giving initial indications that the CWS will not be exceeded. Twenty-four hour values of $PM_{2.5}$ were above the health reference level of 15 $\mu g/m^3$ an average of 5.25% of the time at Skyline and 6.15% of the time at Columneetza from 2001 to 2002.

14. Diurnal patterns of continuous $PM_{2.5}$ at Columneetza show a slight morning peak in mean through 99th percentile concentrations at 0700 hours, and a slight evening peak at 2000 hours. The highest maximum hourly concentrations occur at Columneetza during the morning. A number of factors could contribute to the maximums at these times, including the break-up of the morning inversion, the increase in particulate matter emissions from mobile sources (primarily vehicles) and residential/commercial heating, and contributions from road dust kicked up by morning traffic. At Skyline a muted peak occurs at 0800 hours, but essentially concentrations are constant throughout the day and night, with absolute values similar to those at Columneetza. Influences from nearby industrial/commercial sources and the major traffic corridors near Skyline produce the higher daytime and more constant patterns in $PM_{2.5}$ concentrations measured at this site.

15. Seasonal diurnal patterns of continuous $PM_{2.5}$ indicate that residential wood burning, mobile sources, and possibly open burning in the fall, have an influence on measured ambient $PM_{2.5}$ data at both continuous monitoring sites. Permitted sources also contribute to $PM_{2.5}$ impacts depending on meteorology and source location in relation to receptors.

16. It is evident that traffic patterns and emissions from industrial/commercial activity during the week have an influence on ambient concentrations of $PM_{2.5}$. Weekday (hebdomadal) variations in mean $PM_{2.5}$ concentrations at both Skyline and Columneetza exhibit a weekend minimum (Saturday or Sunday) and a late weekday maximum (Thursday or Friday) at both stations. On average, mean and 75^{th} percentile $PM_{2.5}$ concentrations during the weekday maximum are 20% and 29% higher respectively than the weekend/early weekday low. The weekend and early weekday (Monday/Tuesday) lows at Skyline are associated with reduced activity on Sunday. Emissions are allowed to flush out/settle out during this reduced activity period. Home heating emissions on their own do not appear to be able to sustain the $PM_{2.5}$ levels through the weekend.

17. The Air Quality Index (AQI) indicates that, at times, poor air quality still exists in Williams Lake and that there is room for improvement in reducing fine particulate matter concentrations.

18. Ambient NO_X data shows that NO_2 levels were well below federal objectives for the duration of the monitoring period.

19. Ambient NO_x concentrations were influenced by human activity, with higher values on weekdays than during the weekend. The block averages (before and after burner phase out) show that NO_x was higher in 1996-2000 than in the early 1990s. This may in part be due to the TransCanada boiler emissions having an impact at this location although other sources such as vehicle emissions and home heating also play a significant role.

20. Ozone concentrations have not exceeded the Canada Wide Standard, however values have been close to the standard on occasion, and data should continue to be tracked.

21. Seasonally, ozone concentrations in Williams Lake peak in the spring time when ozone has the greatest chance of being transported to ground level from the troposphere where it naturally occurs in higher concentrations.

22. The data from the hebdomadal analysis provides strong evidence that the anthropogenic NOx that is emitted to atmosphere from vehicles (or other predominantly weekday sources) are acting to consume ozone. This indicates that the airshed is likely limited to the VOCs that are present (the mixture of VOCs and NOx was not conducive to ozone formation), and that photochemical ozone episodes are not likely to occur with current emissions from Williams Lake.

23. In examining ozone trends before and after burner phase out and the subsequent start-up of the TransCanada energy facility, there is very little difference between the two periods in terms of concentration. This could indicate that historically, anthropogenic emissions have not strongly influenced ozone concentrations.

24. PAHs were all below the Texas Effects Screening Levels (ESLs) previously from 1992 to 1994, and they would likely be below the ESLs today. Maximum PAH concentrations occurred during the winter months (home heating) while the minimums occurred in summer.

25. Metals data are all below their respective ESLs, however they appeared to be higher in 1999 when compared to 1996. No significant trend was identified, and further analysis of the 2001 data may provide better insight into the data trends. The most recent data has not been blank corrected at this time, and therefore some parameters may be artificially high

due to false positives from the filter media. A more thorough analysis should be conducted once it has been blank corrected.

26. As outlined in the Air Monitoring and Assessment Strategy for Williams Lake BC 2000-2005 (Plain and Zirnhelt, 2000), airshed dispersion modelling should be conducted using CALMET and CALPUFF to help quantify relative source contributions impacts from all source types in the Williams Lake Airshed.

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