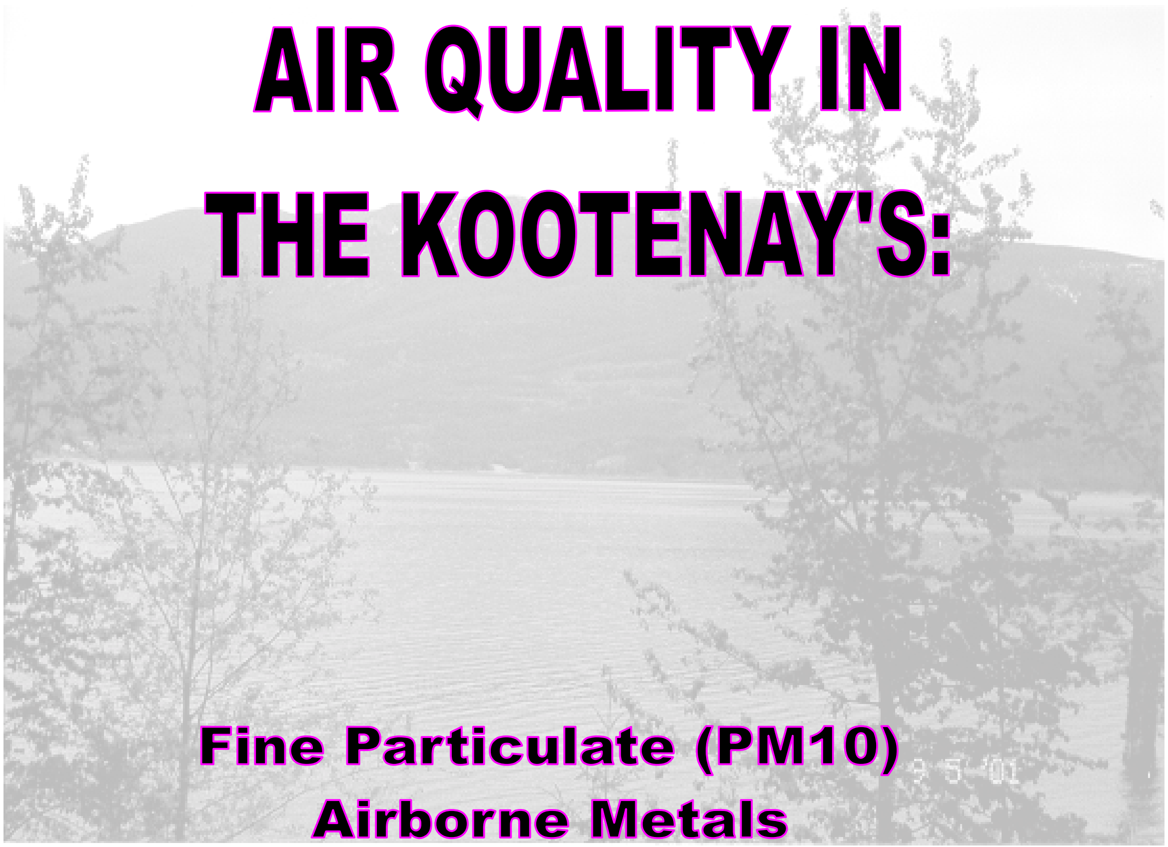
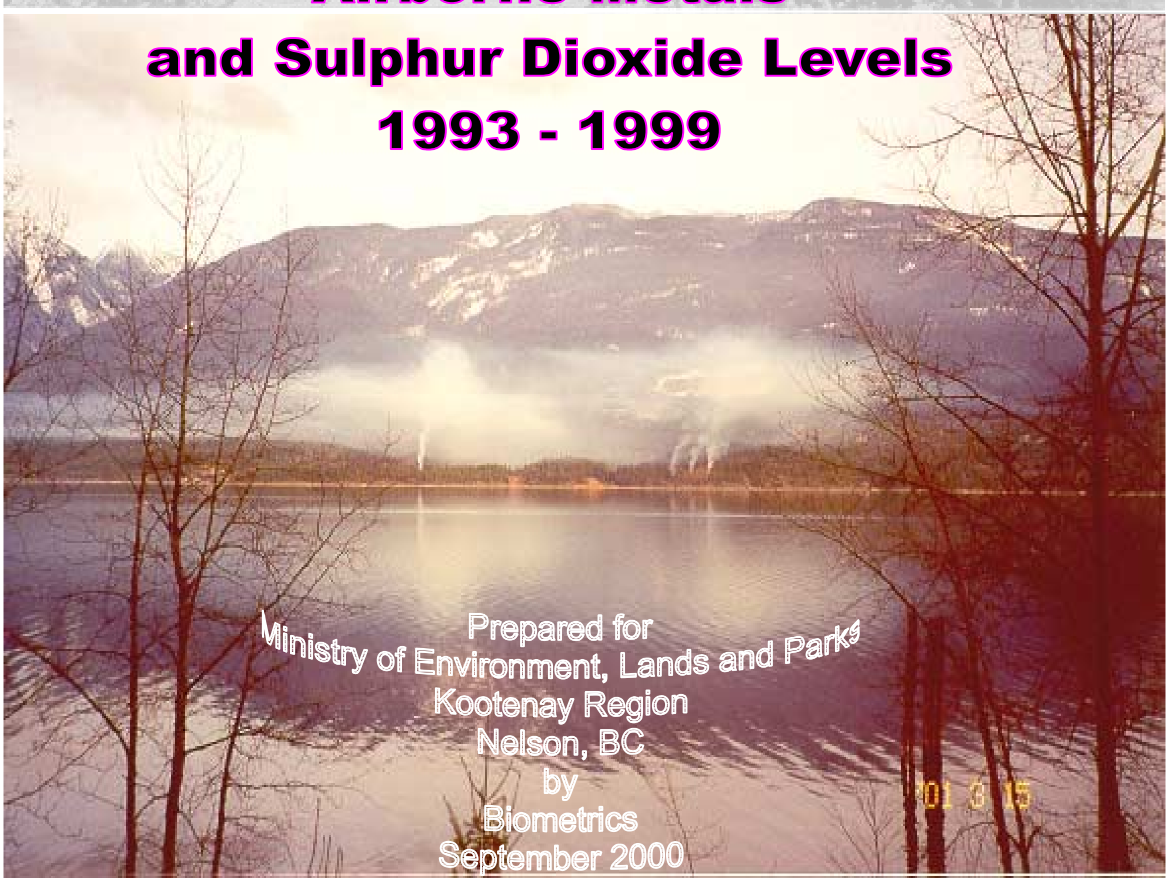


AIR QUALITY IN THE KOOTENAY'S:

Fine Particulate (PM10) Airborne Metals and Sulphur Dioxide Levels 1993 - 1999



Prepared for
Ministry of Environment, Lands and Parks
Kootenay Region
Nelson, BC
by
Biometrics

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Preface

The Ministry of Environment, Lands and Parks (BC Environment) and permittees[1] have been conducting air quality monitoring in communities of the Kootenay Region for a number of years. The monitoring is conducted primarily to evaluate the present air quality and to establish long term trends. Monitoring results are public information and they are available on request. However, given the growing public awareness and concerns about air quality, publication of the results for public examination is important. The most recent report published for this region prior to this one was *Air Quality in the Kootenays, 1992* (Mignacca 1995) BC Environment maintains a website on the Internet on the state of the environment, with air quality reports and updates at **http://www.elp.gov.bc.ca/epd/epdpa/ar/airquality/**

The objective of this report is to enable public examination of the measured air quality data, and not to provide formal assessments of the prevailing air quality. To facilitate examination, all data are presented graphically with appropriate analysis provided.

Comments on this report are welcome and should be submitted in writing to the Regional Pollution Prevention Manager of the Ministry of Environment office in Nelson, B.C.

[1] Permittees are industries that have been granted a waste discharge permit by BC Environment

Executive Summary

This report summarizes the results of air quality monitoring in the Kootenays for the seven years from 1993 through 1999. The objective of this report is to inform the public about air quality in the Kootenays and assist them in understanding air quality monitoring results. Colour coded graphs and plots of the data have been produced and annotated for clarity. All data tables used to produce these graphs are included in the Appendices.

The data presented includes the NAPS (every 6^{th} day) and TEOM (hourly) data for particulate matter (PM_{10}), airborne metals (arsenic, cadmium, lead and zinc) and sulphur dioxide for the communities that have had regular monitoring from 1993 through 1999.

Particulate matter levels remained relatively constant in most communities. Johnson Lake (a 'control' location) and Slocan had the lowest levels of PM_{10} during this reporting period, while Golden had the highest values. Trail - Butler Park readings showed a clear declining trend in PM_{10}.

Airborne metals and sulphur dioxide levels have decreased in the Kootenays during 1993 - 1999. There are still occasional exceedences of Level A objectives, and a few of Level B objectives, in some communities.

The general pattern is one of stable or reduced concentrations of all airborne pollutants, with a few exceptions. Highlights of the analyses are indicated below.

Inhalable Suspended Particulate Matter (PM_{10})

Domenico Mignacca's *Air Quality In the Kootenays 1992* report for BC Environment (1995) identified several areas of concern for PM_{10}. Data records for PM_{10} were analysed for Castlegar, Cranbrook, Creston, Golden, Invermere, Johnson Lake, Nelson, Revelstoke, Slocan (partial data set) and Trail - Butler Park.

The modal value (most commonly occurring) is between 10 and 20 $\mu g/m^3$ at all sites except Johnson Lake where it is lower. Annual average values are below 30 $\mu g/m^3$ for all sites except Golden and below 20 $\mu g/m^3$ for Johnson Lake, Slocan, Cranbrook, and Creston. Golden's elevated readings primarily occur during the winter, which is also the seasonal pattern at Invermere and Revelstoke.

Exceedences of the BC and Canadian 24 hour objective Level A occurred in all communities except Slocan; Johnson Lake had only one exceedence. Golden recorded more exceedences than all other communities combined, most of which occurred during the winter months. Trail is the most improved community for PM_{10} exceedences.

The tracking of Vedal Health Increments, a method of assessing air data which is more sensitive to concentrations of PM_{10} lower than BC Air Quality Objectives, is a valuable addition to the assessment techniques applied to air quality data in the Kootenays. Vedal Health Increments were highest on average at Golden (annual average 385 HI); the next highest was Castlegar (119), followed by Invermere (110) and Nelson (104). The first three of these communities have had slight improving trends in Health Increments during the 7 year period of this report, but in Nelson PM_{10} pollution appears to be getting worse.

Airborne Metals

NAPS data for metals in PM_{10} were analysed for Castlegar and Trail - Butler Park. The Trail data had a 14-month gap in it from late 1995 through late 1996 while the station was shut down during construction of a community recreation centre at Butler Park. During the seven year scope of this report declining trends in arsenic, cadmium and lead were found; there was no change in zinc levels.

Arsenic levels at Castlegar and Trail have been quite low since 1995, with very few exceedences of the BC 24 hour Level A objective except for a period between August and October 1999 when elevated levels were observed at Trail. The annual median values at these two sites are close to the detection levels, and annual maximum values have dropped steadily from 1993 to 1999.

Cadmium also has declined, with few values above the detection limit at either site since 1997. The annual median values at Trail and Castlegar have been equal to the detection limits at each site, and maximum annual values have declined towards the detection limit as well.

Lead levels, which have historically been of concern at Trail, have declined sharply since 1995, with the last exceedence of BC 24 hour Level A objectives occurring in 1997. Annual maximum values observed each year have declined to the detection limit at Castlegar, and are below the Level A objective at Trail.

Zinc in airborne particulate matter at Trail was lower in 1997 - 1999 than the high values observed in 1994 - 1995, but the 7 year time series shows no clear trend. Values of PM zinc at Trail in 1999 included many exceedences of the BC 24 hour Level A objective, and 2 exceedences of the Level B objective. Castlegar zinc levels were higher in 1999 than previously, with a higher median value and more exceedences of Level A and Level B objectives than in earlier years.

Sulphur Dioxide (SO_2)

Sulphur dioxide was monitored hourly at Robson and Trail - Butler Park from 1993 through 1999 with one major gap in monitoring at Trail from November 1995 till June 1996 (as noted above). Clear declining trends are shown in ambient SO_2 at both sites; there have been no exceedences of the 24-hour Level A objective since 1996 in either community.

Ambient SO_2 at Robson has fallen steadily from 1993 in which there were 6 exceedences of the 1-hour Level A objective and 9 exceedences of the 3-hour Level A objective (no exceedences of the Level B objective at Robson) to no exceedences of any kind in 1997 through 1999. The plot of the daily cycle of ambient SO_2 shows a well-defined peak in mid-morning; this is a meteorological phenomenon in which a 'calm' (*i.e.* poorly ventilated) period sets up each day and the airshed can accumulate suspended pollutants for a number of hours.

Trail - Butler Park sulphur dioxide concentrations have been higher than at Robson but have also fallen, especially since 1996. Exceedences of the 3-hour objectives were more common than 1-hour or 24-hour exceedences, emphasising the characteristic brief pulses of high SO_2 that occur in this dataset. Exceedences of all Level B objectives (1-hour, 3-hour and 24-hour) have decreased since 1995, and there were no Level B exceedences observed in 1999. Level A exceedences (all durations) have also become infrequent with only 12 exceedences of the 1-hour objective, 8 exceedences of the 3-hour objective and 1 exceedence of the 24-hour objective in 1999. The daily cycle of SO_2 at Trail shows two well defined peaks; the major one occurs in late morning and a smaller one in the late evening.

Acknowledgments

The author wishes to thank Ernie Tradewell of the Air Resources Branch of BC Environment for assistance in accessing the archived data, and Julia Beatty for her guidance and comments. The analytical plotting software used for the graphics in this report is Plot-It, produced by Scientific Programming Enterprises.

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1. Introduction

In the Kootenays, which are relatively sparsely populated forest land with few heavy industries, people might expect the air to be pollution free. However there are many sources in this region of fine particulate matter, some of it bearing heavy metal contaminants, as well as sulphur dioxide emissions. Concentrations of air pollutants are high enough in several communities to affect human health and the environment.

Airborne particulates are estimated to be 70% anthropogenic (caused by man) and 30% natural in the Kootenays. The primary sources of particulate matter in BC are the wood products industry (point source burning of waste) and railroads, both of which contribute approximately 15% of the total. Prescribed burning (slash) (11%), primary metal manufacturing (7%), mining (6%) and space heating (wood burning appliances) (6%) are the other major sources (Air Resources Branch 1999.) The contribution of each of these sources varies greatly from community to community.

Sulphur dioxide emissions are 100% anthropogenic, with approximately 80% originating with the metal manufacturing at Cominco and 11% at mining sites (Air Resources Branch 1999).

The BC Environment report ‘Air Quality in the Kootenays, 1992' summarized the available data from 1983 to 1992 for the Kootenay region. Since that time, monitoring sites have been added or deleted, detection limits have changed for several variables, and the developing human population and industrial base of the Kootenays have grown. This report is intended to update the review of air quality data for this region and make it available to the public.

PM_{10} is the first contaminant of concern. Very fine particles, small enough to pass through a 10 micron filter, remains suspended in the air for long periods of time. Such fine particulates are easily breathed into the lungs where its physical presence as well as the contaminants in it such as heavy metals cause lung and heart disorders and asthma. Fine particulate matter is produced by many sources in the Kootenays. Large point sources include pulp mills, sawmills, beehive burners, slash burning, and forest fires. Smaller and more disbursed sources such as domestic wood burning appliances, road dust, open burning in back yards and vehicle emissions can also contribute significant particulate pollution.

PM_{10} has been found to cause health effects in concentrations as low as 20 $\mu g/m^3$, which is substantially below the BC Level A objective of 50 $\mu g/m^3$. Research by S. Vedal (1995) devised a method for estimating the health effects of chronic exposure to fine airborne particulate matter which is of special relevance to the Kootenays. Vedal Health Increments were reported for four Kootenay communities in the report ‘*Air Quality Report for British Columbia: Fine Particulate (PM_{10}) Levels 1990 - 1995*.’ In this report Vedal Health Increments have been calculated for the ten communities that have sufficient data from 1993 through 1999.

Heavy metal contamination in airborne particulate matter has been a special concern in the vicinity of Trail, where the Cominco smelter was identified in the past as a point source of airborne metals, especially lead, arsenic, cadmium and zinc. New pollution control upgrades at Cominco have recently come on line (1998), and the impact on air quality is of interest.

Sulphur dioxide, while a gas and not particulate matter when emitted, is a precursor of acid deposition including acid rain, and can also transform into fine particulate matter (sulphates) a few hours after emission.

Readers wishing to review basic information on atmospheric pollution are invited to read Appendix 4, “Basic Principles of Atmospheric Pollution” which is reprinted from the BC Environment report ‘*Air Quality in the Kootenays, 1992*'.

2. Sampling Methodology

Air quality is monitored throughout the Kootenays by several types of air samplers located at stations chosen primarily to measure the impact of air pollution on human health. The schedules of sampling vary according to the priority of the site.

NAPS (National Air Pollution Surveillance) sites are sampled for 24 hours every 6th day throughout the year, using discrete high volume samplers. These samplers require manual loading and unloading of the filters, but the used filters can be archived for future reference as well as providing additional samples for chemical composition, such as airborne metals. NAPS data for PM_{10} and/or metals are collected in Castlegar, Elkford, Invermere, Johnson Lake (a control site), Nelson, Radium, Revelstoke, Slocan, and Trail. The data at Elkford and Radium were insufficient for analysis in this report.

BC Environment has set up more intensive continuous sampling for PM_{10}, using a TEOM (Tapered Element Oscillating Microbalance) on an hourly basis at Cranbrook, Golden, Creston, and Trail. TEOM data is more expensive than the high volume discrete samplers and does not provide a store of used filters for other analyses. However it generally is very reliable, needing less maintenance and is therefore less subject to human error.

Continuous TECO samplers record hourly SO_2 measurements by exposing ambient air to a beam of ultraviolet light and measuring the intensity of radiation emitted, which is proportional to the concentration of SO_2. Measurements are taken every few seconds, and the average of the hour is logged in a data recorder.

An hourly data record provides a wealth of information by recording every day instead of every 6th day, and by recording hour-to-hour fluctuations in airborne contaminants. In addition, the continuous monitors are usually connected to a telemetry system which allows real-time access to the incoming data and creates the potential for ‘real time’ management of air quality.

3. Quality Assurance and Data Analysis

3.1 Quality Assurance

Strict protocols have been developed by BC Environment (ARB, 1996) for the siting, installation, operation and calibration of all of the samplers used. An audit program assures that these procedures are followed by regional Ministry staff, contractors and permittees.

All filters obtained from the high-volume discrete samplers are sent to approved laboratories for analysis, and the laboratories are required to regularly calibrate and test the accuracy and resolution of their equipment according to BC Environment requirements (CAEAL EDQA Regulations)

The resulting data are submitted directly to the central electronic database maintained by BC Environment in Victoria, which is supposed to screen the incoming data for reliability, flag high or unusual results for the immediate attention of regional managers, and archive the data record for future reference. In practice much of the data appear to have been archived without careful screening, adjustmenting for field or travel blanks, and trimming to the appropriate number of significant figures.

In this report, metal concentration data recorded as 'zero' has been taken to be less than the minimum detection level.

3.2 Data Analysis and Technical Terms

Before perusing the results presented in this report, the reader should review the following descriptions of the data analysis procedures and definitions of the technical terms used to describe the analyses done and the results obtained.

The first step in analysis was to examine the ***'time series***' of the data: *i.e.* the values observed, plotted along the time scale of observation. The time series plots included the air quality objectives as horizontal bars and allow the reader to spot exceedences of these limits and to see the seasonal pattern of high values recorded over the years.

Data gaps are also plainly evident in the time series. '***Data capture***' is the term used to describe the number of observations archived for a given time period. Usually the data capture is expressed as the '***% data capture***' which is the percentage of data successfully gathered, compared to the maximum possible number of observations in the time period. When the % data capture is below 75%, the data are insufficient to provide reliable means that can be fairly compared to means calculated from more complete data sets. Time periods having less than75% data capture are flagged in the graphs. The reasons for the lack of data capture vary, but are almost always related to instrument failure.

The next step in analysing each data set was to determine the '***frequency distribution***' of all of the observations. Most familiar statistical methods are designed to be used with data that are 'normally' distributed, which is to say, the frequency distribution looks like a bell-shaped, symmetrical curve. In fact, most air pollution data, including all of the data sets in this report, are not normally distributed. There is a high proportion of data at or near the analytical detection limit with relatively infrequent high values. This lack of symmetry is not easily fixed by mathematical procedures (such as transformations). To present the data most understandably, the simplest descriptive techniques have been used, rather than resorting to complex analytical techniques that would be unfamiliar to many readers.

For PM_{10} and SO_2 data, the ***'mean'*** of a group of values is synonymous in this report with '***average***': the value obtained by adding all the values and dividing by the number of values. Where the data includes records "less than the detection limit" (<DL), the value of the analytical detection limit has been used to calculate the mean or average. This may introduce a small upwards bias in means or averages calculated from many <DL values, but does not lead to errors in interpretation.

For metal concentrations, where changing detection limits and a very high proportion of <DL data created too much bias to use the above method, '***median***' values were used as the indicator of the central value in the data. A median is that value above which and below which half of the observations lie. For a data set in which more than half of the observations are <DL, the median will be equal to the detection limit.

A ***'standard deviation'*** is a number that represents the amount of spread around the mean in the data distribution. In a symmetrical distribution, the standard deviation is the number which, when added to and subtracted from the mean, gives the boundaries within which 68.3% of the data lie. Unfortunately, when the data are not symmetrically distributed above and below the mean, as is the case with air quality data, the standard deviation is biassed. Air quality data is 'skewed left', meaning that there is a high frequency of low values which is not balanced by the frequency of high values. The calculated standard deviation is symmetrical (*i.e.* equal range above and below the mean), but when the data are skewed left, the first standard deviation above the mean will not contain as many observations as the first standard deviation below the mean. Nevertheless, for the purposes of data description, standard deviations are the familiar statistic, and the use of standard deviations allows comparison with similar data sets. The reader should be aware of the fact that in air pollution data sets, the first standard deviation above the mean contains somewhat less than the 34.1% of the data than it should by definition contain.

For the sulphur dioxide data, where 3-hour and 24-hour average values must be compared to objectives for these time periods, these averages have been computed using the ***moving (or rolling) average*** method. With this method, every possible consecutive 3-hour time period and every possible 24-hour time period is evaluated, within data capture starting and ending time points. Thus in a year with a complete and unbroken hourly data record, there would be 365*24=8760 hourly observations, 8760-4=8756 3-hour averages, and 8760-22=8738 24-hour averages. By increasing the number of data time periods over which a single reading may have influence, there is effectively 'more data' and more opportunities for exceedences. Thus a single high hourly reading has the potential to create 1 hourly exceedence, three 3-hour exceedences, and many 24-hour exceedences.

4. Measures of Air Quality

4.1 PM_{10}

The quality of the air in a region is evaluated by comparing observed concentrations with air quality objectives that have been set by provincial and national authorities for the protection of the environment and human health. The BC objective for 24-hour periods is 50 $\mu g/m^3$ (ARB 1996) and the proposed Canadian guideline is 60 $\mu g/m^3$ (under development as part of the Canadian Environmental Act, CEPA) These 'objectives' represent the maximum average concentration of PM_{10} that is desirable over a 24 hour period.

4.1.1 NAPS concentration data

The national sampling program collects 24-hour samples every 6^{th} day, for 61 samples in most years. NAPS data 'catches' on average one-sixth of the short-term episodes of high values, if and when they occur, and samples all days of the week equally. Assuming that natural events (such as forest fires) occur randomly in time, and human impacts are either random or related to the 7-day weekly work schedule, the regular NAPS schedule is sufficient to accurately estimate the annual mean.

4.1.2. TEOM concentration data

The highly automated TEOM monitors make determinations of PM_{10} many times an hour and record the hourly average. They 'catch' brief episodes of high ambient concentrations and allow the daily pattern of PM_{10} levels to be evaluated. They also provide regular daily averages for every day, so no extrapolation between sampling days is needed and no impacts to air quality are missed. Annual means based on TEOM are calculated as the average of the daily means.

4.1.3. Vedal Health Increments

Research into health effects of exposure to PM_{10} (Vedal, 1995) has shown that daily average values over 20 $\mu g/m^3$ are associated with increased respiratory and cardiac problems, asthma and obstructive pulmonary disease. Vedal Health Increments (HI) were designed to link air quality monitoring results with these predicted health impacts. Each increase of 10 $\mu g/m^3$ in PM_{10} over 20 $\mu g/m^3$ (in the daily average) is associated with a linear increase in health effects for that day. Thus the number of such increments provides an estimate of the increased impact. Daily increments can be calculated from TEOM data, and those calculated from NAPS data must be multiplied by the number of days between readings to produce an equivalent figure. HI based on NAPS data are not as accurate as those based on continuous data.

Each daily HI is estimated to cause:

- 1.0% increase in total number of deaths
- 3.4% increase in number of deaths due to respiratory problems
- 1.4% increase in number of deaths due to cardiac problems
- 0.8% increase in hospitalizations due to respiratory problems
- 0.6% increase in hospitalizations due to cardiac problems
- 0.7% increase in hospitalizations due to asthma
- 2.3% increase in emergency visits due to chronic obstructive pulmonary disease
- 3.4% increase in emergency visits due to asthma
- 4.1% increase in days absent from school

It is important to note that the incremental health impacts of elevated PM_{10} are based on *daily* measures of health – *e.g.* hospitalizations per day due to respiratory problems. The annual total of HI does not apply to annual measures of health. For example, if a community had 100 HI in a year, this means that on an average daily basis 100 / 365 = 0.27 is the daily average health increment. As regards days absent from school, 0.27 multiplied by 4.1% for the increase per HI in school absenteeism = 1.1% average daily increase in days absent from schools. In other words, a community with 100 HI per year could expect about a 1% increase in school absenteeism.

4.2 Metals

BC Ambient Air Quality 24-hour Objectives for metals are established to protect human health and the environment. Level A objectives constitute the 'maximum desirable' level, below which the air may be considered to be unpolluted. Level B is the 'maximum acceptable' level, and values below this level are consistent with good health of humans, animals and vegetation; sensitive individuals may experience discomfort when exposed to values above the Level B objective. Level C objectives, above which there is a diminishing margin of safety, have not been established for heavy metals in British Columbia.

4.3 SO_2

As with metals, BC Environment has established Ambient Air Quality Objectives for Levels A, B and C. There are separate objectives based on the duration of elevated sulphur dioxide levels: 1-hour, 3-hour, 24-hour and 1 year objectives have been established to protect human health and the environment from exposure to high SO_2 concentrations. Short term objectives reflect the importance of detecting brief exceedences that may not last long enough to effect the daily or annual means but may have serious impact during their short durations. The relevant objective values are plotted on the graphs of SO_2 values.

5. PM_{10} in the Kootenays

PM_{10} levels from 7 NAPS sites and 3 TEOM sites, plus 9 months of TEOM data at Golden, are summarized below. The available data records from 1993 through 1999 were used, although in many cases there were gaps in the record and several sites were not being monitored as early as 1993. Where episodic data were collected to monitor specific events (*e.g.* beehive burning, forest fires, etc.) these extra data were not included in estimates of period means as they would tend to bias the statistics.

Each site is presented with several pages of graphs. The composition, purpose and general interpretation of each graph type is as follows:

- **a**. Time series – all available data plotted against time. This histogram (for NAPS data) or set of annual graphs (TEOM data) shows at a glance when data were collected, when high values occurred, and indicates whether there has been a trend or sudden change in values.
- **b**. Frequency distribution of the data – for all data 1993 - 1999. This gives an overview of the proportion of the time (days) that PM_{10} values were within each 10$\mu g/m^3$ increment within the range of values observed. Each bar of the histogram represents all observations within a 10μg range – *e.g.* the bar labelled '20' is the % frequency of observations with values between 10.01 and 20.00 $\mu g/m^3$.
- **c**. Annual means with standard deviations and maxima. This graph summarizes the data for each year in most concise format, and compares it to the BC objectives and Canadian guidelines. The standard deviation of the year's data is drawn as a pink area behind the histogram bars that represent annual means. The standard deviation indicates the range of values above and below the mean in which 68% of all observations lie. The maximum daily observation of each year is plotted above the year's histogram bar as a downward pointing triangle.
- **d.** Annual frequency of exceedences of BC objectives, Canadian air quality guidelines and Vedal Health Increments. Exceedences are shown as a histogram plotted on the first Y axis (left), while increments are shown on the same graph but plotted on the second Y axis (right). These figures summarize the information on exceedences and show if there have been trends over the 7 year period in the frequency of these excursions, or in health increments. ***Note that for NAPS data, only 1/6 of the days of the year have been measured, and by extrapolation the true number of exceedences and health increments would be estimated to be 6 times the observed numbers reported here.***
- **e.** 6-month period averages – The double bars in this histogram are labelled with one year. The blue bar, 'Winter' is the mean of available data from October of the previous year through March of the current year, *e.g.* the bar labelled 1994 includes the winter data from October 1993 through March 1994. The red bar, 'Summer', is the mean of available data from April through September. These graphs identify the seasonal variation of $PM_{10.}$
- **f.** Monthly Means and Maxima. This set of annual graphs shows the average of NAPS or daily values during each month of monitoring, as well as the maximum NAPS or daily value during the month.
- **g.** Annual Cycle - monthly means across all years. These plots show the annual

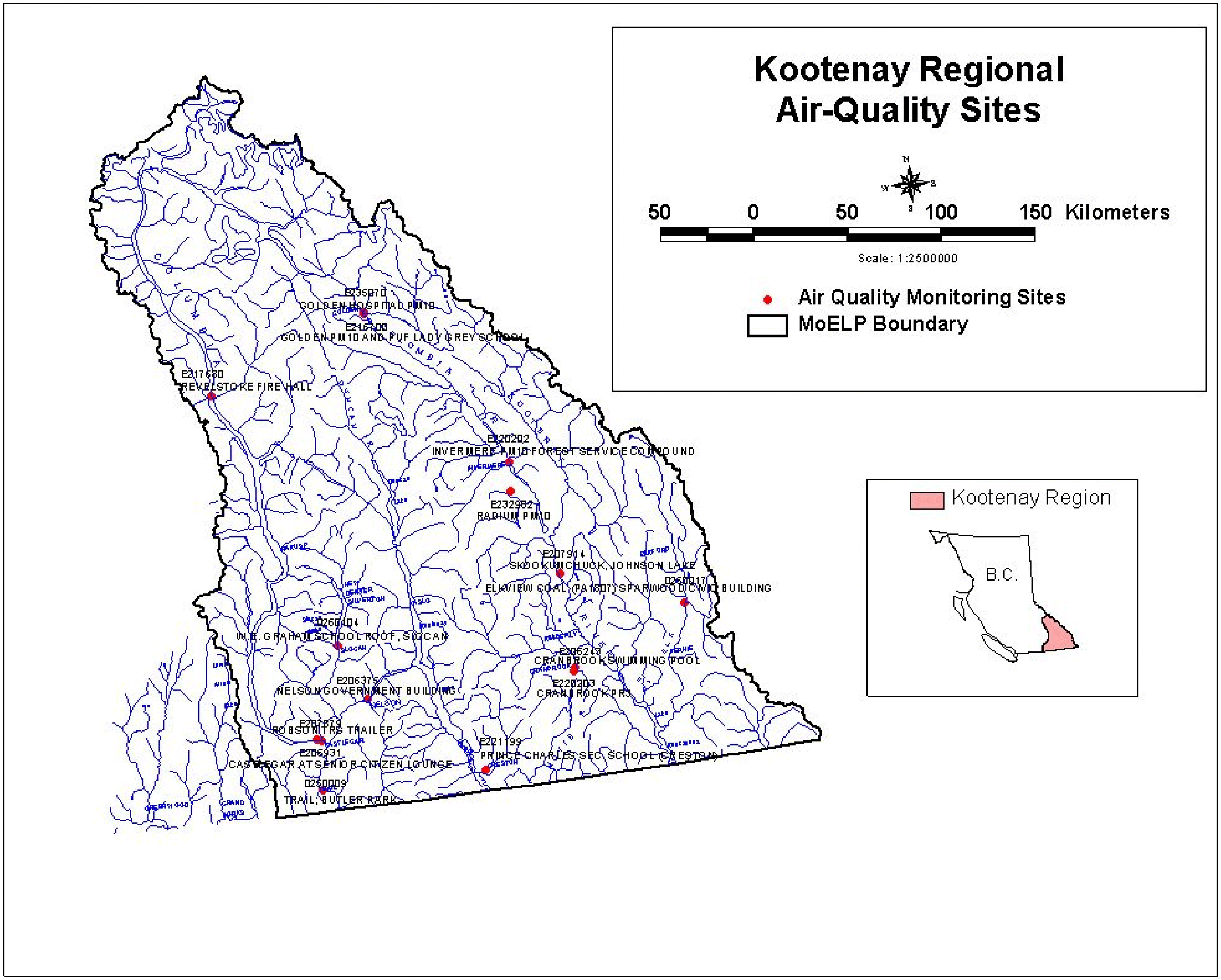
cycle of variation in PM_{10} and identify the months in which high values have most frequently occurred during 1993 - 1999.

- **h.** Daily Cycle - for TEOM data only. These hourly means show the daily cycle, which helps identify the source of PM_{10} pollution and lends understanding to the pattern of human exposure to high levels when they occur.

The data presented graphically is also available in Appendix 1 in table form.

Datasets with less than 75% data capture are indicated with an asterisk in the graphs and tables. Adequate data capture is an important consideration in comparing results. Statistics based on datasets with less than 75% data capture should be considered to be possibly biassed and less reliable than more complete data records.

This study found an improving trend in PM_{10} values at a number of communities in the Kootenays, but values are still high compared to other regions in British Columbia. There are many locations that have several exceedences of the BC objective ($50\mu g/m^3$ per day) each year, and most communities accumulate Vedal Health Increments each year.



Map 1. Kootenay Regional Air-Quality Sites

5.1 CASTLEGAR

Castlegar has a high volume NAPS station; data from January 1, 1993 through August 28, 1999 were made available for this report. The time series graph begins the graphical record for Castlegar in **Figure 1a**. Data capture was better than 75% in all years except for 1999 in which there was a gap from February 23rd through May 6th, and then the available data record ended in August. There is the appearance of a slight declining trend in PM_{10} values from 1993 through 1996, but a return to higher values in 1997 and subsequently.

The frequency distribution of data for Castlegar (**Figure 1b**) shows that the modal value of PM_{10} during the 7 year period was 10 - 20 $\mu g/m^3$. Concentrations of PM_{10} above the BC objective of 50 $\mu g/m^3$ occurred approximately 4% of the time. The time series shows no obvious increasing or decreasing trend in high values. The magnitude of occasional peak values appears to have declined over the 7 year period, but it is not possible to be certain of this with NAPS data since many exceedences may have occurred on days that were not sampled.

The annual summary chart (**Figure 1c**) for Castlegar clearly shows the declining trend in PM_{10} values until 1996 and the increasing trend afterwards. Annual means ranged from 17 to 28 $\mu g/m^3$. Although most of the maxima were above BC objectives and Canadian guidelines, all of the means and standard deviations were well below.

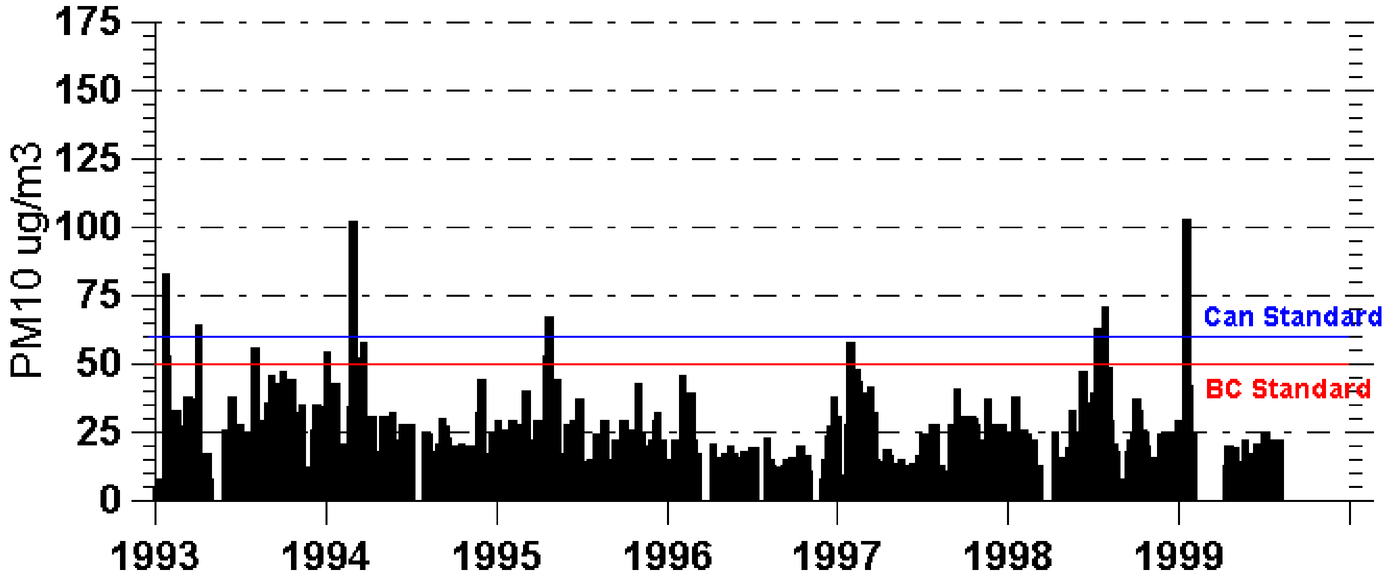
There were exceedences of BC objectives and Canadian guidelines (**Figure 1d**) in every year except 1996 at Castlegar. Most of these exceedences occurred during the winter months. Although exceedences were infrequent, the Vedal Health Increments (HI) plotted on the same figure (right side Y axis) indicate that there are probably health impacts due to elevated PM_{10} in this community. Since this is NAPS data, the true number of exceedences and health increments may be 6 times the numbers shown. The annual average accumulation of 19.8 HI is equivalent to 119 HI if measured daily. At this level of pollution, the impacts indicated by Vedal would be less than 1% per year except for deaths due to respiratory disease (1% increase), emergency visits due to asthma (1% increase), and days absent from school (1% increase).

There is no consistent seasonal pattern to mean PM_{10} values at Castlegar, as shown in **Figure 1e.** The final bar includes data from only April and May.

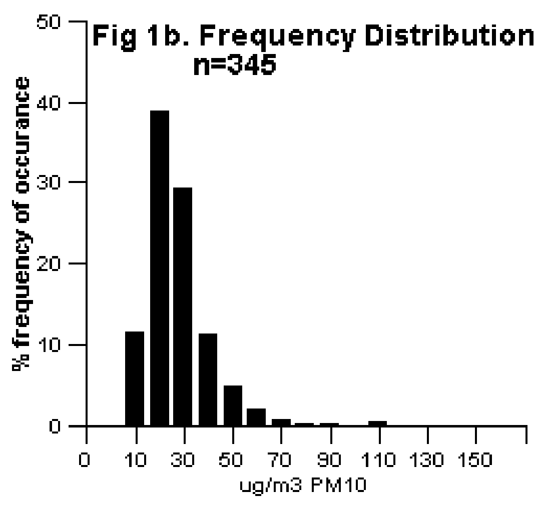
The plots of monthly means and maxima is shown in **Figure 1f**. Note that these monthly means based on only 4 or 5 observations are not as well-determined as means of daily data would be.

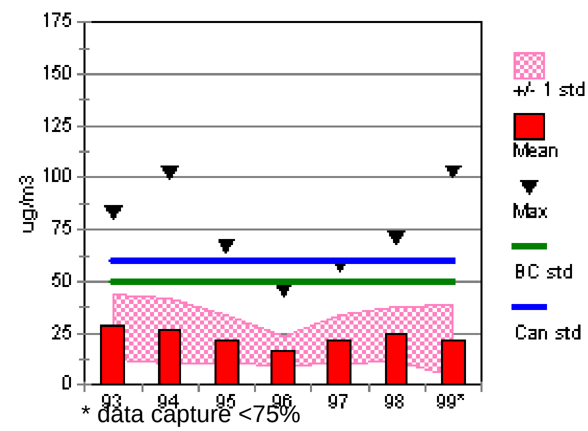
The Annual Cycle (**Figure 1g**) highlights the elevated winter (Feb - Apr) PM_{10} levels; which is often related to burning wood for domestic heating. There is a secondary peak in August which may be related to dry summer conditions such as dust, forestry activities or wild fire.

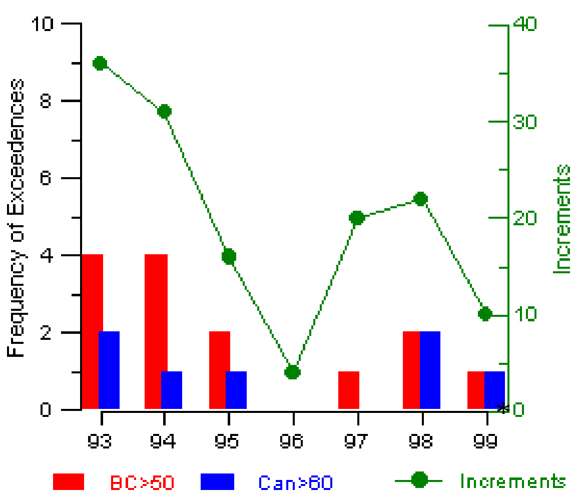
Figure 1 **CASTLEGAR PM_{10}**



1a. Time Series







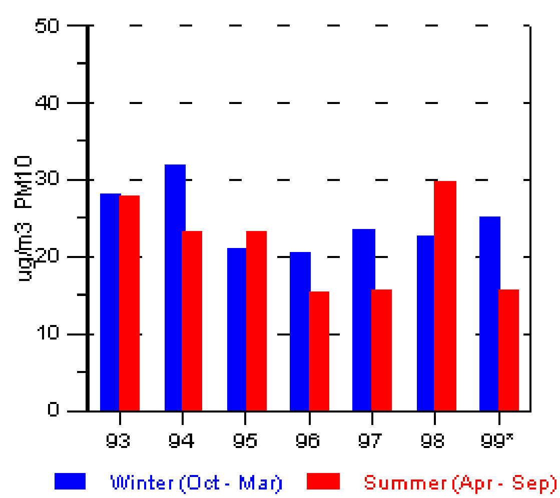


Figure 1 continued–CASTLEGAR PM_{10}

Figure 1f. Monthly Means and Maxima

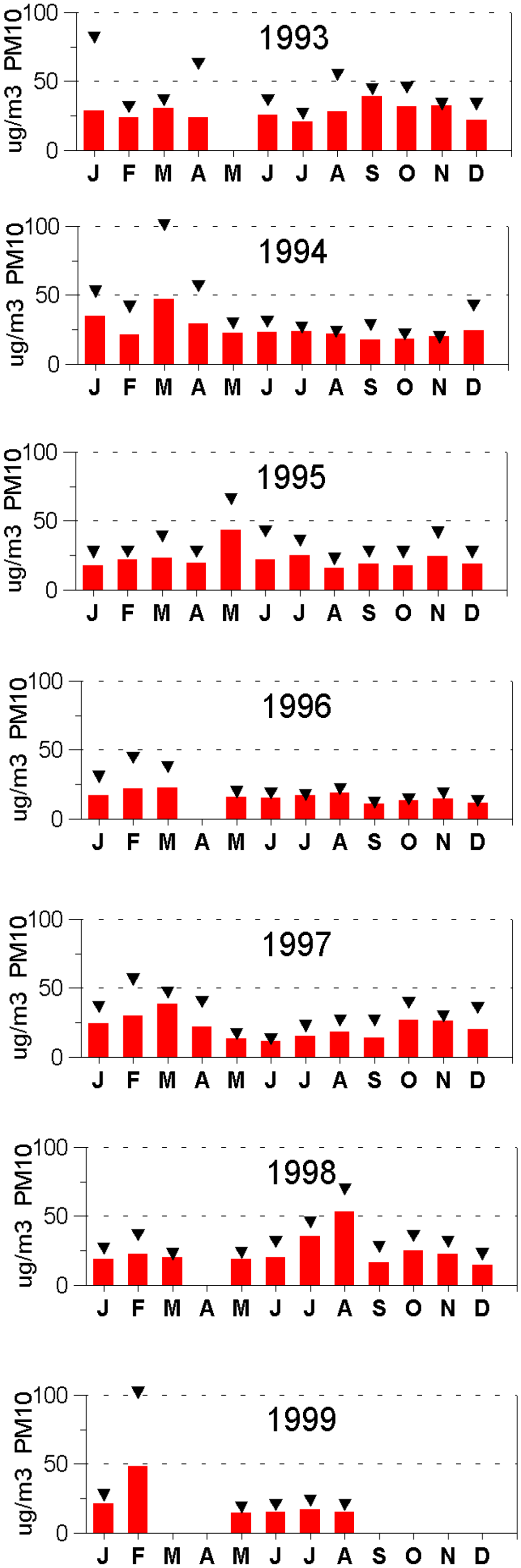
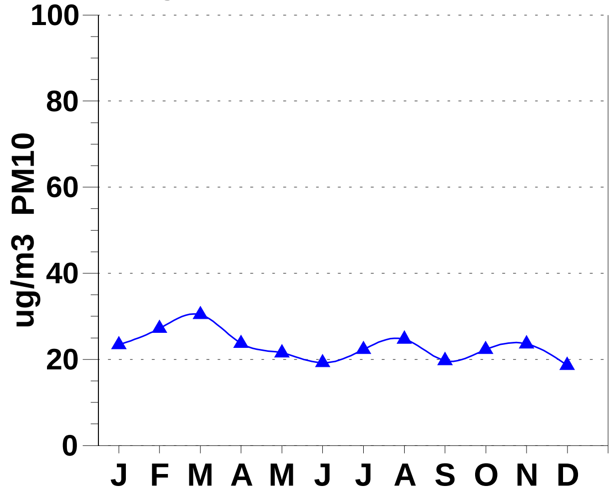


Fig 1g. Annual Cycle of PM10 Monthly mean value 1993 - 1999



5.2 GOLDEN

The NAPS station at Golden (**Figure 2a**) has been augmented (later replaced) with a TEOM station which came on line on February 11, 1999 (**Figure 2a1**). Thus the data are a combination of 6-day interval and hourly data. Data capture was greater than 75% for all years.

The NAPS data 1993 - 1998 show a clear annual cycle with elevated values occurring most frequently during the winter months; this pattern is consistent with wood burning for heat being a dominant contributor to high PM_{10}. The continuous data for 1999 show very high values in February and March. When both types of samplers were operating, in February, the continuous TEOM monitor picked up much more PM_{10} than the manual NAPS monitor.

NAPS and TEOM data were used together to calculate the frequency distribution (**Figure 2b**) of these data. The modal value of PM_{10} is 10 - 20 $\mu g/m^3$. The high 'tail' of this distribution is quite drawn out, and 13% of the observations are ≥ 50 $\mu g/m^3$.

The annual summary chart, **Figure 2c**, shows annual means between 27 and 39 $\mu g/m^3$, which are the highest mean values found among the Kootenay communities in this report. There is no obvious time trend in these annual means. The upper end of the standard deviations for the annual datasets skirts the BC objective value of 50 $\mu g/m^3$, and indicates that there are frequent exceedences in this area.

In order to combine NAPS records with daily TEOM records for the calculation of exceedences and health increments (HI) (**Figure 2d)** each NAPS record was multiplied by the number of days between measurements. Therefore the resulting numbers are much larger (approximately 6 x) than the similar graphs for the communities monitored with NAPS data only. (See discussion of the Castlegar HI data on page 10.) HI averages 388 total per year, and 1.06 increments *per day* in Golden, which translates into annual impacts slightly greater than the list on page 5; *e.g.* 1.06% increase in number of deaths.

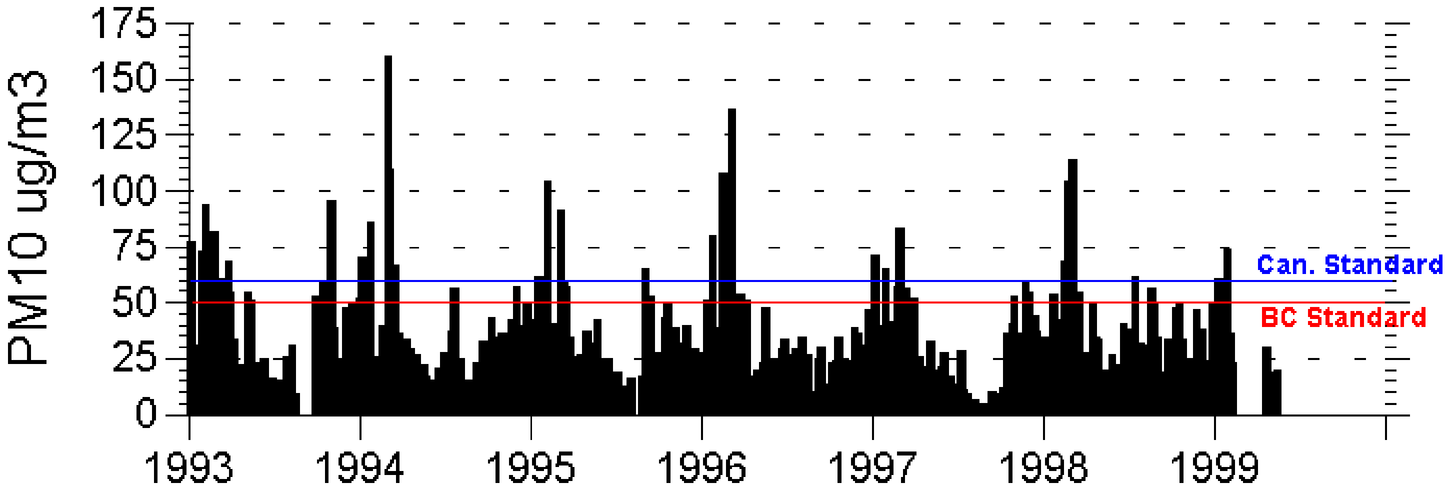
The plot of seasonal means (**Figure 2e**) shows that winter levels of PM_{10} are consistently higher than summer values. The lower mean shown for the winter ('00*') is based on incomplete data, being only the months of October - December 1999; the time series shows that the highest values occur during January - March. Residential wood burning stoves and road dust are the likely causes of such a pattern. While summer means are similar to those in most Kootenay communities, the winter PM_{10} values at Golden are the highest in the province (SOE website).

The plots of monthly means and maxima is shown in **Figure 2f**. The monthly means based on NAPS data (1993 - 1998) are not as accurate as the monthly means based on daily data for 1999.

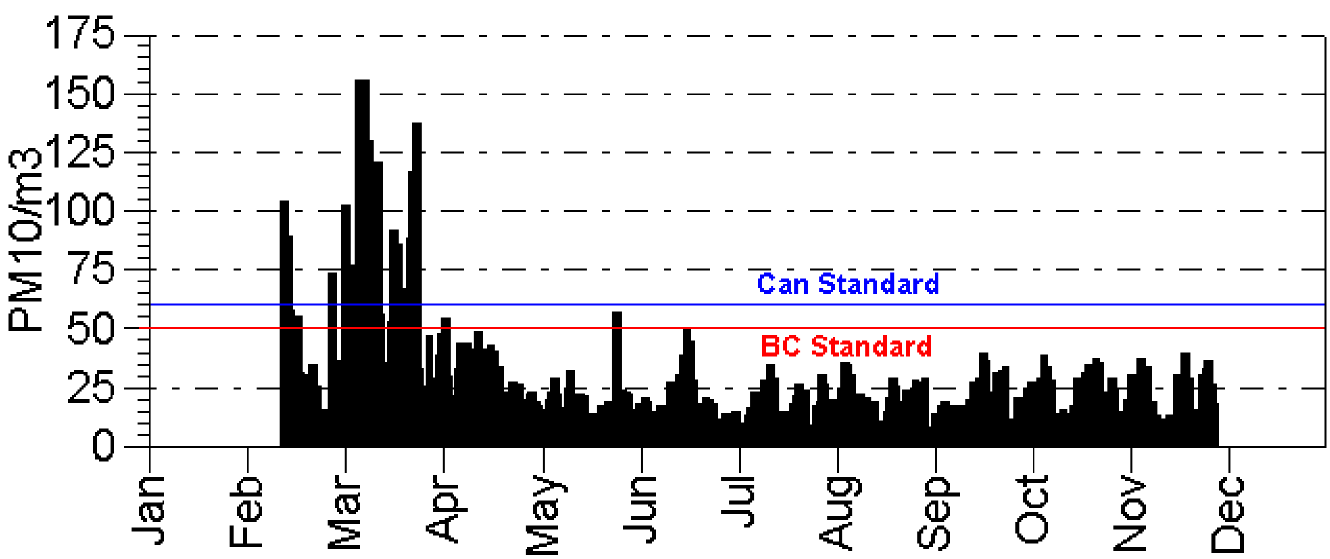
The Annual Cycle (**Figure 2g**) shows higher values from October through March, but quite a bit of variation throughout the year. The high mean value for March appears to occur not because March PM_{10} values are always much higher than other months but rather because they have never been low during the 7 year period. Likewise, June is not always the lowest month, but it did not show any elevated PM_{10} levels.

The plot of hourly means from the TEOM data (**Figure 2h**) shows a well-defined daily cycle with peak levels of PM_{10} between 6 - 8 am and much higher peak levels between 6 - 9 pm each day. These hours are the primary home heating hours during the winter; they are a little early and late respectively to correspond with road traffic, and there is not a likely connection with forestry or industrial activity at these times. The hour-to-hour variation at Golden has the largest amplitude of any site included in this report, and the high hourly values observed are the highest.

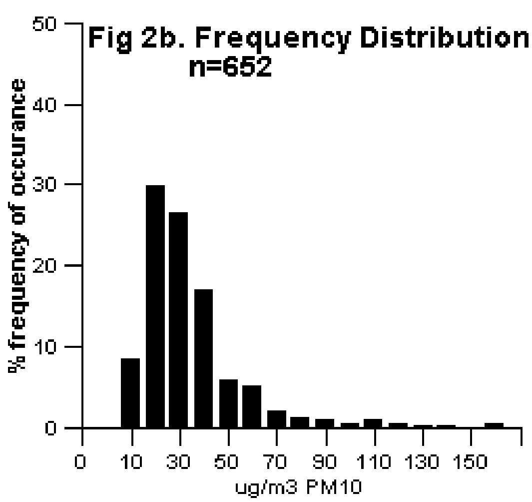
Figure 2. **GOLDEN PM$_{10}$**



2a. Time series -- NAPS data



2a1 Continuous data, 1999



2c. Annual Means, std. dev. & Maxima

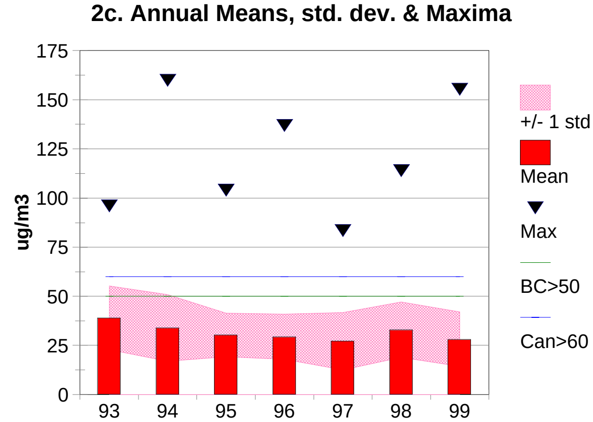


Figure 2 continued – GOLDEN PM_{10}

Fig 2d. Exceedences of Air Quality Standards

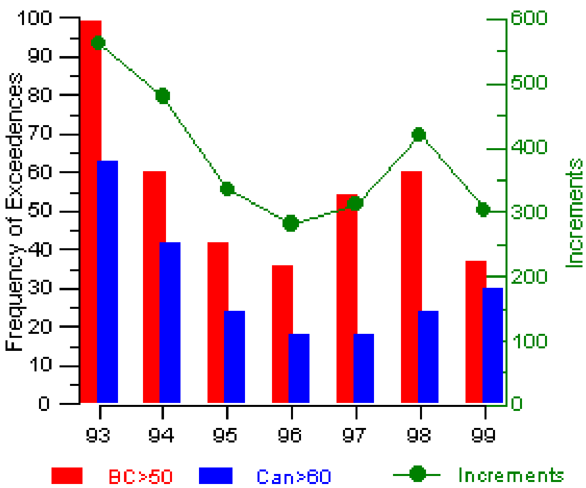


Fig 2e. 6-Month Period Averages

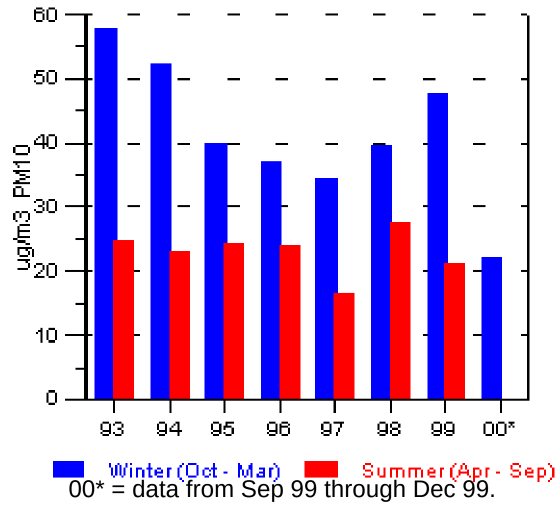
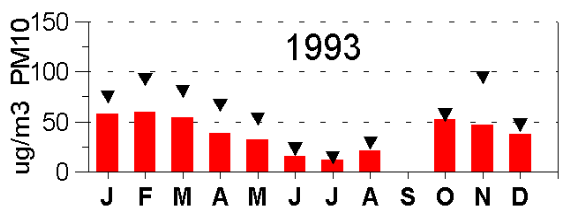
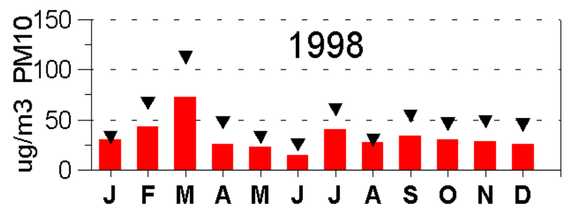
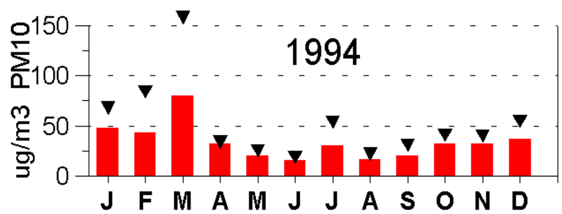
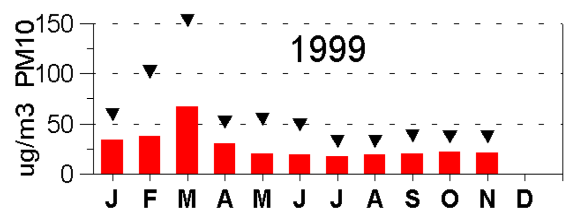


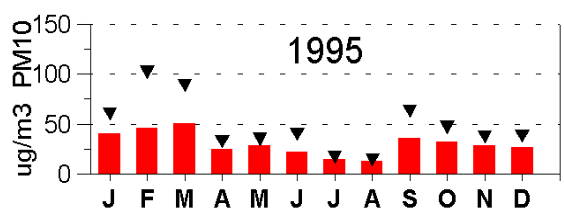
Figure 2f. Monthly Means and Maxima

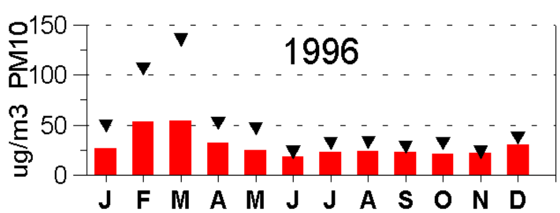












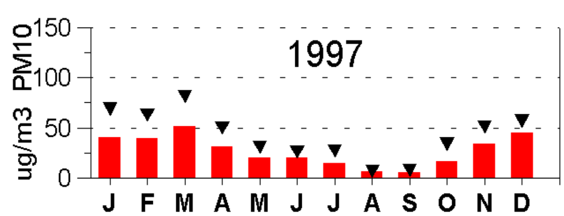


Fig 2g. Annual Cycle of PM10
Monthly mean value 1993 - 1999

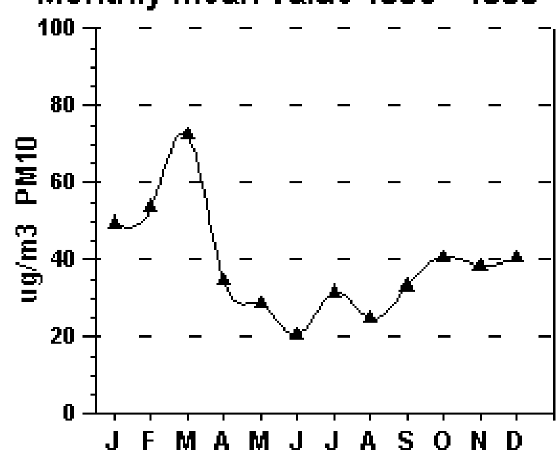
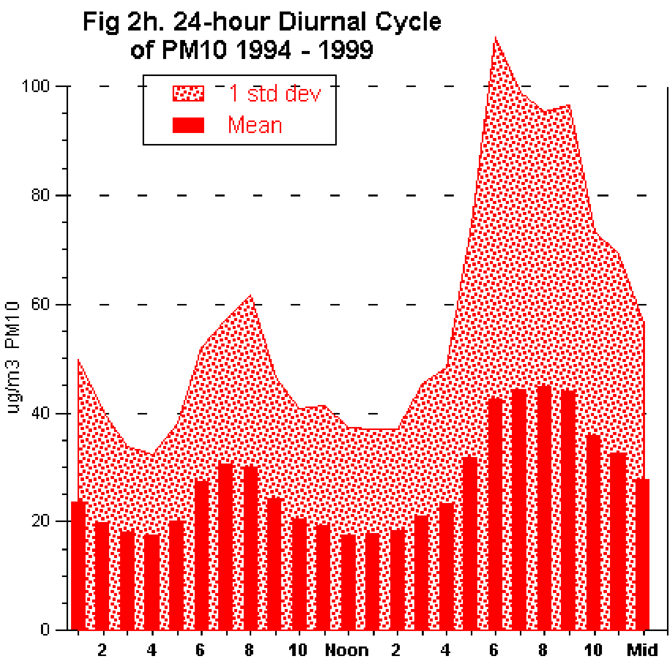


Figure 2 continued – GOLDEN PM_{10}



5.3 INVERMERE

Invermere has been monitored with a NAPS station since March 1994 (**Figure 3a**). Due to the late start in 1994, data capture for this year is less than 75% although the record is complete after startup. The record for 1999 is also less than 75% data capture because of the gap in March and April and the end of the record (or available data) in May. The data from 1994 through 1999 show no trends, and particulate matter levels rarely exceed BC objectives or Canadian guidelines.

The modal PM_{10} value is 10 - 20 $\mu g/m^3$ (**Figure 3b**).

The annual summary of means and standard deviations (**Figure 3c)** illustrates the low levels of PM_{10} in this community, but most years have had maxima that exceeded BC and Canadian objectives.

The plot of exceedences (**Figure 3d**) shows that despite the low number of values greater than the BC objectives or Canadian guidelines, the number of Vedal Health Increments (HI) is substantial. The data frequency distribution shows that a high proportion of the Invermere data falls between 20 and 50 $\mu g/m^3$, and in this range health increments are accumulating even though there are no exceedences flagged. Note that the results for 1999 are based on only 23% data capture, and probably are not a good estimate for the entire year. Since this is NAPS data, the true number of exceedences and health increments may be 6 times the numbers shown. The annual average of 18.3 HI per year is equivalent to 110 HI per year if HI could be measured daily.

Seasonal means (**Figure 3e**) at Invermere show higher winter levels. Note that the first winter bar and the last summer bar are based on incomplete data.

Monthly means and maxima (**Figure 3f**) are consistent with these observations.

Other than higher values during February and March, the Annual Cycle (**Figure 3g**) shows no strong patterns.

Figure 3. **INVERMERE PM_{10}**

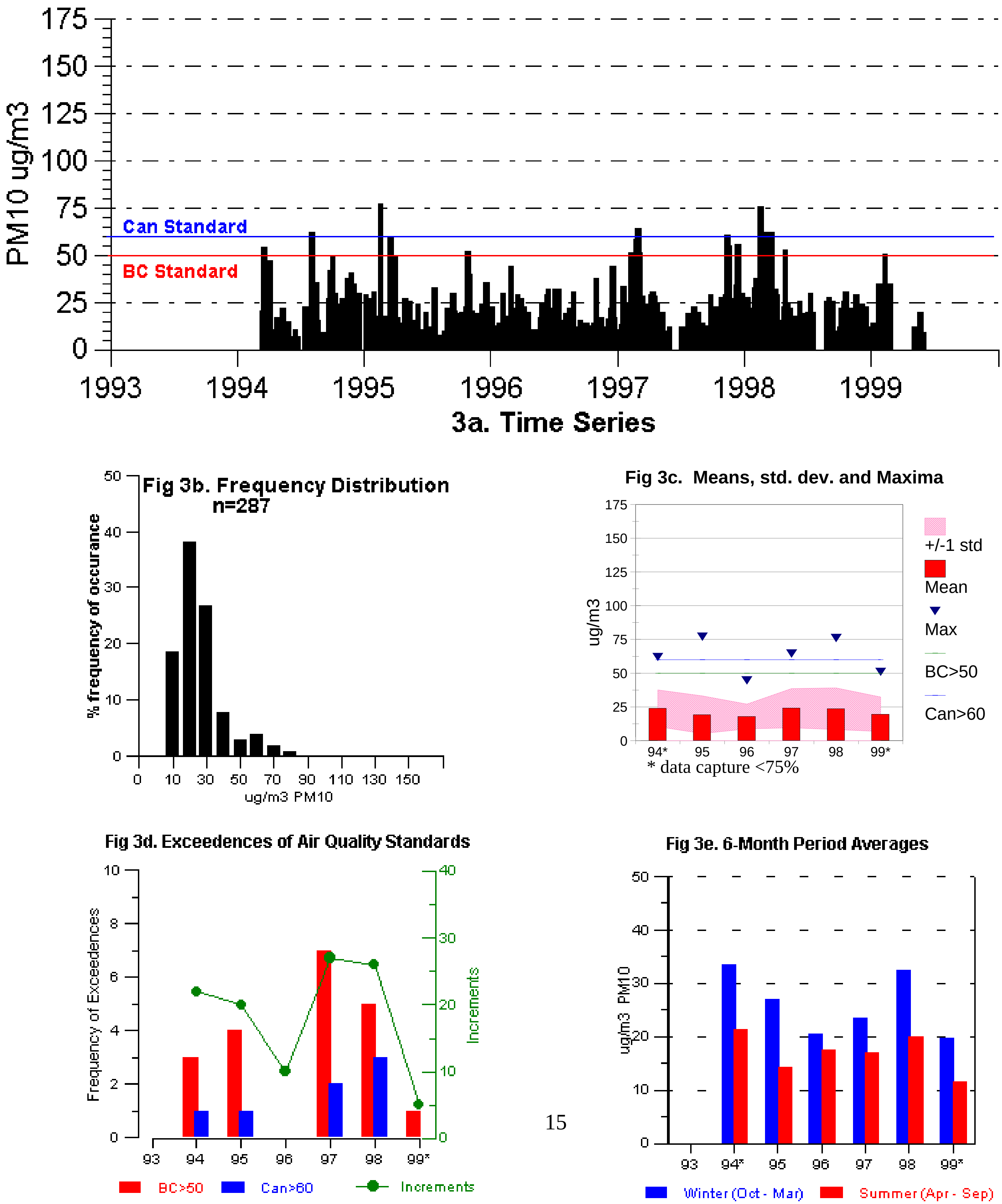
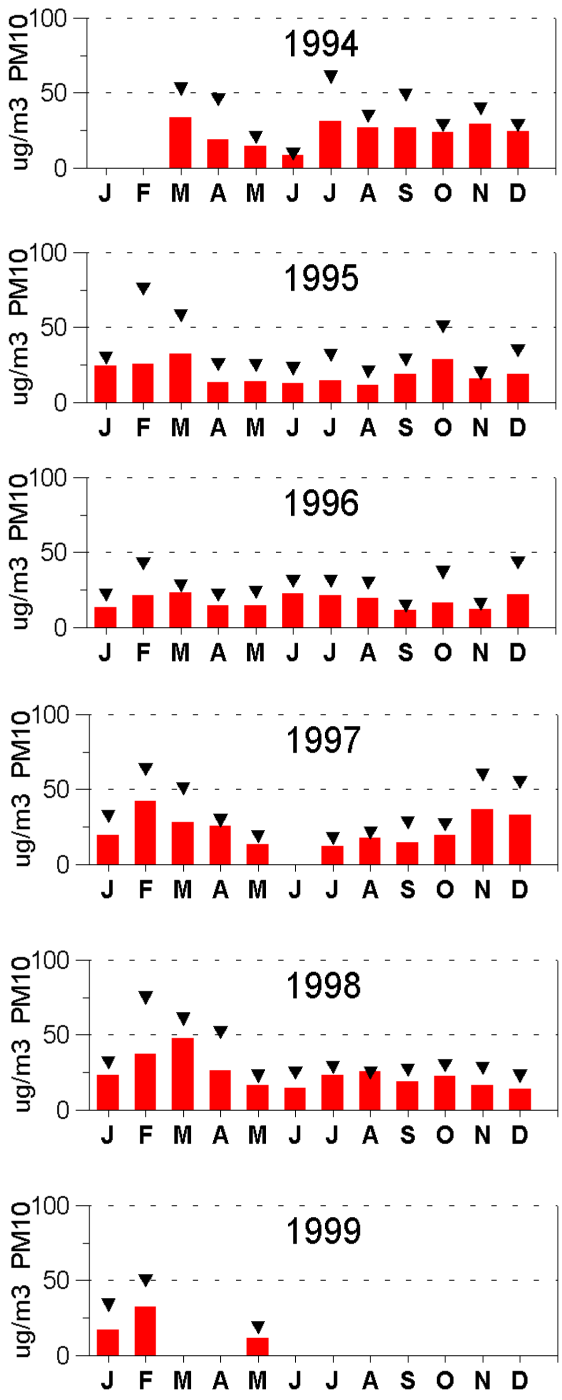
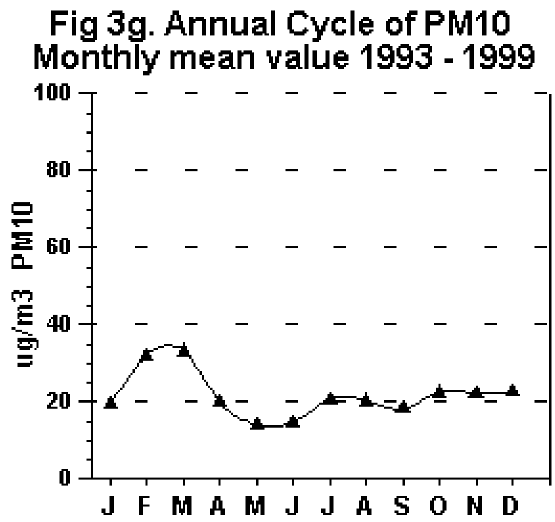


Figure 3 continued – INVERMERE PM_{10}

Figure 3f. Monthly Means and Maxima





5.4 JOHNSON LAKE

The NAPS record of PM_{10} at Johnson Lake (**Figure 4a)** shows low levels during most of the 7 year period of this data summary. The summer of 1998 had the highest values, which occurred during two episodes (one in late April / early May, and one in July) but even these included only one exceedence of the BC objective.

The modal value of PM_{10} (**Figure 4b**) is 0 - 10 $\mu g/m^3$, and only a small fraction of observed values were over 40 $\mu g/m^3$. Johnson Lake is one of the cleaner areas being monitored in the Kootenays, and results from this area are used as a 'pristine' baseline.

The annual summary chart (**Figure 4c**) also clearly shows the low average values and low standard deviations of this site.

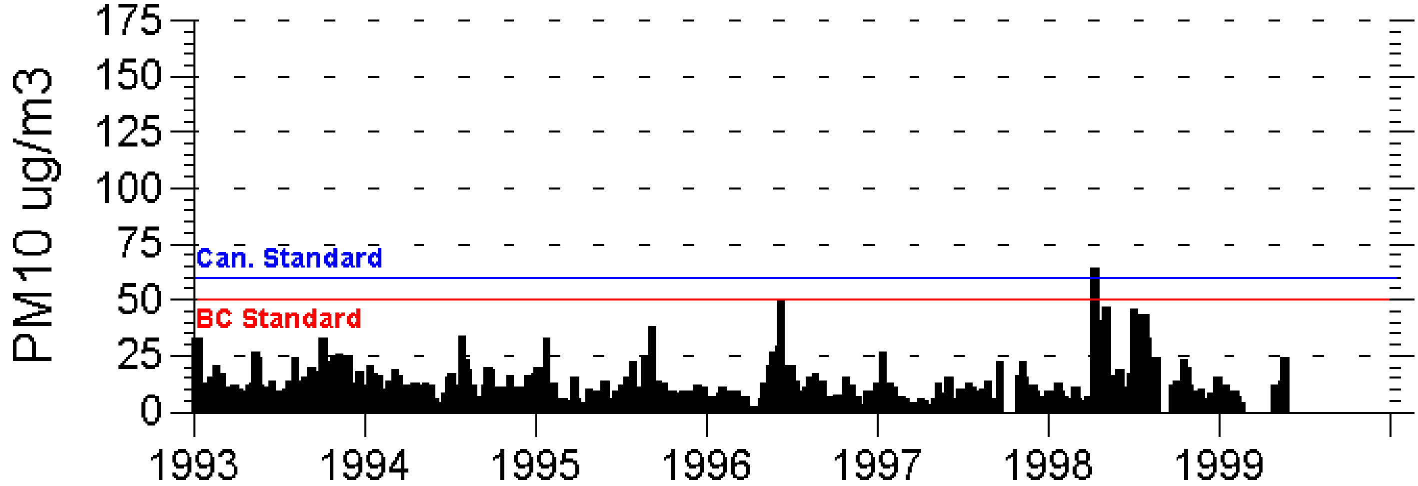
The record of exceedences and Vedal Health Increments (**Figure 4d**) also shows minimal problems with PM_{10} at Johnson Lake. Since this is NAPS data, the true number of exceedences and health increments may be 6 times the numbers shown. The annual average of 3.4 HI is equivalent to 20 HI if measured daily. Johnson Lake has the lowest number of Health Increments of the communities covered in this report.

Seasonal means (**Figure 4e**) at Johnson Lake do not show a consistent pattern of winter or summer elevations. The two episodes of high values in 1998 both occurred during the 'summer' period of that year in which there were a number of large forest fires in BC; these two data points cause the mean of this period to be the highest for this site.

Monthly means and maxima (**Figure 4f**) are consistent with these observations.

The Annual Cycle (**Figure 4g**) at Johnson Lake shows no strong pattern other than a slight elevation of PM_{10} during July and August.

Figure 4. **JOHNSON LAKE PM_{10}**



4a. Time series

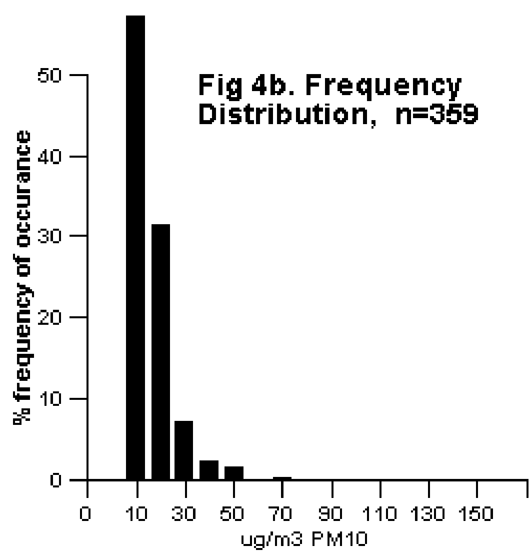
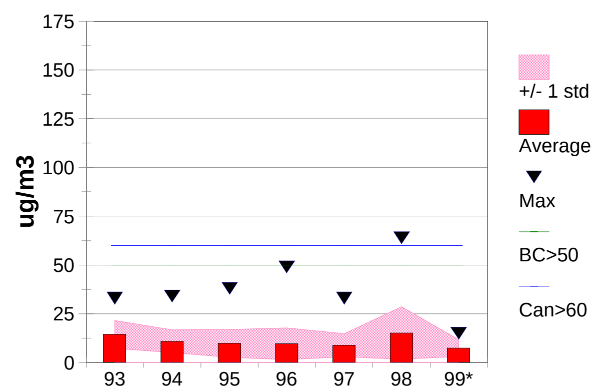


Fig 4c Means, std. dev. and Max values



* data capture >75%

Fig 4d. Exceedences of Air Quality Standards

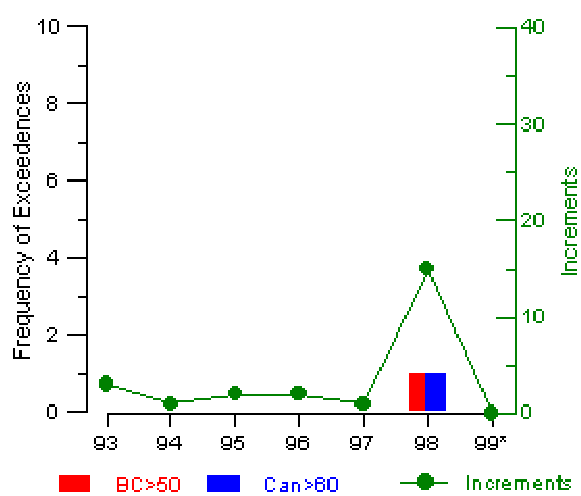


Fig 4e. 6-Month Period Averages

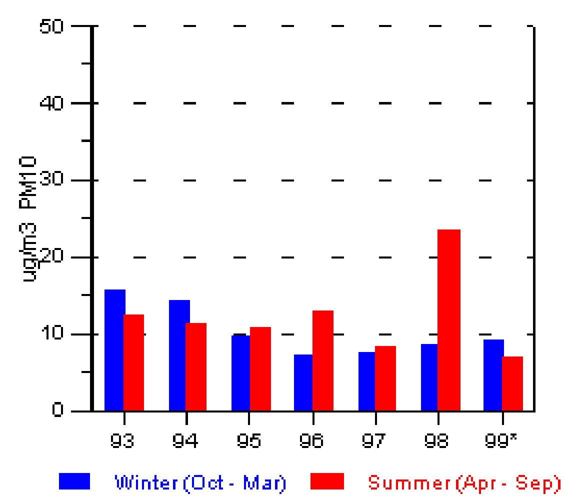
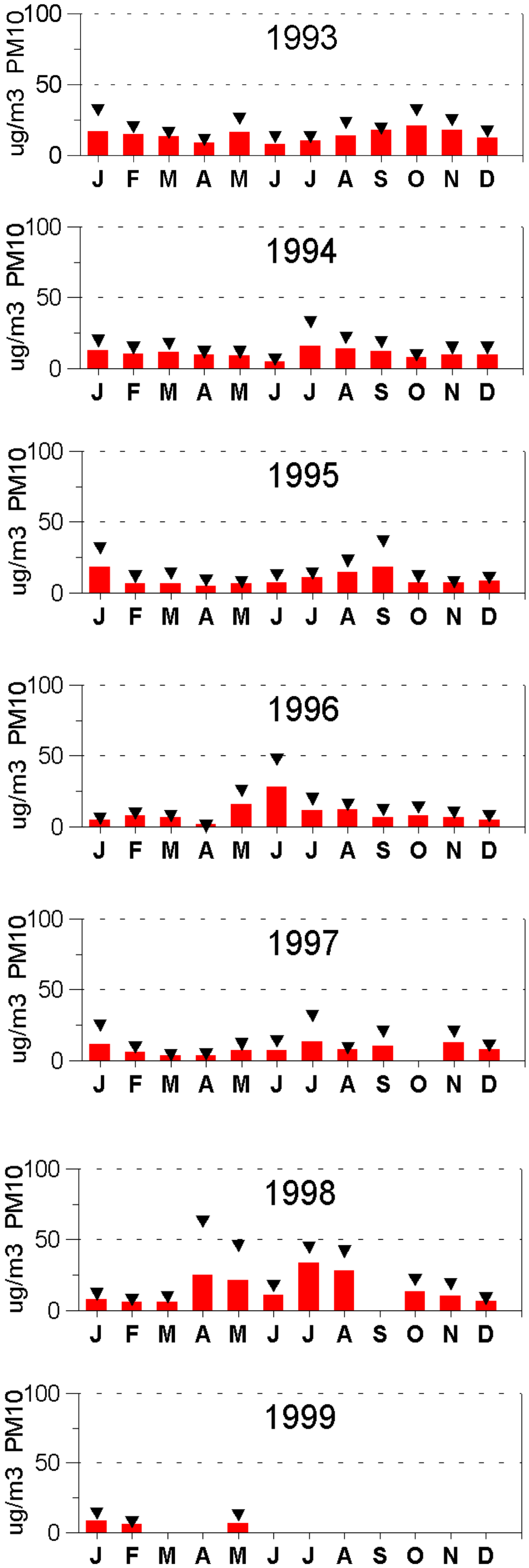
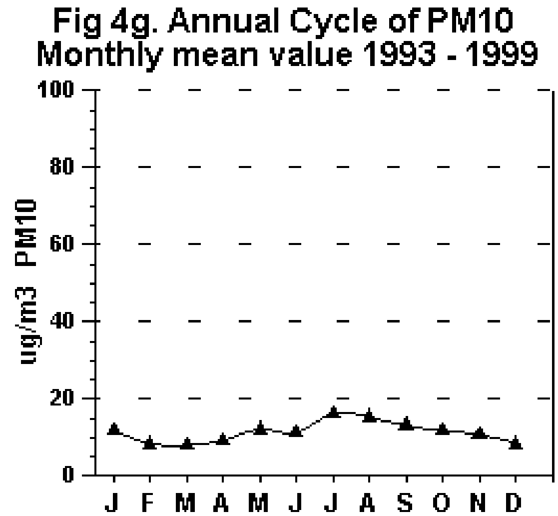


Figure 4 continued – JOHNSON LAKE PM_{10}

Figure 4f. Monthly Means and Maxima





5.5 NELSON

Particulate matter at Nelson (**Figure 5a**) was monitored sporadically in 1993 and until September of 1994; these two years have less than 75% data capture. The record for 1999 was also incomplete. In addition, there is a brief gap in the 1998 record occurring during the time of year in which the highest values of 1996 and 1997 occurred.

The 7 year time series shows a slight increasing trend during the period 1993 - 1999, with both the frequency of high values and the average value gradually creeping upward.

The frequency distribution (**Figure 5b**) of the 319 observations has its mode at 10 - 20 $\mu g/m^3$, which is the same as most of the other communities in this data report.

The graph of annual means, standard deviations and maxima (**Figure 5c**) shows the slight increasing trend in PM_{10} values, but also shows that the standard deviation has remained below the BC objective.

Figure 5d clearly shows an increasing trend in exceedences and health increments (HI) at Nelson, bearing in mind the low rate of data capture for 1999. Since this is NAPS data, only 1/6th of the days have been measured, and therefore the estimated total number of exceedences and increments would be approximately 6 times these values. The annual average of 17.3 HI is equivalent to 104 HI if measured daily, and the 50 HI measured in 1998 (the last full year of data collection) is equivalent to 300 HI if measured daily.

Seasonal means at Nelson (**Figure 5e**) show that the summer means that have increased over recent years more than winter means. Data for 1993, 1994 and 1999 is incomplete.

Monthly means and maxima by years (**Figure 5f**) distinguishes two very different summers in 1997 and 1998, with the first having fairly consistent PM_{10} from May through September while 1998 had high values in July and August. 1998 results appear to have been influenced by long-range transport of particulate matter from forest fires in Washington State, Alberta, Saskatchewan, the Northwest Territories and the Yukon.

The Annual Cycle (**Figure 5g**) at Nelson indicates similar high values in winter (Feb - April) and in the warmest months (July-August).

Figure 5. **NELSON PM_{10}**

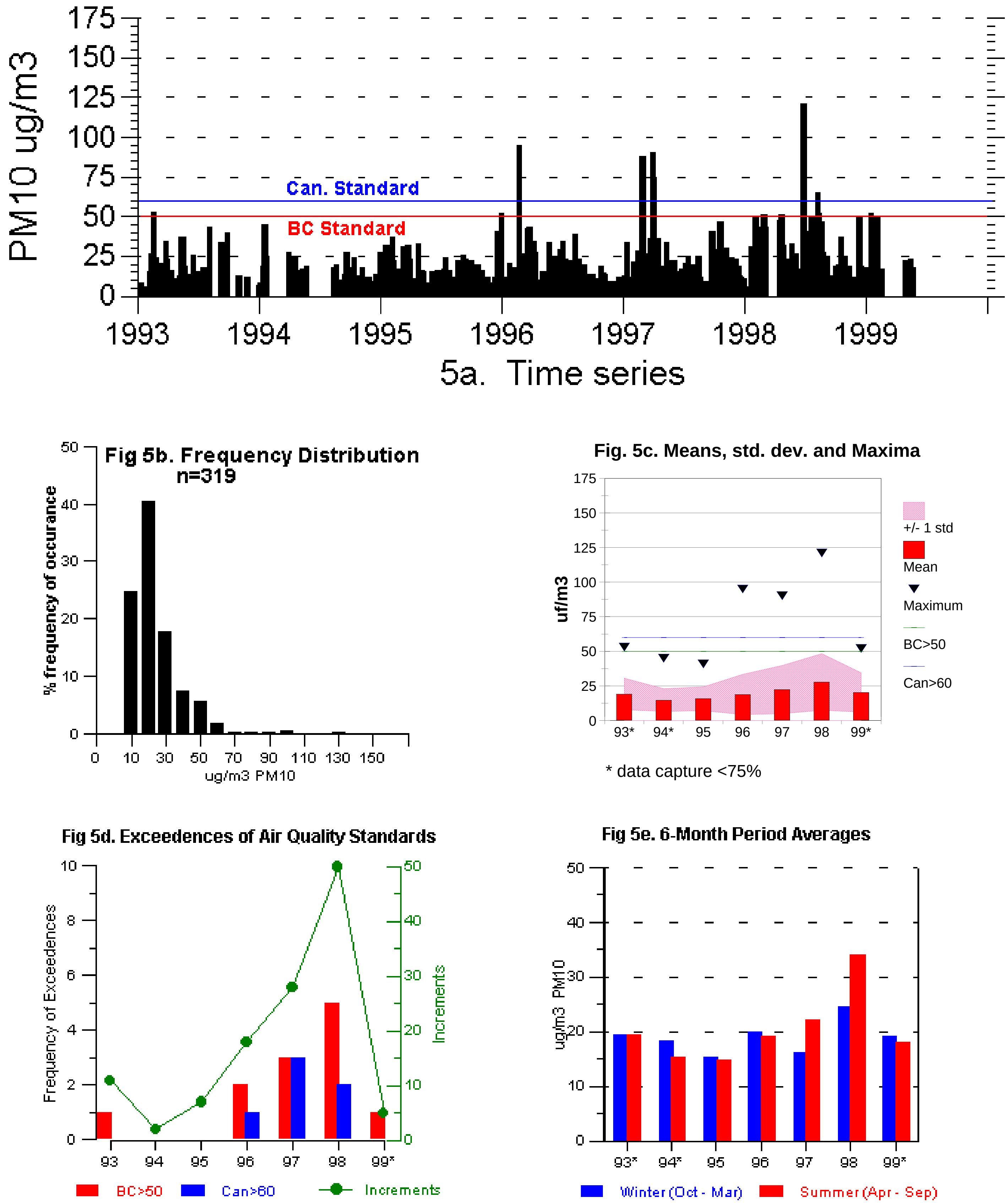


Figure 5 continued – NELSON PM_{10}

Figure 5f. Monthly Means and Maxima

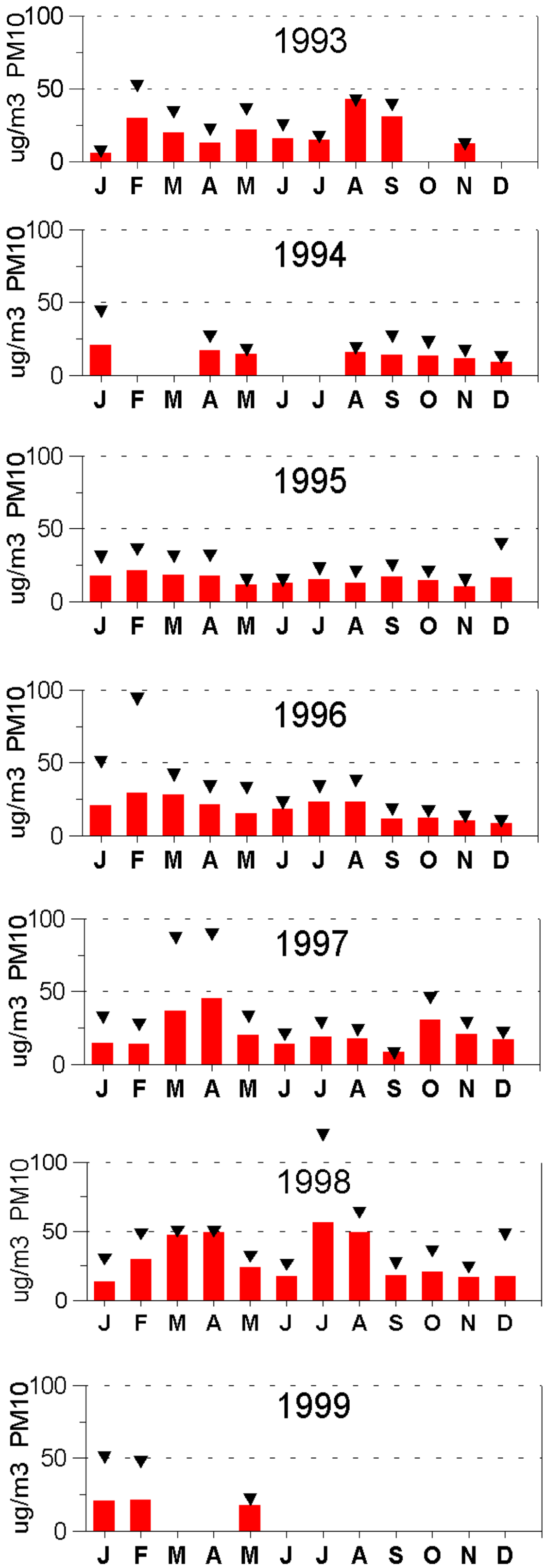
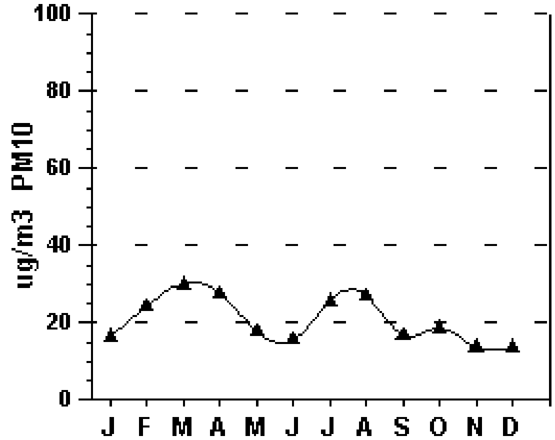


Fig 5g. Annual Cycle of PM10 Monthly mean value 1993 - 1999



5.6 REVELSTOKE

The time series of NAPS data for Revelstoke (**Figure 6a**) has few gaps in the years 1993 through 1998, but only partial data for 1999. PM_{10} values are generally low, with few exceedences of BC or Canadian objectives. There appears to be a slight elevation in values in 1997 and 1998.

The modal value in the frequency distribution (**Figure 6b**) of the 340 records from Revelstoke is 10 - 20 $\mu g/m^3$.

Annual means, standard deviations and maxima (**Figure 6c**) for Revelstoke show the consistency of means between 20 and 25 $\mu g/m^3$ and standard deviations below 40 $\mu g/m^3$. Most years had one or more values above the BC objective (50 $\mu g/m^3$) but few above the Canadian guideline (60 $\mu g/m^3$).

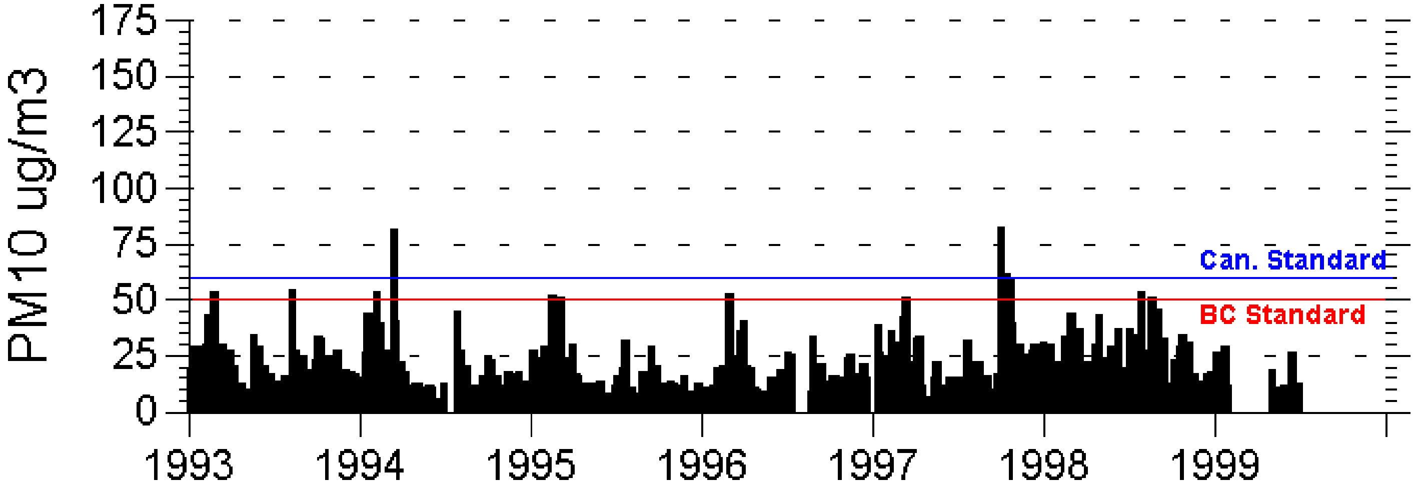
Although there are exceedences (**Figure 6d**) of the BC Air Quality Objective every year, there are only 2 exceedences of the Canadian guideline, and the number of Vedal Health Increments (HI) is below average for the monitored Kootenay communities. Since this is NAPS data, the true number of exceedences and health increments may be 6 times the numbers shown. The annual average accumulation of 10.0 HI is equivalent to 60 HI if particulates were measured daily. At this level, Vedal's relationship to health impacts would predict less than 1% increase in the annual average rate of any of the parameters shown on page 5.

Seasonal means (**Figure 6e**) show a pattern of winter values averaging higher than summer values. The final winter bar is missing February and March data, while the summer bar is based on data from May and June only.

Monthly means and maxima (**Figure 6f**) are consistent with this interpretation.

The Annual Cycle of PM_{10} at Revelstoke shows some late winter and mid-summer high monthly means like many of the other communities in the Kootenays; this may be related to dust from the river area (railway and road dust).

Figure 6. **Revelstoke PM_{10}**



6a. Time series

Fig 6b. Frequency Distribution
n=340

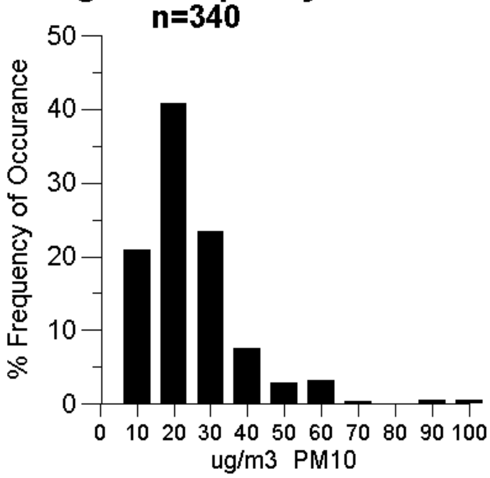
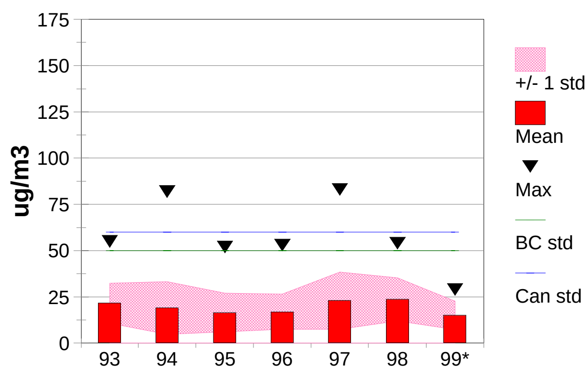


Fig 6c. Means, std. dev. & Maxima



* data capture <75%

Fig 6d. Exceedences of Air Quality Standards

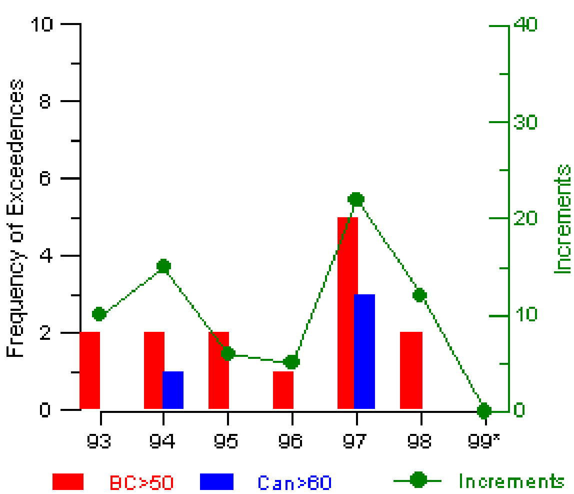


Fig 6e. 6-Month Period Averages

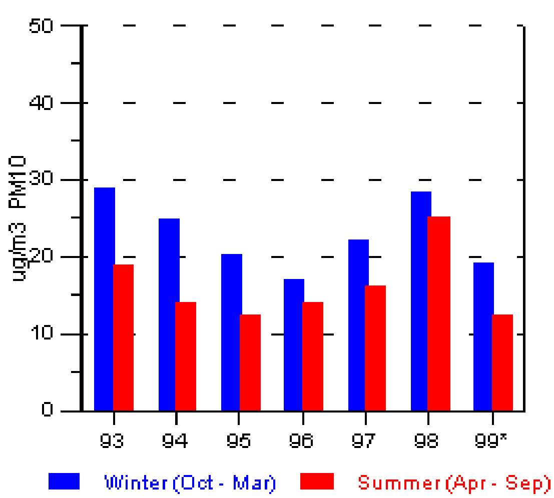
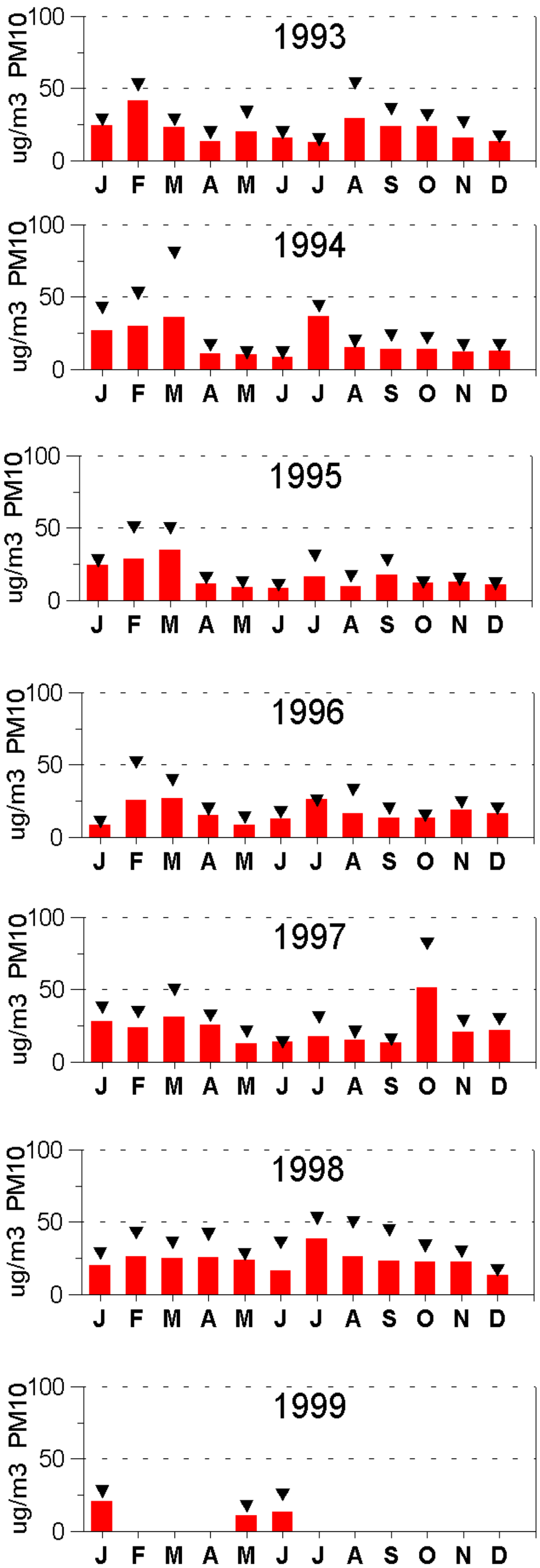
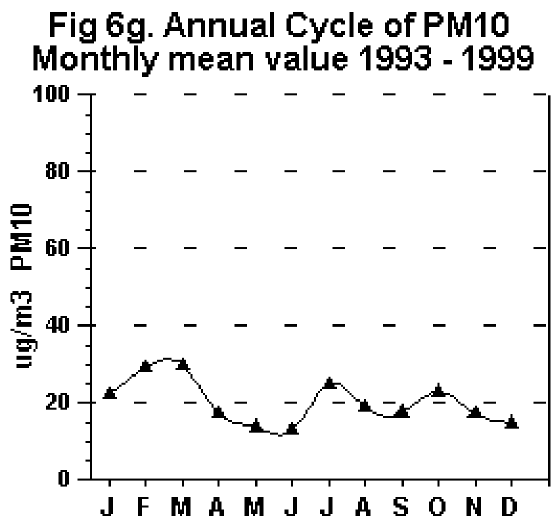


Figure 6 continued – REVELSTOKE PM_{10}

Figure 6f. Monthly Means and Maxima





5.7 SLOCAN

Figure 7a shows that high volume data was collected on an irregular NAPS schedule at Slocan in 1993 and 1994, but the frequency of sampling was not maintained in 1995. No data were collected in 1996 and 1997. Some data was collected again in the winter of 1998/1999, but not on a regular (*i.e.* 6-day) NAPS schedule. Data collection may have been done to monitor particular events, and therefore may be biassed. These data are therefore not directly comparable to NAPS data from other communities.

The frequency distribution (**Figure 7b**) of Slocan data (155 records) has a mode of 10 - 20 $\mu g/m^3$.

The annual means, standard deviations and maxima in **Figure 7c** are the lowest PM_{10} values among the Kootenay communities in this report.

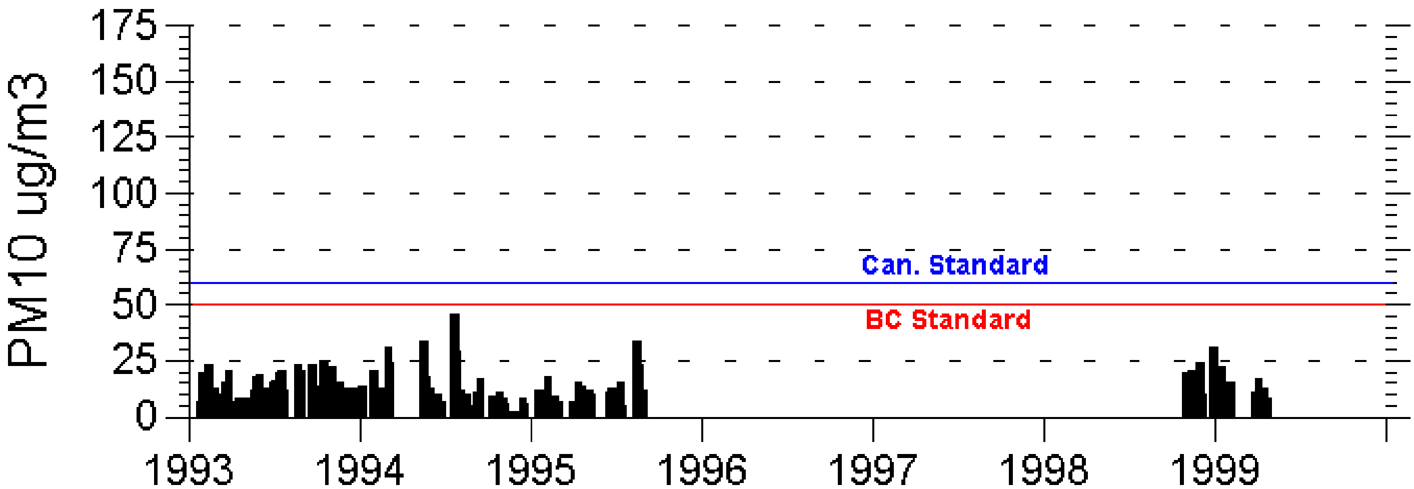
Since the data for Slocan is substantially incomplete, it is difficult to interpret the plot of exceedences and health increments (HI) (**Figure 7d**); possibly much has been missed, but the data that were collected do not indicate any problems in this area.

Seasonal means calculated on incomplete data at Slocan (**Figure 7e**) show no particular patterns.

Monthly means and maxima (**Figure 7f**) from incomplete data are consistent with the interpretation above.

Despite incomplete data at Slocan, the Annual Cycle plot (**Figure 7g**) shows fairly clearly that this community is not affected by winter sources of PM_{10}. The high value shown for August is the product of the one elevated record in 1995.

Figure 7. **Slocan PM$_{10}$**



7a. Time series

Fig 7b. Frequency Distribution
n=155

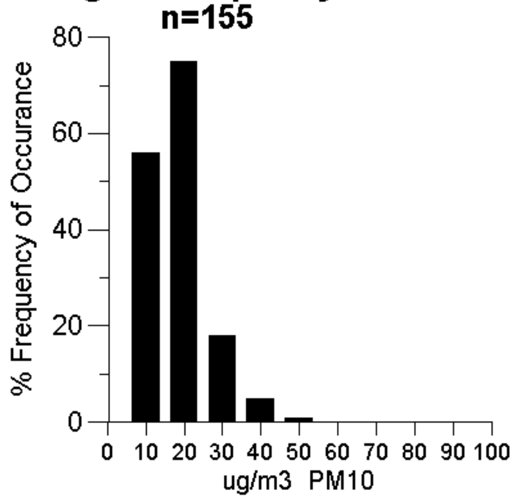
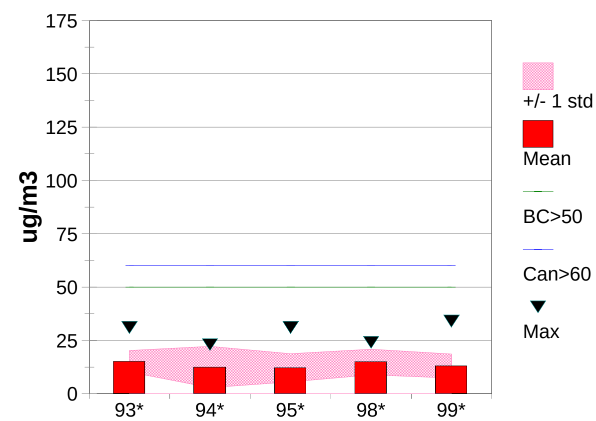


Fig 7c. Means, std.dev. and Maxima



* data capture <75%

Fig 7d. Exceedences of Air Quality Standards

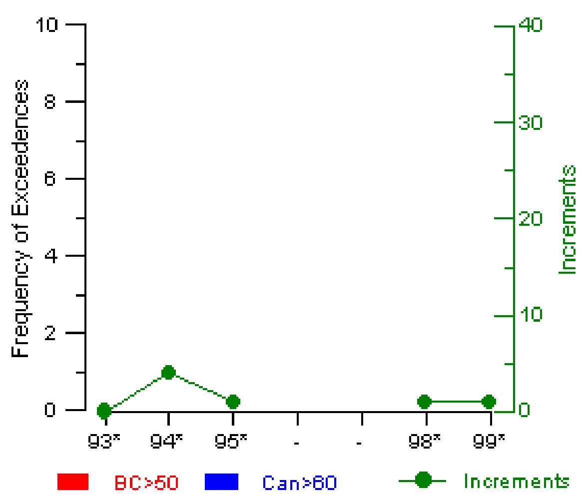


Fig 7e. 6-Month Period Averages

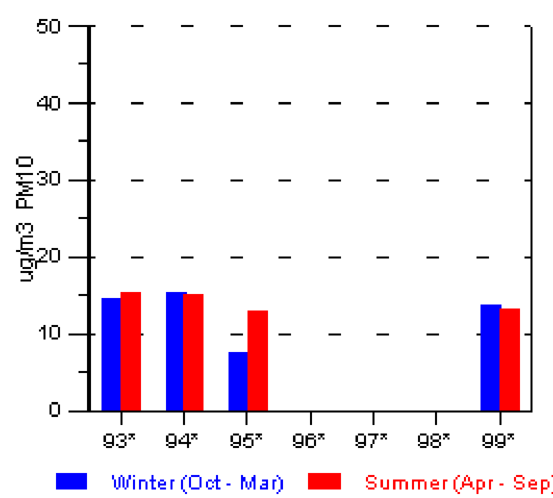


Figure 7 continued – SLOCAN PM_{10}

Figure 6f. Monthly Means and Maxima

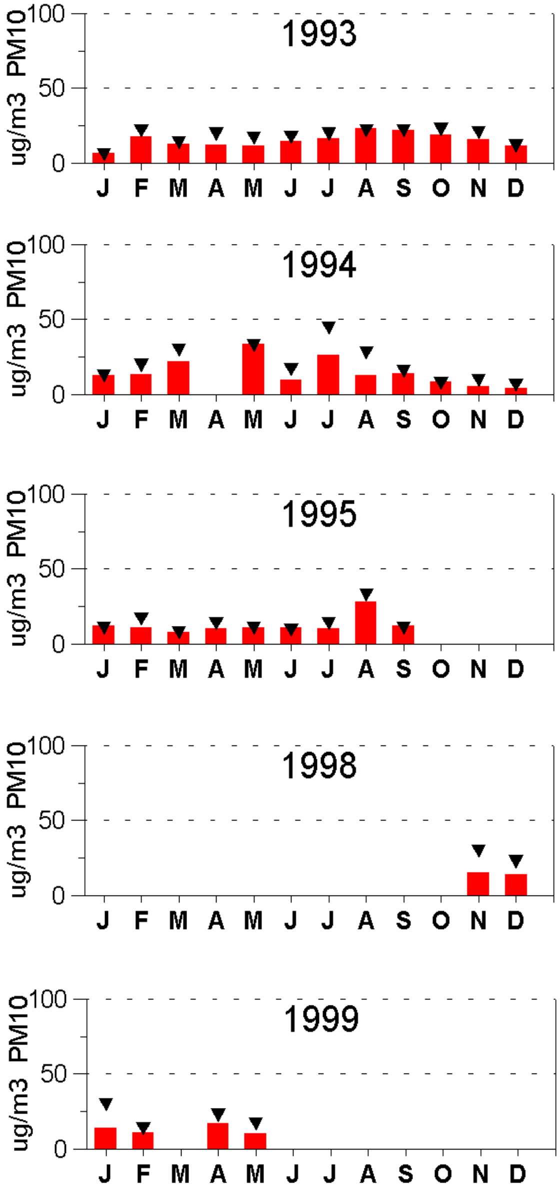
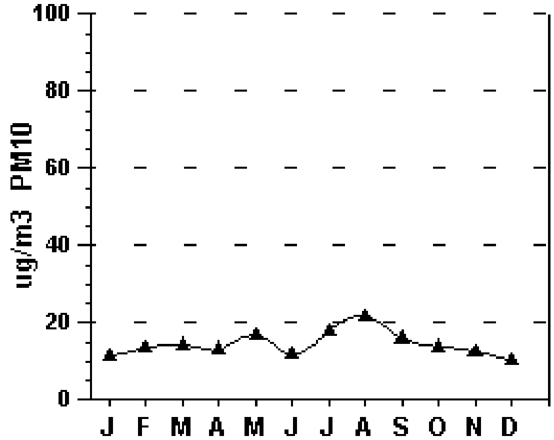


Fig 7g. Annual Cycle of PM10
Monthly mean value 1993 - 1999



5.8 CRANBROOK

TEOM sampling began at Cranbrook on April 20, 1994 and ran until November 28, 1998. Some NAPS data were collected in 1999. The time series of daily averages of the hourly data is shown in **Figure 8a.** Since the record starts in 1994 after the peak winter times for elevated PM_{10} episodes, and has a gap in it for February and part of March in 1995, it is not until 1996 that the data show the brief but intense episodes of PM_{10} that seem to be common in the winter in Cranbrook; these are probably due to wood smoke and weather conditions (inversions).

Frequency distribution of 1617 daily averages (**Figure 8b**) shows that the 10 - 20 $\mu g/m^3$ category is the modal value at Cranbrook; just over 2% of the daily averages are greater than 50 $\mu g/m^3$ which is the BC objective.

The plot of annual means, standard deviations and maxima (**Figure 8c**) shows very consistent annual means at Cranbrook, all below 20 $\mu g/m^3$; there are no trends evident.

The Exceedences and Health Increments observed at this TEOM site (**Figure 8d**) and the two following sites are much higher than those recorded at NAPS sites, due to the daily record rather than every 6^{th} day record. The appearance of a sharp increase in exceedences between 1994 - 1997 may be partly due to the gaps in monitoring during the winter months in 1994 and 1995. It is not possible to say whether the better year (few exceedences) observed in 1998 was the start of an improving trend.

Seasonal (6-month period) means calculated on daily average data (**Figure 8e**) show no obvious trends or patterns, nor do the month means and maxima shown in **Figure 8f**.

The Annual Cycle for 1994 - 1998 (**Figure 8g**) shows that February is on average the month with the highest PM10 levels (average = 29.4 μg/m3) with all other months averaging between 12 and 22 μg/m3.

The Diurnal Cycle (**Figure 8h**) shows a clearly defined pattern of two daily peak times for PM_{10} levels: 7 - 8 am and 7 - 8 pm, with higher values midday than overnight. Since the Annual Cycle showed highest values during the winter, this diurnal pattern is consistent with wood burning for heat as the primary source of PM_{10} in this community.

Figure 8. **CRANBROOK PM_{10}**

Figure 8a. Time Series – Daily averages by year.

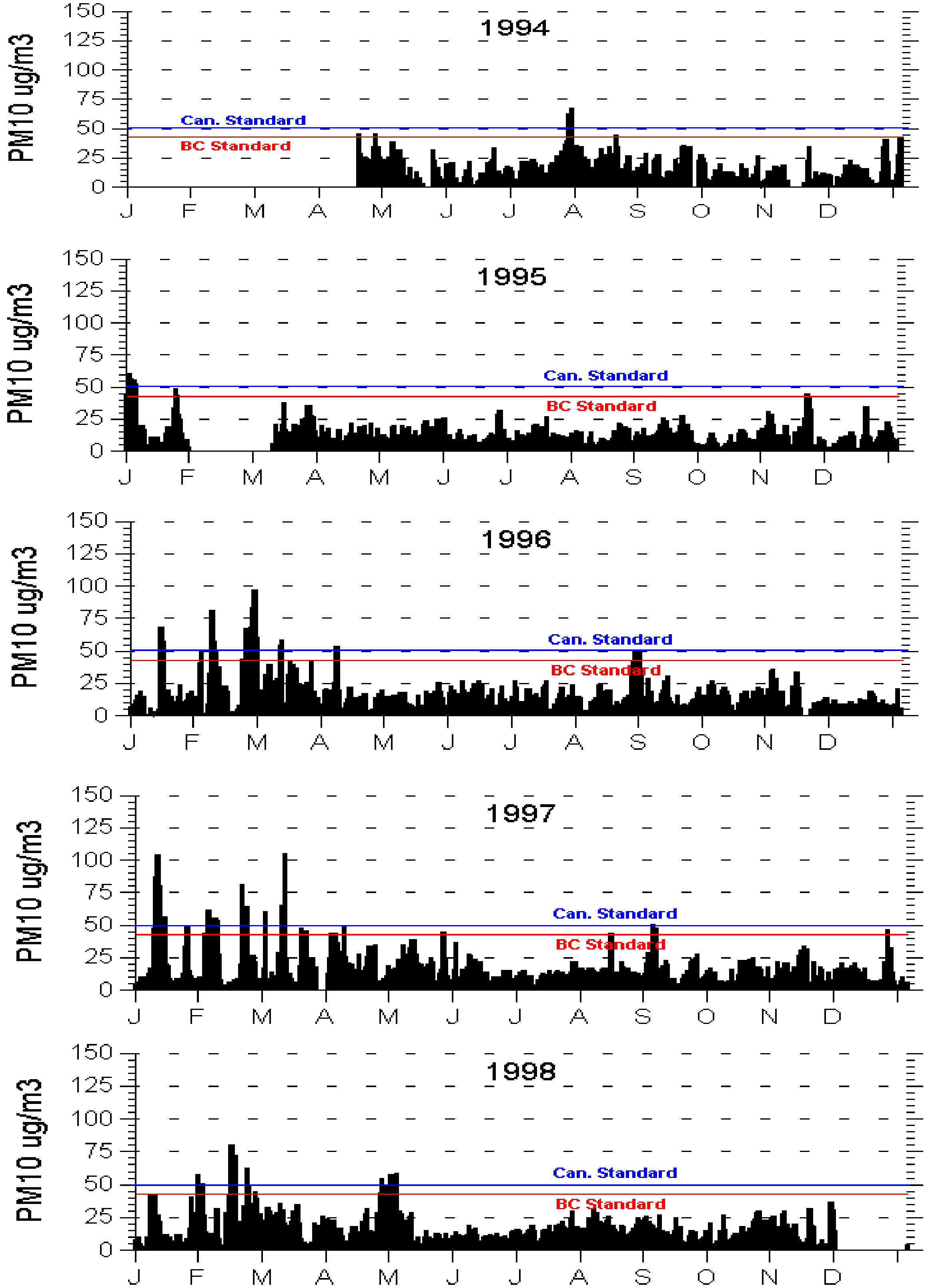


Figure 8 continued: CRANBROOK PM_{10}

Fig 8b. Frequency Distribution
n=1617

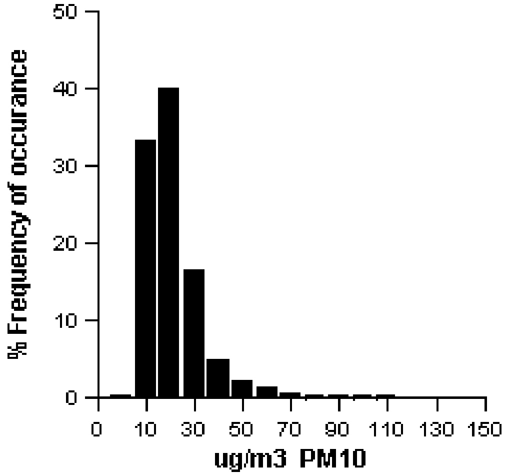


Fig 8c. Means, std. dev. and Maxima

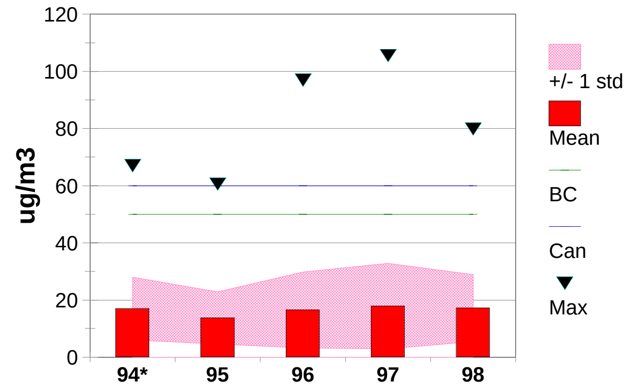


Fig 8d. Exceedences of Air Quality Standards

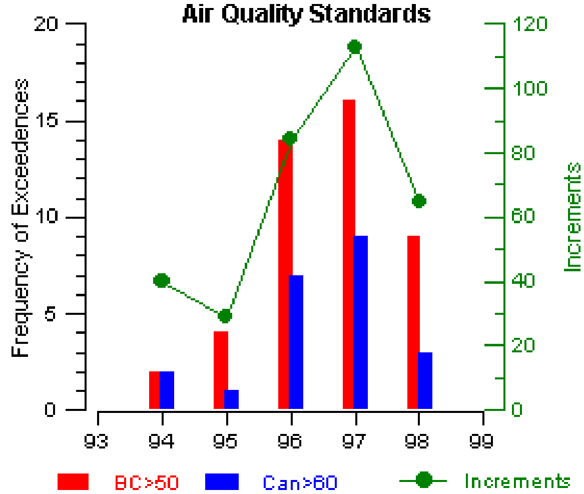
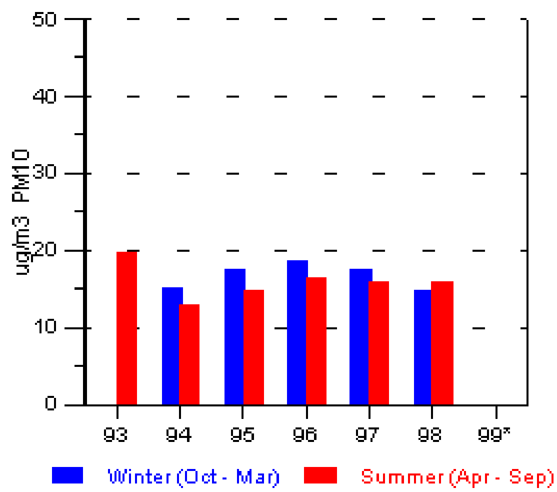


Fig 8e. 6-Month Period Averages



Note: no data for '93 or '99.

Figure 8f. Monthly Means and Maxima

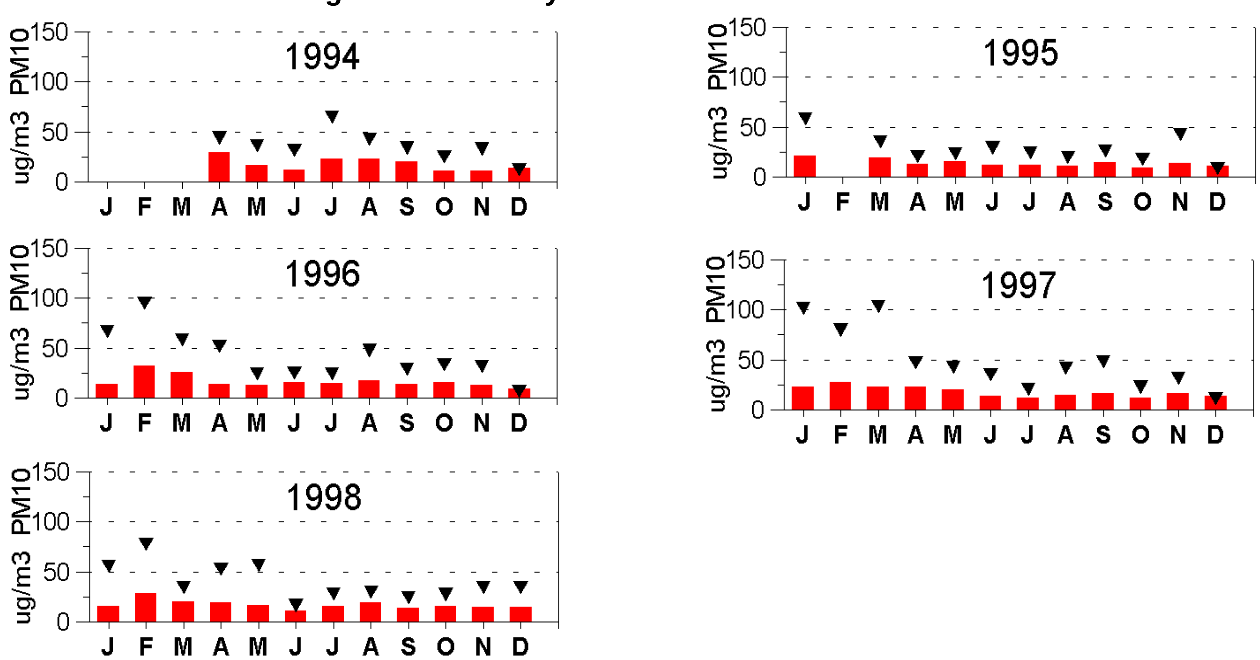
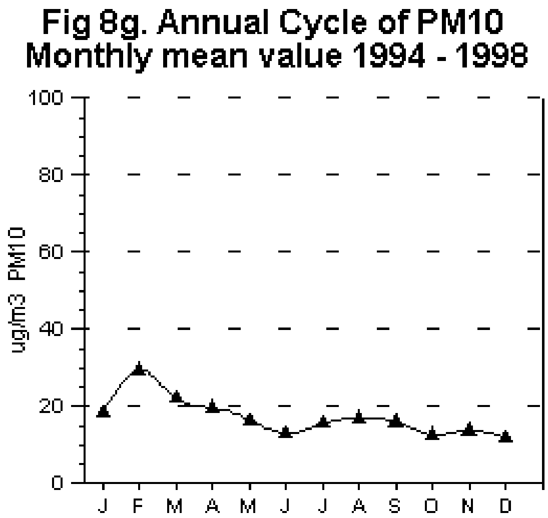
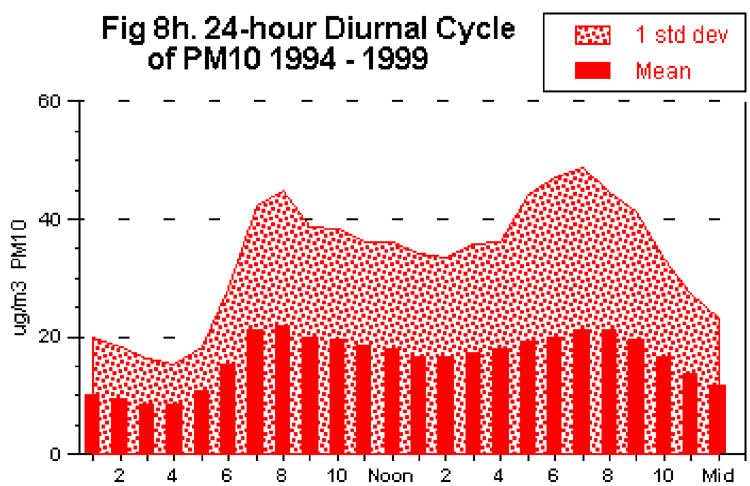


Figure 8 continued: CRANBROOK PM_{10}





5.9 CRESTON

Continuous sampling at Creston has been erratic since it began in October 1994, due to instrument problems. The Time Series (**Figure 9a**) shows that only 1997 and 1998 have data capture >75% (based on 365 daily means per year). Sampling during the winter months indicates a similar pattern to Cranbrook with brief but intense episodes of elevated PM_{10}. Creston also has periods of buildup and decline of PM_{10} at times of year when these are not seen at other Kootenay communities.

The modal concentration of PM_{10} at Creston (**Figure 9b**) is 10 - 20 $\mu g/m^3$.

The annual means, standard deviations and maxima shown in **Figure 9c** show no trend in means, but there has been a trend in maximum values over the 6 years. It is important to note that 4 of the 6 years have less than 75% data capture.

Exceedences (**Figure 9d**) showed an increasing trend from 1994 through 1997, and appear to have sharply dropped off since then. The data record of 1999 is far from complete but it does cover the times of year in which exceedences are most common; therefore the fact that no exceedences were observed is noteworthy. While Health Increments (HI) peaked in 1998, the decline in Health Increments in 1999 is very substantial.

Seasonal (6-month period) means shown in **Figure 9e** indicate a declining trend in winter PM_{10} values since 1997, but no obvious trend in summer values.

The monthly means and maxima plotted in **Figure 9f** make it clear that the decreasing trend in PM10 values has been more obvious in maxima than in means. Since June of 1997 the monthly maxima of the summer and fall seasons have been consistently below 50 μg/m3.

The annual cycle of PM_{10} levels as shown in **Figure 9g** shows the highest monthly average levels (27 and 25 μg/m3) occurring in February and March, with the other months of the year averaging between 15 and 21 μg/m3.

As in Cranbrook, the Diurnal Cycle of PM_{10} (**Figure 9h**) at Creston suggests residential wood burning appliances and dust as the main source of particulate matter in this community.

Figure 9. **CRESTON PM_{10}**

Figure 9a. Time Series – Daily averages by year.

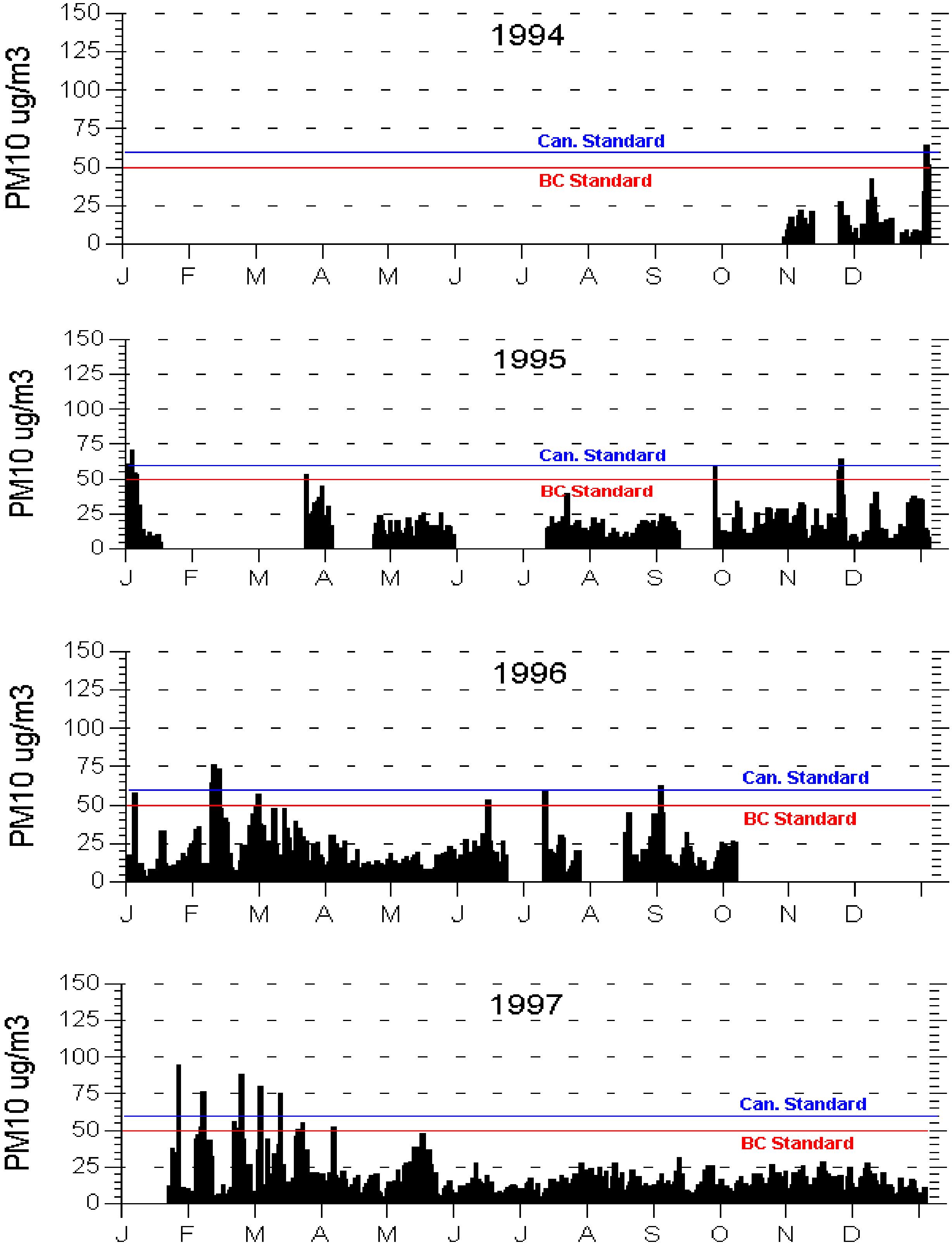
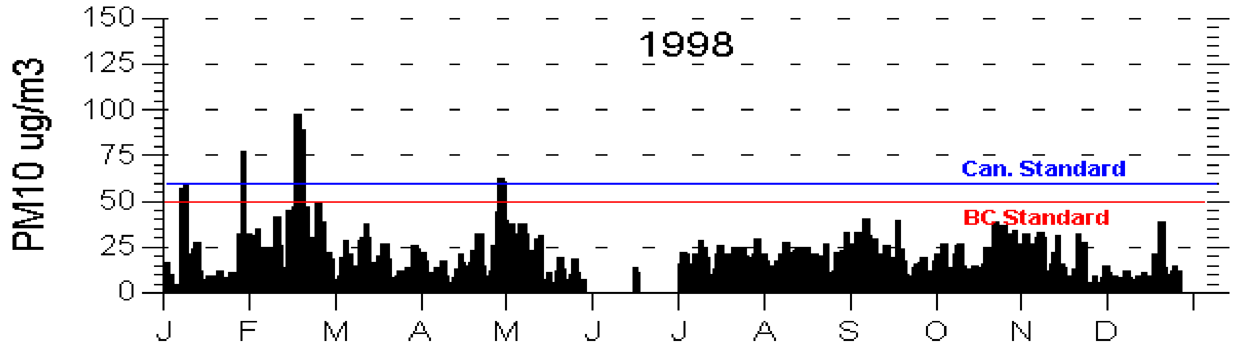


Figure 9 continued CRESTON PM_{10}



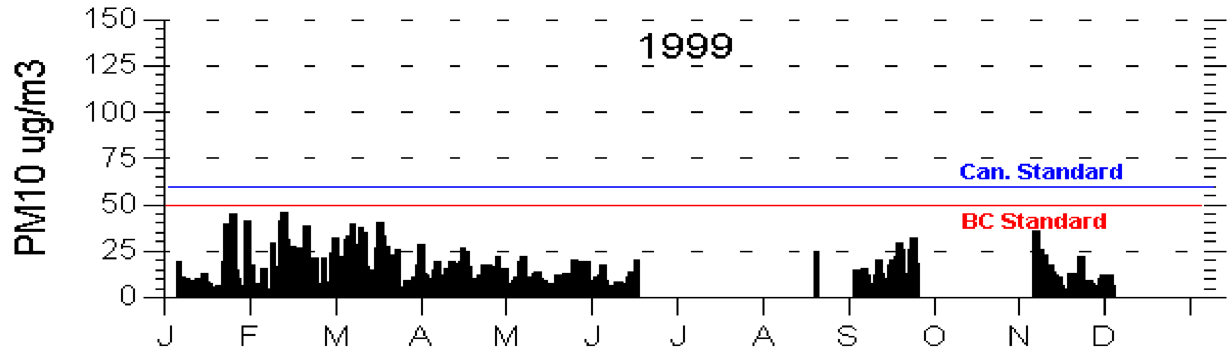


Fig 9b. Frequency Distribution
n=1392

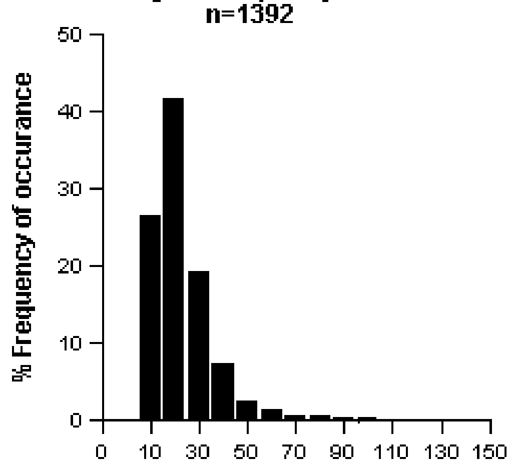
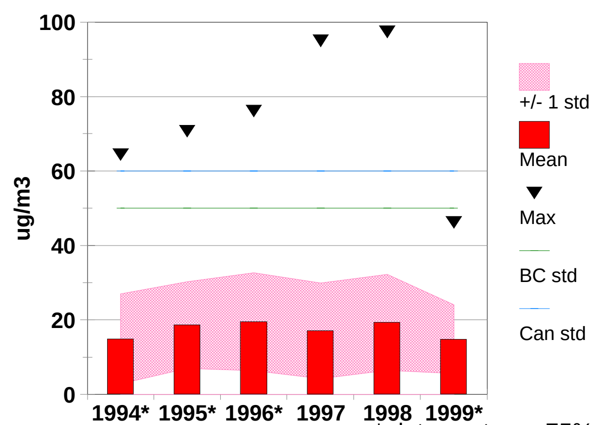


Fig. 9c. Means, std. dev. and Maxima



* data capture <75%

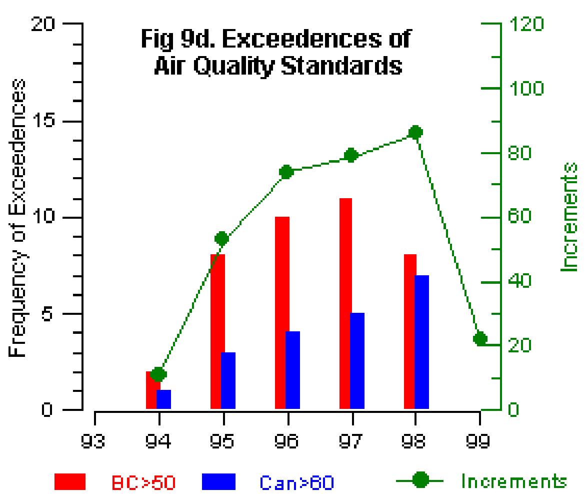


Fig 9e. 6-Month Period Averages

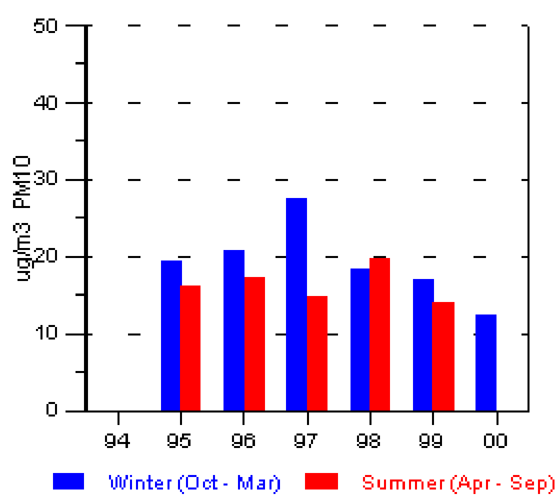


Figure 9 continued CRESTON PM_{10}

Figure 9f. Monthly Means and Maxima

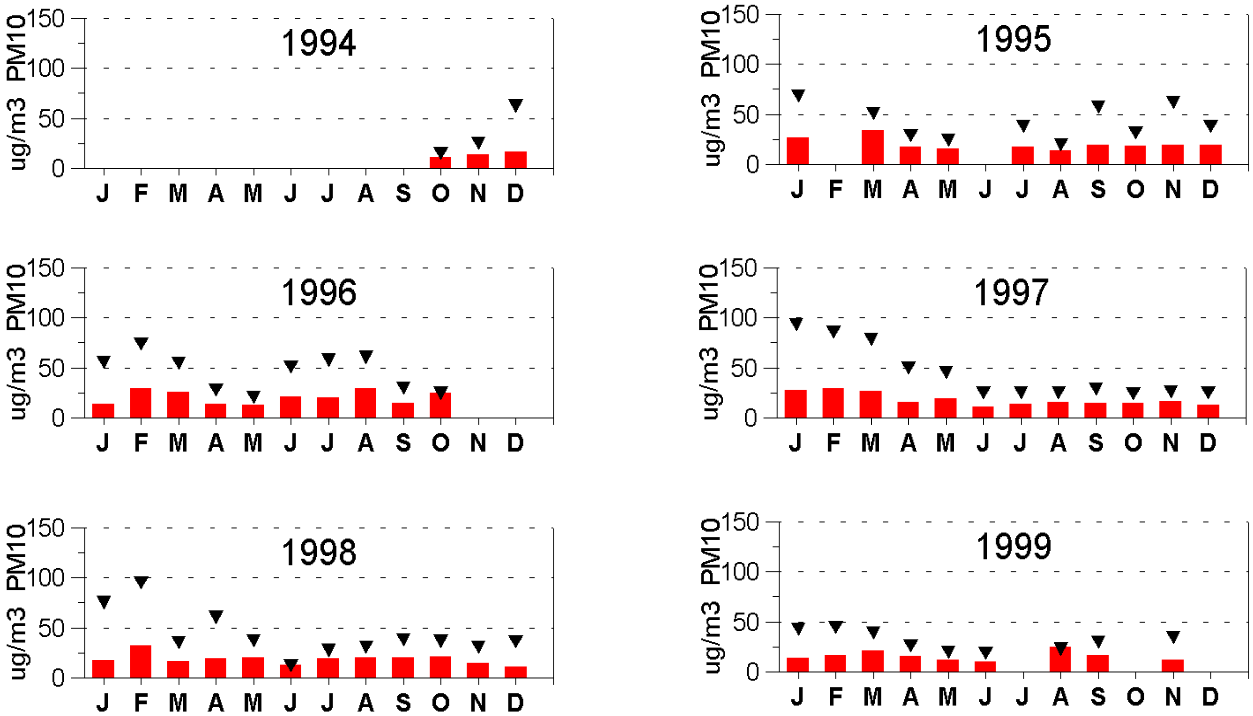


Fig 9g. Annual Cycle of PM10
Monthly mean value 1994 - 1999

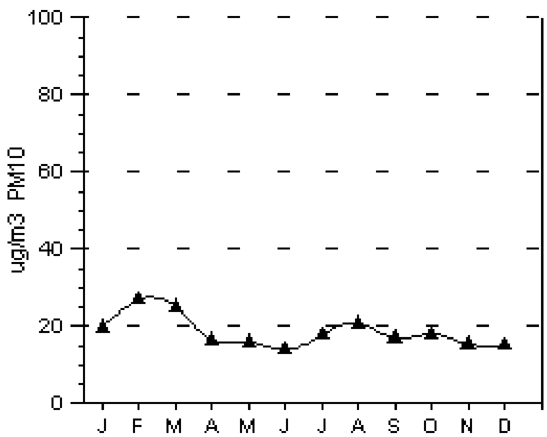
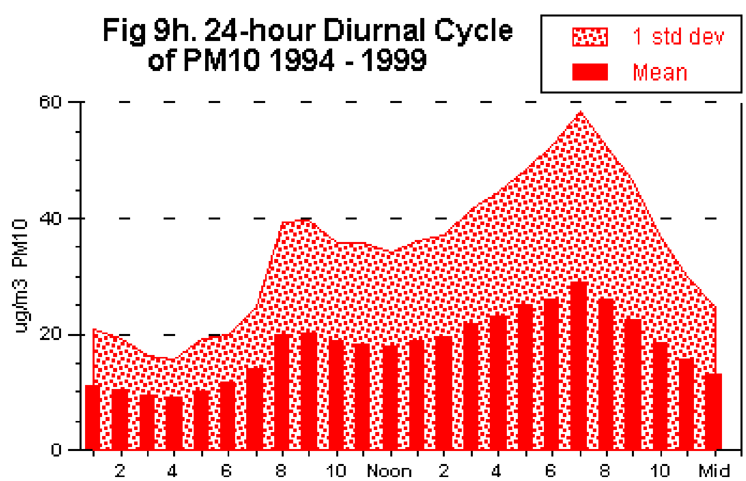


Fig 9h. 24-hour Diurnal Cycle
of PM10 1994 - 1999



5.10 TRAIL

The Trail area is monitored in many locations; the data in this report came from the TEOM sampler at Butler Park. The Time Series (**Figure 10a**) shows some long gaps in these data. In 1995 - 1996 the instrument was shut down to avoid the local influence of construction of a new recreational building in Butler Park There are many brief high values in 1994, but subsequently there has been a decline both in the mean and in the frequency of excursions.

The mode of the Frequency Distribution (**Figure 10b**) is the 10 - 20 $\mu g/m^3$ category, which indicates lower levels of PM_{10} exposure in Trail than in many other Kootenay communities.

The annual means, standard deviations and maxima at Trail (**Figure 10c**) show a slight decreasing trend both in annual means and in the maximum values observed each year.

The decline in exceedences and health increments shown in **Figure 10d** is impressive, especially considering that the 1999 TEOM data was complete except for a 6 week lapse in late winter, and shows no PM_{10} levels approaching the provincial or Canadian objectives.

Seasonal mean values (**Figure 10e**) of PM_{10} also show a clear declining trend since 1994.

Monthly Means and Maxima (**Figure 10f**) also shows the decline in mean and maximum values, with the lower levels quite consistent after 1996.

The annual cycle of monthly average values (**Figure 10g**) shows little difference throughout the year, with the highest monthly values occurring in August and September.

The Diurnal Cycle (**Figure 10h**) at Trail is quite different than those seen at Cranbrook and Creston. The daily peak values occur from mid-morning thru the middle of the afternoon, which suggests that the Cominco lead-zinc smelter is the primary contributor.

Figure 10. TRAIL - Butler Park PM_{10}

Figure 10a. Time Series

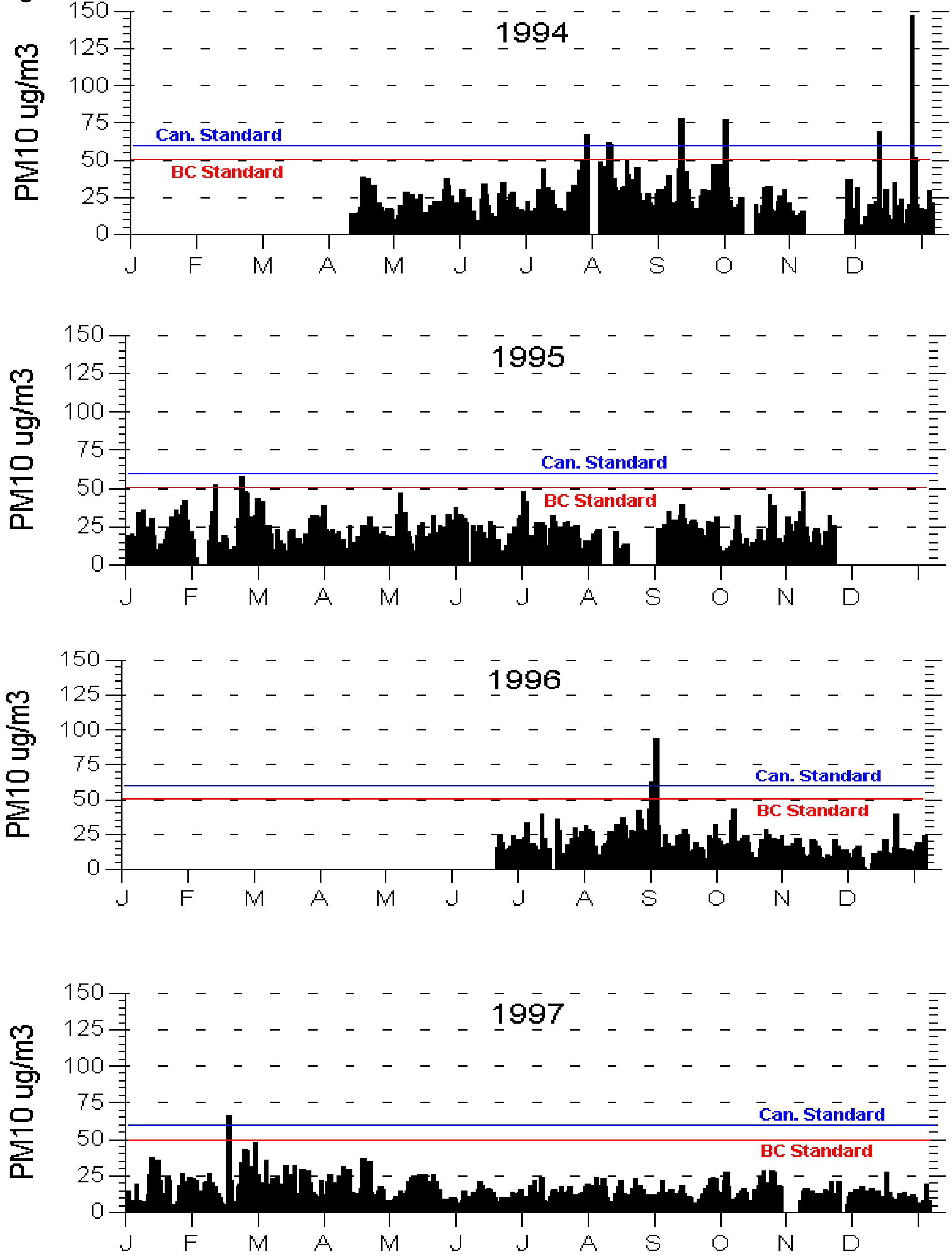
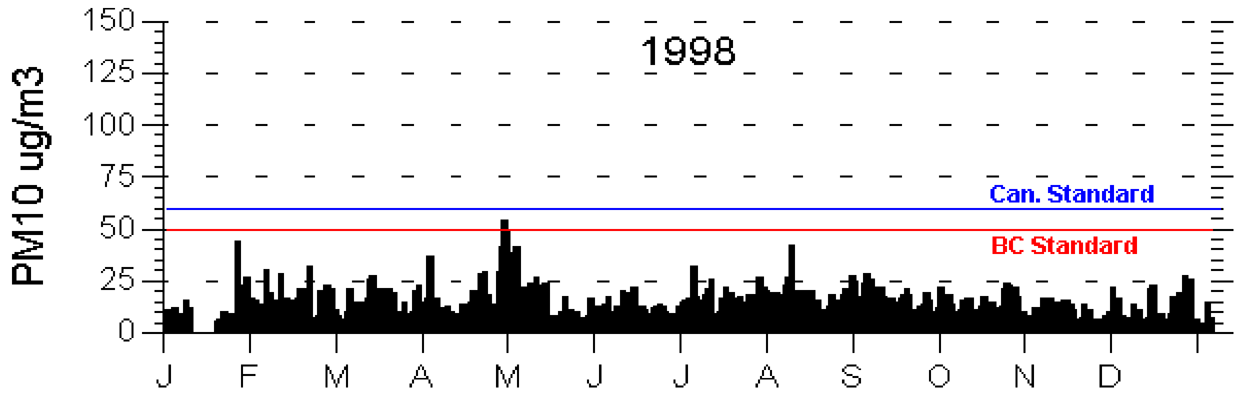
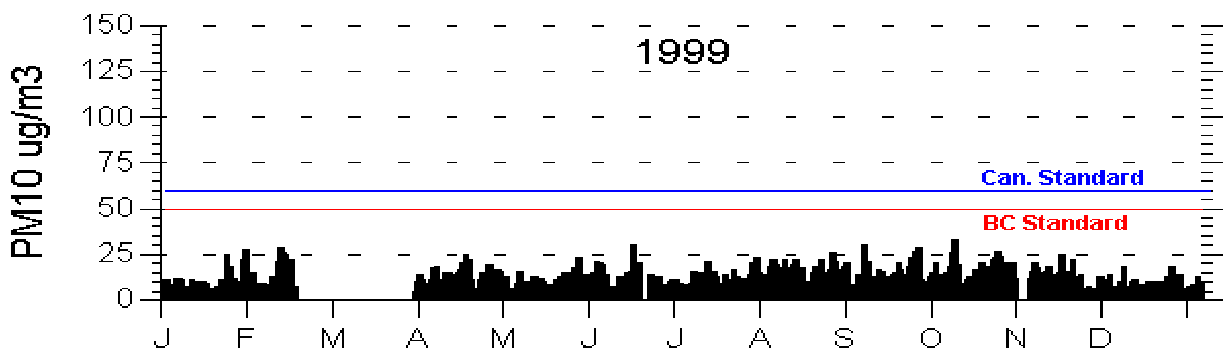
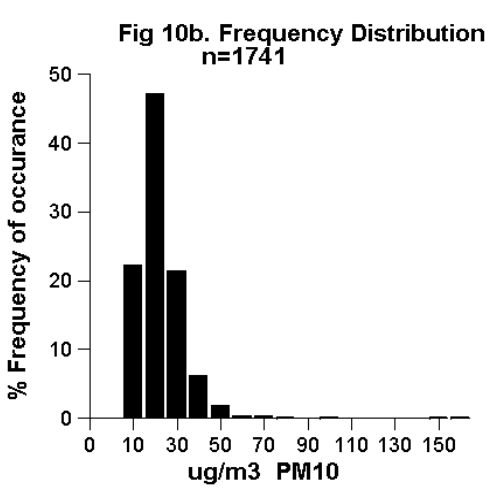
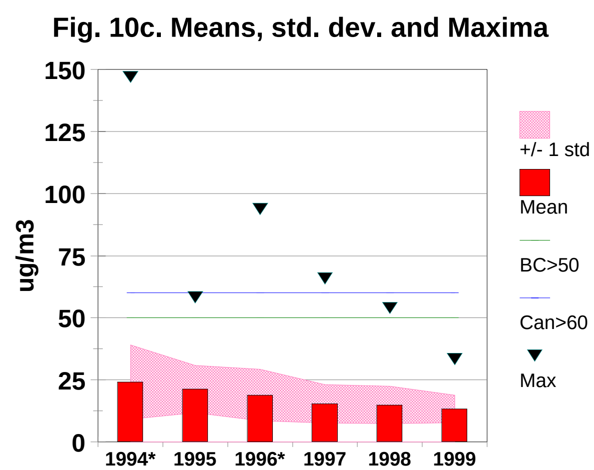


Figure 10 continued TRAIL - Butler Park PM_{10}









* data capture <75%

Figure 10 continued TRAIL - Butler Park PM_{10}

Fig 10d. Exceedences of Air Quality Standards

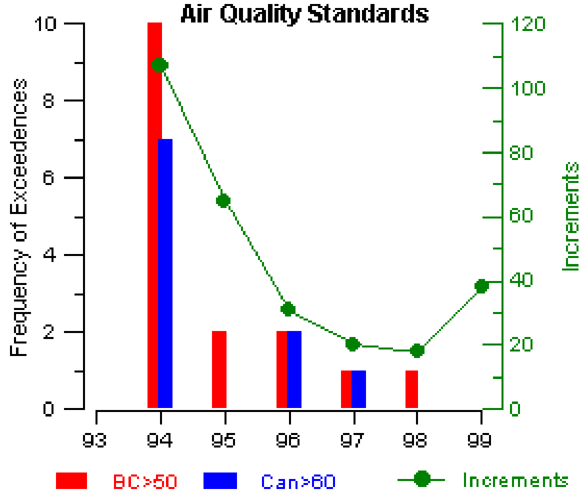
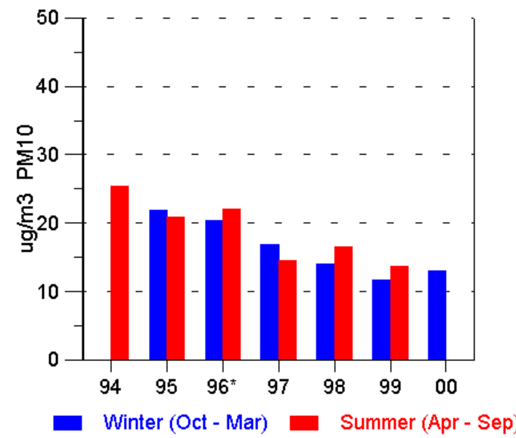


Fig 10e. 6-Month Period Averages



Note: no data for '93; no exceedences in '99.

Figure 10f. Monthly Means and Maxima

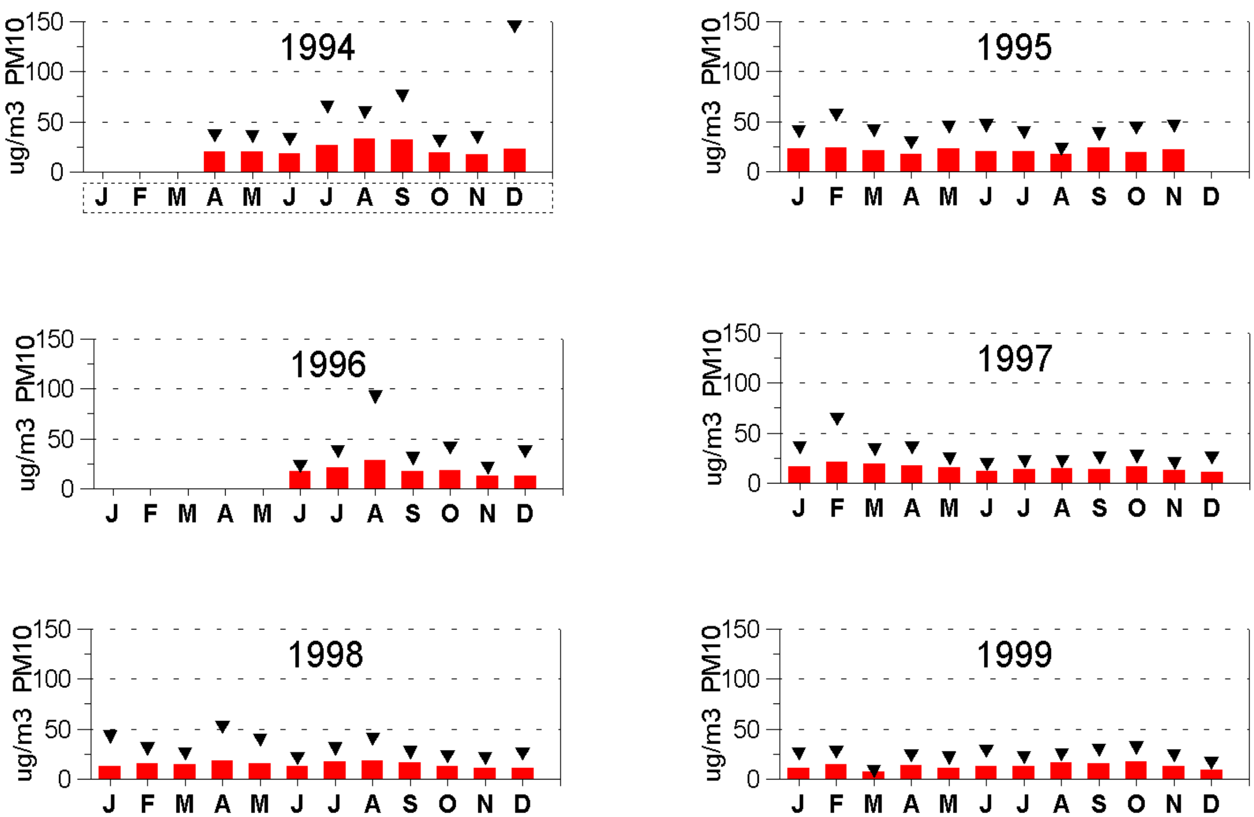
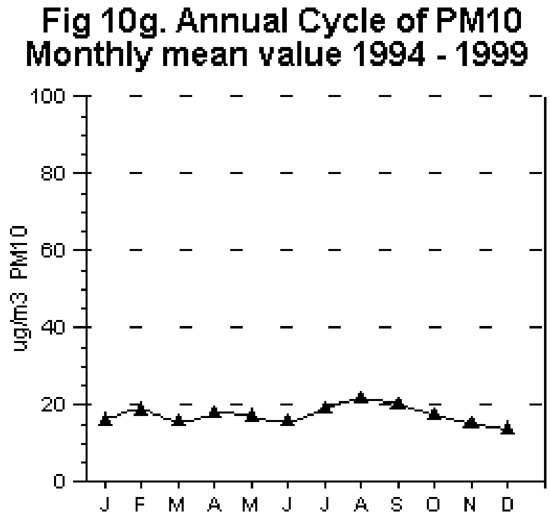
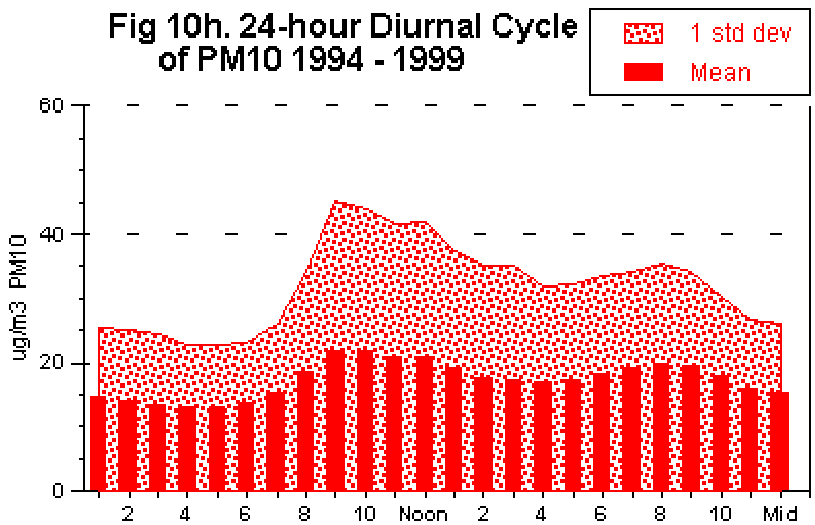


Figure 10 continued TRAIL - Butler Park PM_{10}





6. Airborne Metals in the Kootenays

The primary source of ambient metal in the Kootenays is the Cominco smelter in Trail. Airborne particulate metals are monitored concurrently from the hi-volume samples taken for PM_{10} monitoring, done on a NAPS schedule (*i.e.* for 24 hours every 6^{th} day). A spectrum of metals are analysed in Castlegar and Trail - Butler Park. The available data records from 1993 through 1999 are reviewed here.

These long term metal records are made irregular by changes in laboratory detection limits and data recording changes which have occurred during the 7 year period of this study. Some datasets have been divided into before and after particular changes in detection limits.

A summary of the results for both sites and all metals is shown in the table below. Note that all metals are recorded in *micro*grams per cubic metre.

Table 1. Summary of metal data: Castlegar and Trail, 1993 - 1999.

	Castlegar			Trail - Butler Park		
Metal	Count	Mean	Maximum	Count	Mean	Maximum
Ag-T (µg/m3)	185	0.001	0.01	161	0.005	0.06
As-T (µg/m3)	357	0.069	0.42	170	0.057	0.40
Be-T (µg/m3)	105	<0.001	<0.01	154	<0.001	<0.01
Bi-T (µg/m3)	185	0.005	0.05	161	0.014	0.33
B--T (µg/m3)	185	4.811	11.30	161	4.523	9.67
Cd-T (µg/m3)	357	0.014	0.39	170	0.032	0.18
Co-T (µg/m3)	185	0.001	0.01	161	0.001	0.01
Cr-T (µg/m3)	185	0.021	0.07	161	0.020	0.03
Cu-T (µg/m3)	357	0.357	1.28	170	0.396	0.92
Mn-T (µg/m3)	185	0.018	0.09	161	0.028	0.07
Mo-T (µg/m3)	185	0.001	<0.01	161	<0.001	0.01
Ni-T (µg/m3)	185	0.004	0.03	161	<0.001	0.01
Pb-T (µg/m3)	357	0.261	8.71	170	0.617	4.37
P--T (µg/m3)	185	0.052	0.12	161	0.064	0.17
Sb-T (µg/m3)	185	0.017	0.09	161	0.002	0.09
Se-T (µg/m3)	185	0.003	0.02	161	0.001	0.02
Si-T (µg/m3)	185	0.071	1.83	161	0.028	0.24
Sn-T (µg/m3)	185	0.005	0.02	161	0.001	0.04
Sr-T (µg/m3)	185	0.365	0.70	161	0.335	0.70
Te-T (µg/m3)	185	0.002	0.02	161	0.001	0.03
Ti-T (µg/m3)	185	0.142	0.41	161	0.159	0.48
Tl-T (µg/m3)	185	0.005	0.04	161	<0.001	0.01
V--T (µg/m3)	185	0.015	0.03	161	0.016	0.04
Zn-T (µg/m3)	357	0.415	4.60	170	1.776	6.30
Zr-T (µg/m3)	185	0.004	0.01	161	0.004	0.01

The metals that have air quality objectives and are present at levels of concern in the Kootenays are lead, arsenic, cadmium and zinc. Lead is classified as a toxic substance under the Canadian Environmental Protection Act (CEPA). Arsenic and cadmium are included within the Priority Substance List of CEPA.

There is a page of graphs for each metal which includes both Trail and Robson data in order to facilitate comparison between the two sites. Many of the graphic treatments used for PM_{10} cannot be used on the metals data because of problems with high rates of less than detection limit data, changing detection limits, and data gaps at different times at the two sites. The composition, purpose and general interpretation of each graph type is as follows:

- **a and b** . Time series – all available data plotted against time. These two histograms, **a** before and **b** after the change in detection limits, shows at a glance when data were collected, when high values occurred, and indicates whether the Ambient Air Quality Objectives have been exceeded.
- **c** Frequency Distribution of the data – for all data 1993 - 1999. This gives an overview of the proportion of the time (days) that metal values were within each increment (0.5 $\mu g/m^3$ for arsenic and cadmium, 0.1 $\mu g/m^3$ for lead and 0.05 $\mu g/m^3$ for zinc) within the range of values observed. Each bar of the histogram represents all observations within the μg category below – *e.g.* the bar labelled ‘1' on the zinc frequency distribution is the % frequency of observations with values between 0.51 and 1.00 $\mu g/m^3$.
- **d**. Annual medians and maxima. This graph simplifies the information in the time series, in a manner that is statistically suitable for this kind of data. The maximum daily observation of each year is plotted above the year’s histogram bar as a downward pointing triangle.

The data presented graphically is also available in Appendix 2 in table form.

This study found declining trends in three of the four metals (arsenic, cadmium and lead) at both communities, but values are still high compared to other regions in British Columbia.

6.1 ARSENIC

The Level A objective for arsenic is 0.1 μg/m3, but until September 1996 this was also the detection limit for arsenic, as shown in **Figure 11a** which has the x-axis drawn at the detection limit. All of the visible data are above the Level A objective, but only one value at Trail exceeds the Level B objective. **Figure 11b** accommodates the reduced detection limit by moving the x-axis down to the origin. It is obvious that arsenic levels declined sharply at both sites in 1996 and have stayed low, although there were quite a few high values and exceedences of the Level A objective at Trail in late 1999.

The frequency distribution of the arsenic data (**Figure 11c**) shows that 94% of all readings at Castlegar and 75% at Trail have been at or below the detection limit, while at Trail 18% of the readings have been between 0.1 and 0.2 $\mu g/m^3$ (just over the Level A objective).

The plot of annual medians and maxima (**Figure 11d**) shows that the detection limits are the medians every year for Castlegar, and the maxima show a clear downward trend. The pattern for Trail is very similar, although with a few higher values, and the downward trend is very strong.

Figure 11 ARSENIC

Figure 11a Arsenic at Trail and Castlegar
Jan 1993 - Sept 1996
Detection Limit = 0.1 ug/m3

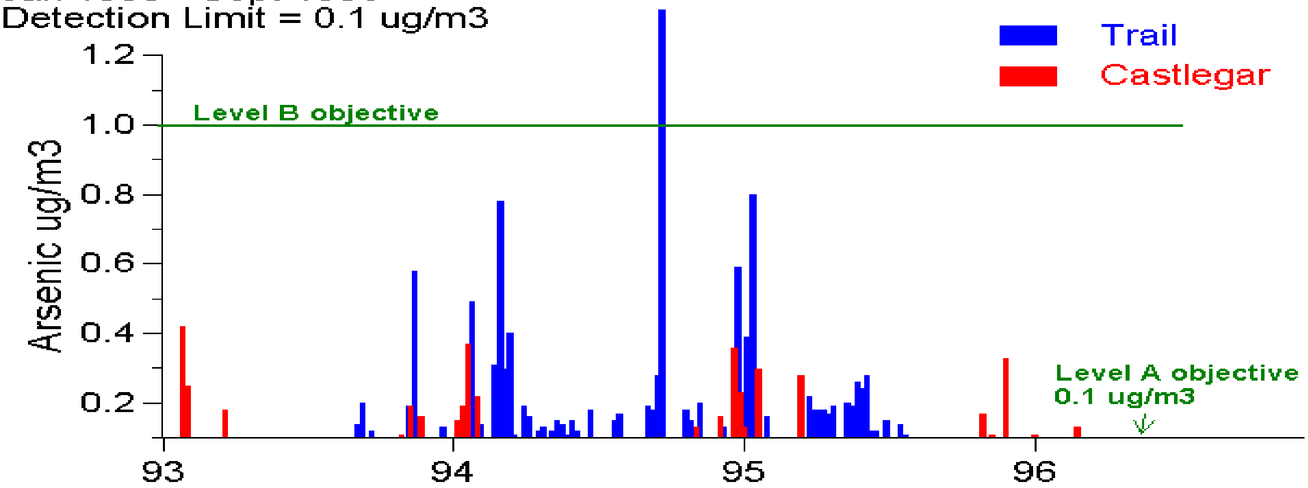


Figure 11b ArsenicTime Series
Sept 1996 - Dec 1999
Detection Limit = 0.01 ug/m3

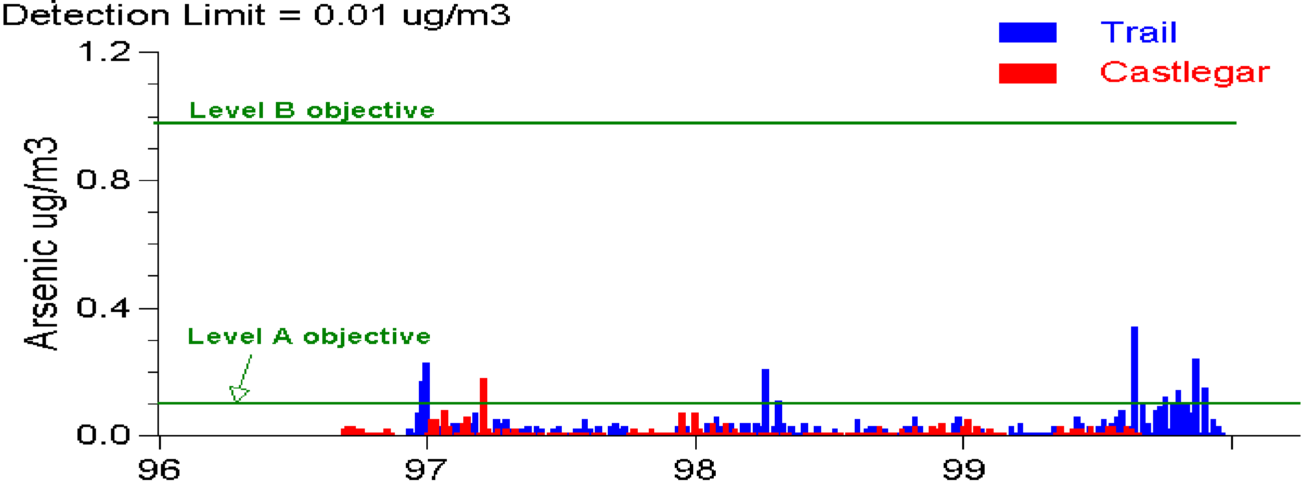
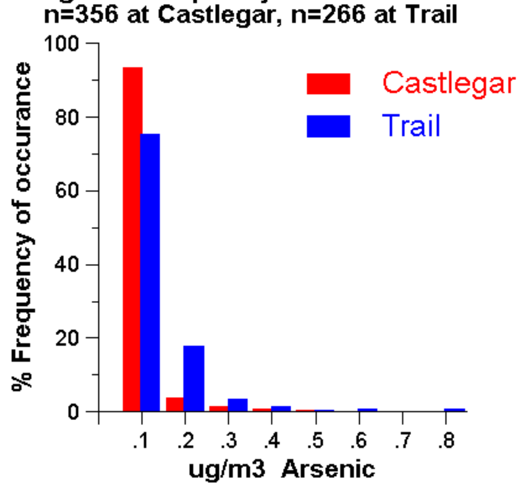


Fig 11c. Frequency Distributions
n=356 at Castlegar, n=266 at Trail



.2

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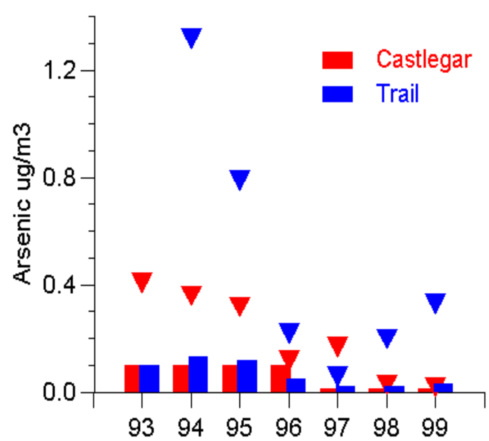
Figure 11d. Medians and Maxima



CADMIUM

The time series of cadmium levels at Castlegar and Trail (**Figure 12a&b**) shows frequent exceedences of the Level A objective in 1993 through 1999, but there is only one exceedence of the Level B objective. The baseline of the data record, filled in by Castlegar values in red, shows that the recorded DL shifted from 0.01 $\mu g/m^3$ in 1993/94 to 0.03 $\mu g/m^3$ in late 1995 and 1996; the effective DL may have been higher than 0.01 $\mu g/m^3$ during the earlier period. In 1996 when the pollution control measures at Cominco began to have effect, there appears to have been another change in DL, but also the data record began to record <DL data as zero. In any case, there was a sharp decline in airborne cadmium levels and the rate of excursions was greatly reduced.

The frequency distribution of the data from both sites (**Figure 12c**) shows the preponderance of detection limit data.

The pattern in annual medians and maxima (**Figure 12d**) is much the same for cadmium as for arsenic, with Castlegar medians being equal to the detection limit except in 1996. The medians at Trail are constant at 0.3 from 1993 through 1996, and then drop off to the detection limit as well. Maxima at both sites show a clear downward trend.

Figure 12 CADMIUM

Figure 12a CadmiumTime Series
Jan 1993 - Sept 1996
Detection Limit = 0.01 ug/m3

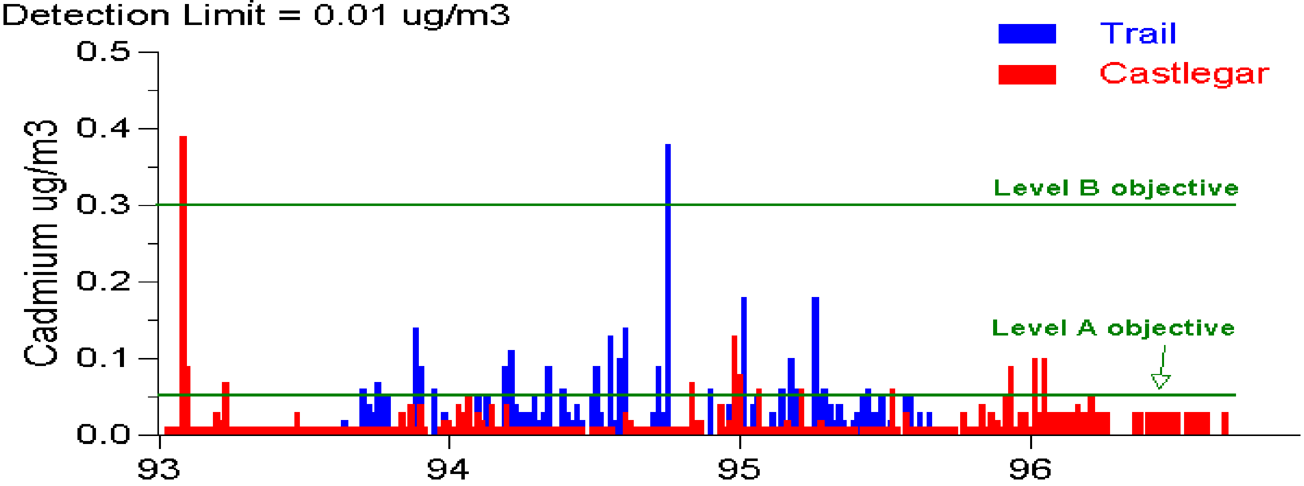


Figure 12b CadmiumTime Series
Sept 1996 to Dec 1999
Detection Limit = 0.001 ug/m3

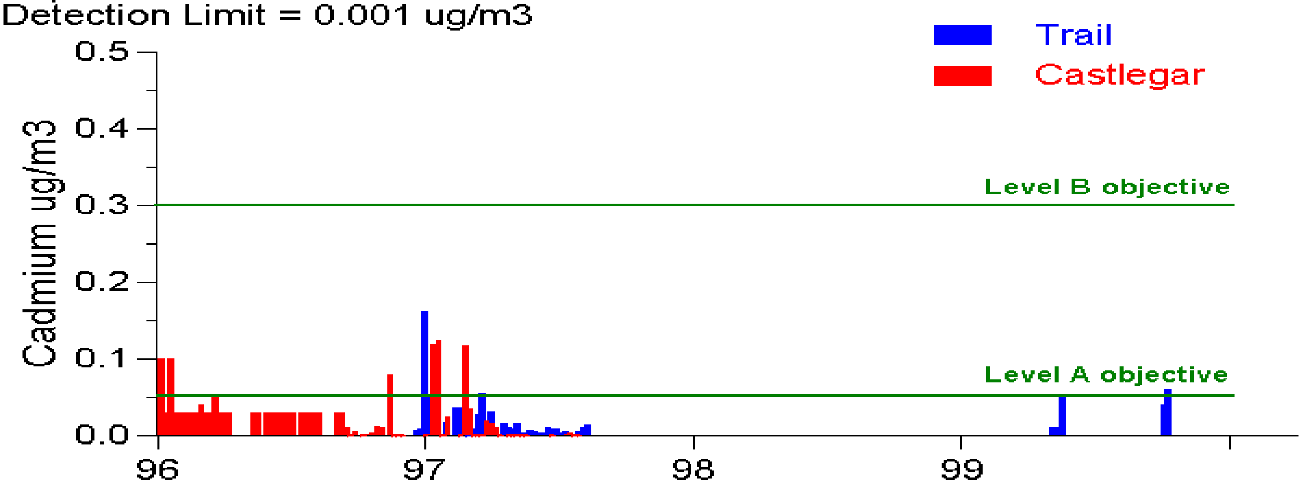


Fig 12c. Frequency Distributions
n=356 at Castlegar, n=266 at Trail

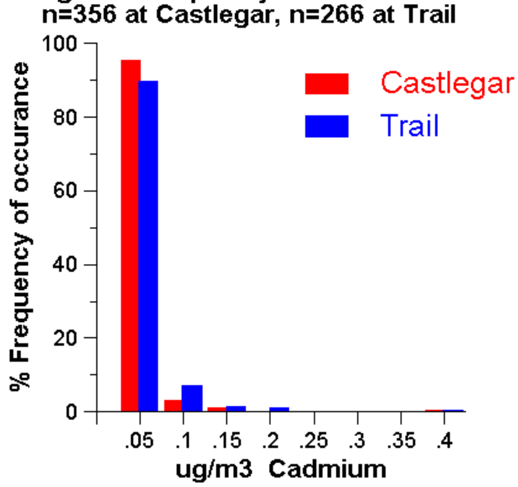
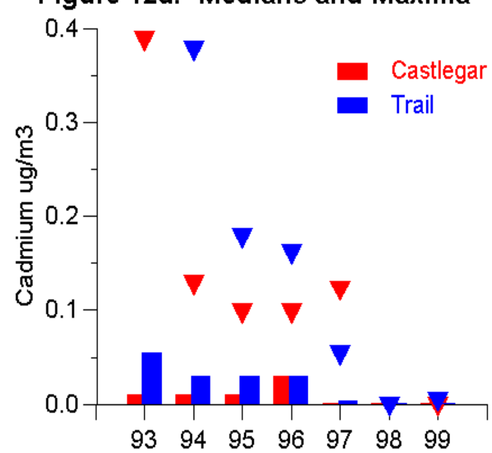


Figure 12d. Medians and Maxima



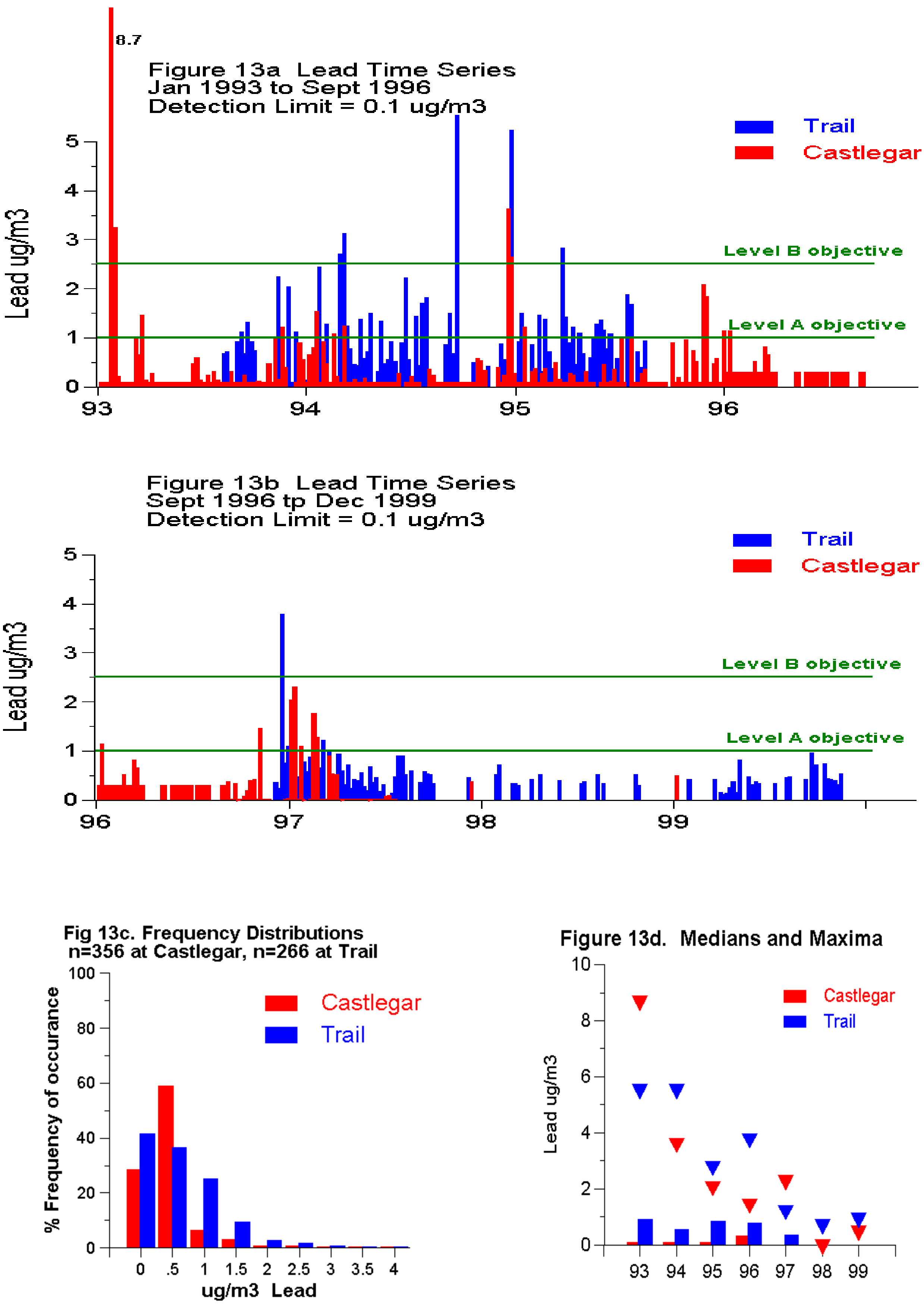
6.3 LEAD

Lead levels were high in the Trail area during 1993 through 1997 (**Figure 13 a & b**) but have been sharply reduced as of mid-1997; there have been no exceedences since that time. The Castlegar time series shows the same changing DLs seen for cadmium; changes in the detection limit make it difficult to use statistics on these data. Few records exceeded the detection limit except in 1994 and 1995.

The frequency distribution (**Figure 13c**) is also influenced by the changing detection limits since <DL data divides into two categories (‘0' and ‘0.5' $\mu g/m^3$). Clearly there have been more observations about the Level A objective (1.0 $\mu g/m^3$) at Trail than at Castlegar.

Likewise, the annual medians and maxima (**Figure 13d**) show very strong downward trends at Castlegar and Trail, with the medians declining to the detection limit.

Figure 13 LEAD



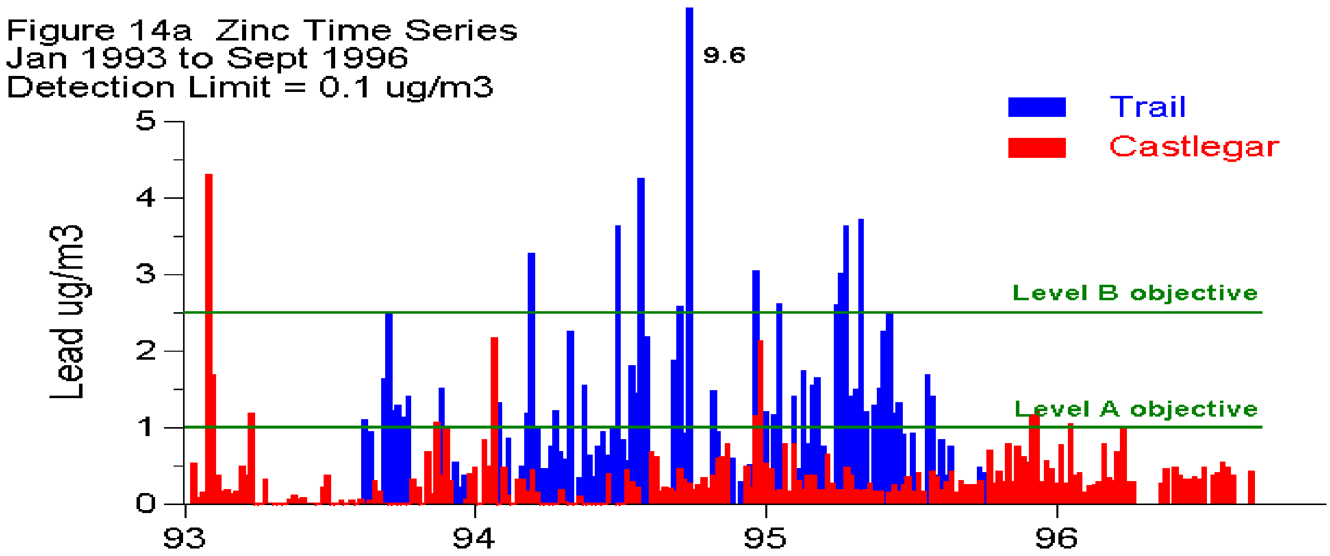
6.4 ZINC

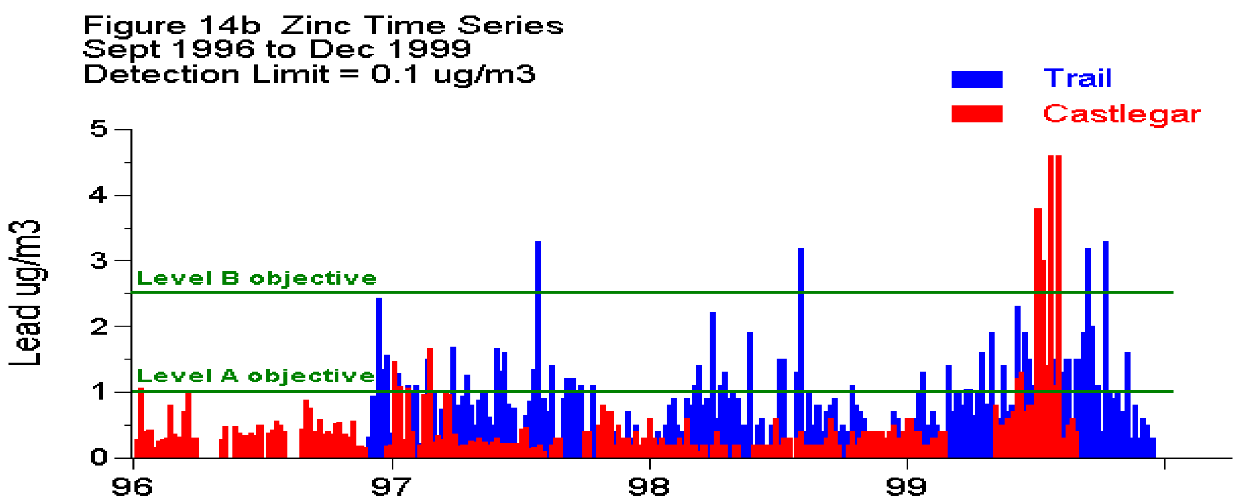
Zinc is the metal that is most frequently in excess of the Level A and B objectives, and the sharp decline seen in the other metals in 1997 has not been strongly evidenced in this dataset (**Figure 14 a & b**). Many exceedences of both A and B objectives occurred in 1999 at both Trail and Castlegar.

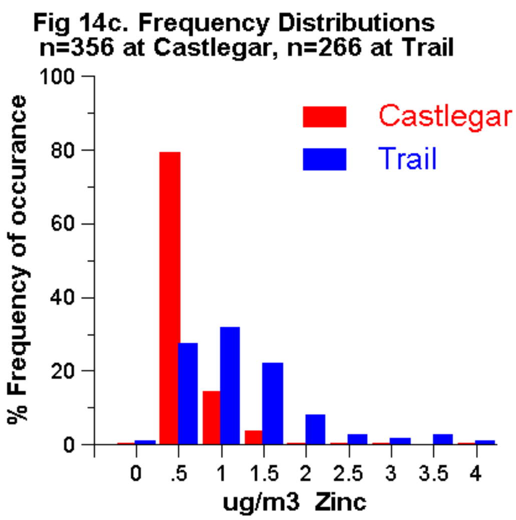
The frequency distributions of the data (**Figure 14c**) are different for the two communities. Castlegar data shows a single dominant value (79% of the observations are in the 0.0 to 0.5 $\mu g/m^3$ category). The Trail distribution spreads 82% of the data over three categories (0.0 to 1.5 $\mu g/m^3$), showing much more frequent occurrences of observations in the higher range.

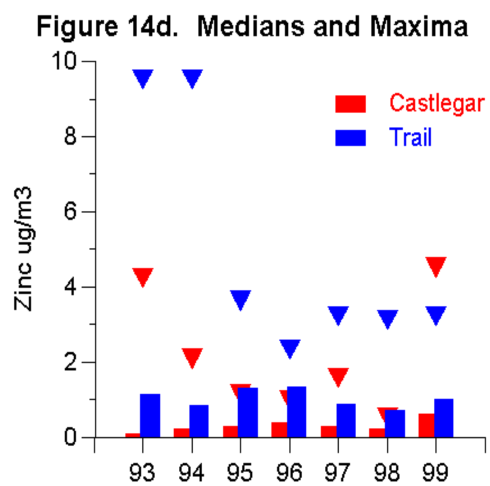
In contrast to the declining trend shown in the other metals, the annual medians and maxima for zinc do not show a downward trend at Castlegar or Trail (**Figure 14d**). The concentrations in these two communities have been fairly constant and in particular 1999 had a number of high values that brought up both the medians and the maxima.

Figure 14 ZINC









7. Sulphur Dioxide

Sulphur dioxide (SO_2) is measured continuously with TECO low-flow automatic samplers at Robson and Trail; both samplers were on line in January 1993 and continue to the present. SO_2 is measured every few seconds, and an hourly mean is logged at the end of each hour.

Sulphur dioxide is released into the atmosphere by natural decomposition, but concentrations reaching nuisance or environmentally hazardous levels are generally the product of industrial processes such as smelting, pulping, battery recycling, and burning oil for heat. SO_2 can be the cause of acid precipitation and can precipitate as fine particulate matter (sulphate). Level A and Level B concentrations for British Columbia Ambient Air Quality Objectives have been set for sulphur dioxide for 1-hour, 3-hour, 24-hour and 1 year averages. The data from 1993 through 1999 was evaluated against these objectives.

Each SO_2 site is presented with several pages of graphs. The composition, purpose and general interpretation of each graph type is as follows:

- **a**. Time series – all available data (daily averages) plotted against time. This set of annual graphs shows when high values occurred, and indicates whether there has been a trend or sudden change in values. Note that daily averages of zero occur commonly for SO_2 which are not gaps in the data record but rather ambient concentrations less than the instrumental DL.
- **b**. Frequency distribution of the data – for all hourly data 1993 - 1999. This gives an overview of the proportion of the time that SO_2 values were within each 50μg/m^3 increment within the range of values observed. Each bar of the histogram represents all observations within a 50μg range – *e.g.* the bar labelled '50' is the % frequency of observations with values between 1 and 50 μg/m^3.
- **c**. Annual averages. This bar graph shows the average daily value for each year and compares it to the annual Level A and Level B objectives.
- **d**. Monthly maxima. The maximum hourly value recorded each month has been graphed, with one line connecting the months for each year.
- **e.** Annual frequency of exceedences of BC air quality objectives. The yearly frequencies of each type of exceedence are shown as a histogram. These plots summarize the information on exceedences and show if there have been trends over the 7 year period in the frequency of these excursions.
- **f.** Daily Cycle - These hourly means show the daily cycle, which helps identify the source of SO_2 pollution and lends understanding to the pattern of human exposure to high levels when they occur.

The data presented graphically is also available in Appendix 3 in table form.

7.1 ROBSON SO_2

Data capture has been excellent at this site. A two month gap in the data record in 1994 and a one month gap in 1995 were the only notable lapses.

The time series of SO_2 data at Robson (**Figure 15a**) shows very clearly the declining trend in sulphur dioxide concentrations as well as the reduction in frequency of episodes of higher values. The frequency with which zeros were recorded in the earlier years of this time series has also declined, which may be due to enhanced accuracy at the low end of the scale. During the 7 year period of this study, there are been no exceedences of the 24-hour Level B objective at Robson, and there have been no exceedences of the 24-hour Level A objective since 1996.

Even at reduced levels of SO_2 in this community, a strong seasonal pattern is retained, with highest values in the colder months of the year and lowest values during June, July and August. Since domestic burning of fuel oil for heat is not sufficient to generate this pattern (Beatty, pers. comm.) it may be due to seasonal climate effects, such as better ventilation of the valley during the summer.

The Frequency Distribution of hourly data at Robson (**Figure 15b**) shows that the great majority (67%) of readings at this site have been zero.

Average annual sulphur dioxide concentrations (**Figure 15c**) have been declining steadily since 1994 and have not exceeded the 1-year Level A objective during the years covered by this report.

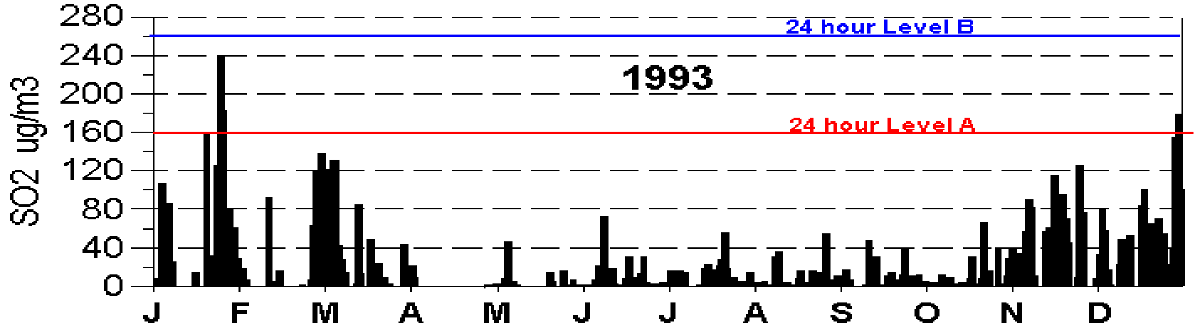
The monthly maxima of hourly values, shown in **Figure 15d**, show little variation within the fairly narrow range of values observed. The 1-hour Level B objective of 900 $\mu g/m^3$ has never been exceeded, and the 1-hour Level A objective of 450 $\mu g/m^3$ has rarely been exceeded, even by the maximum values occurring each month.

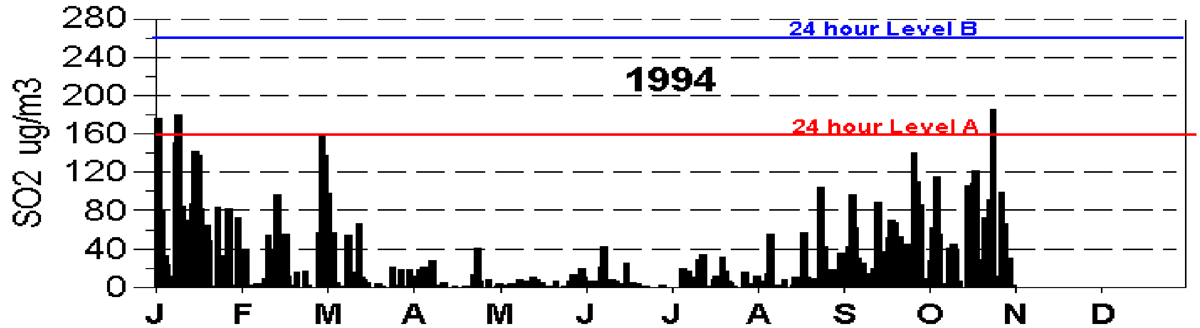
The plot of exceedences (**Figure 15e**) is accompanied by some annotation to assist in interpretation. There was a declining trend in the frequency of exceedences of the SO_2 air quality objectives from 1993 through 1996, and there were no exceedences observed in 1997 - 1999.

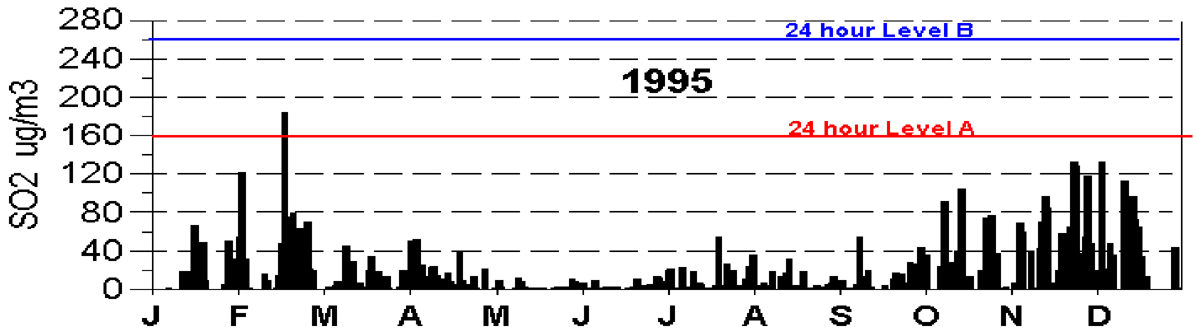
The diurnal pattern of SO_2 values at Robson (**Figure 15f**) shows a single sharp peak at 9am with no elevations in the evenings. Since these hourly means are strongly affected by the higher values in the earlier years of the dataset, the data from the most recent 12 months (October 1998 through September 1999) were also analysed to see if the diurnal pattern had changed as SO_2 declined. The peak shown by the more recent data has less amplitude and lasts from 9 to 11 am, but it is essentially the same pattern.

Figure 15. **ROBSON SO_2**

Figure 15a. Time Series – Daily averages by year.







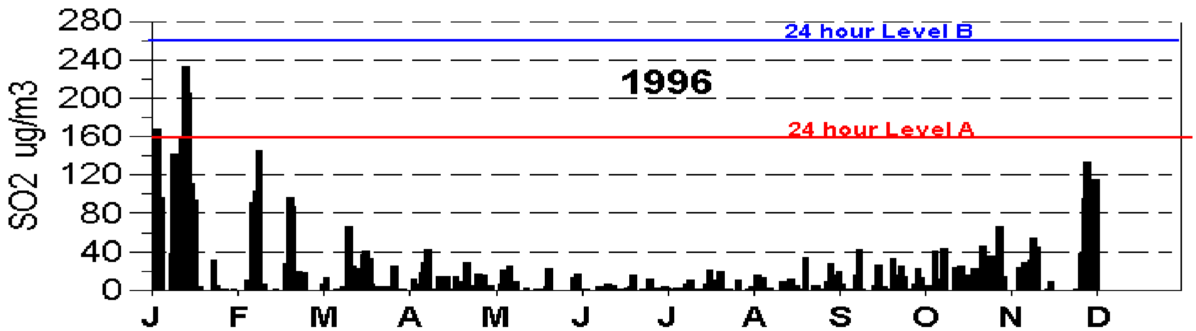


Figure 15 continued ROBSON SO_2

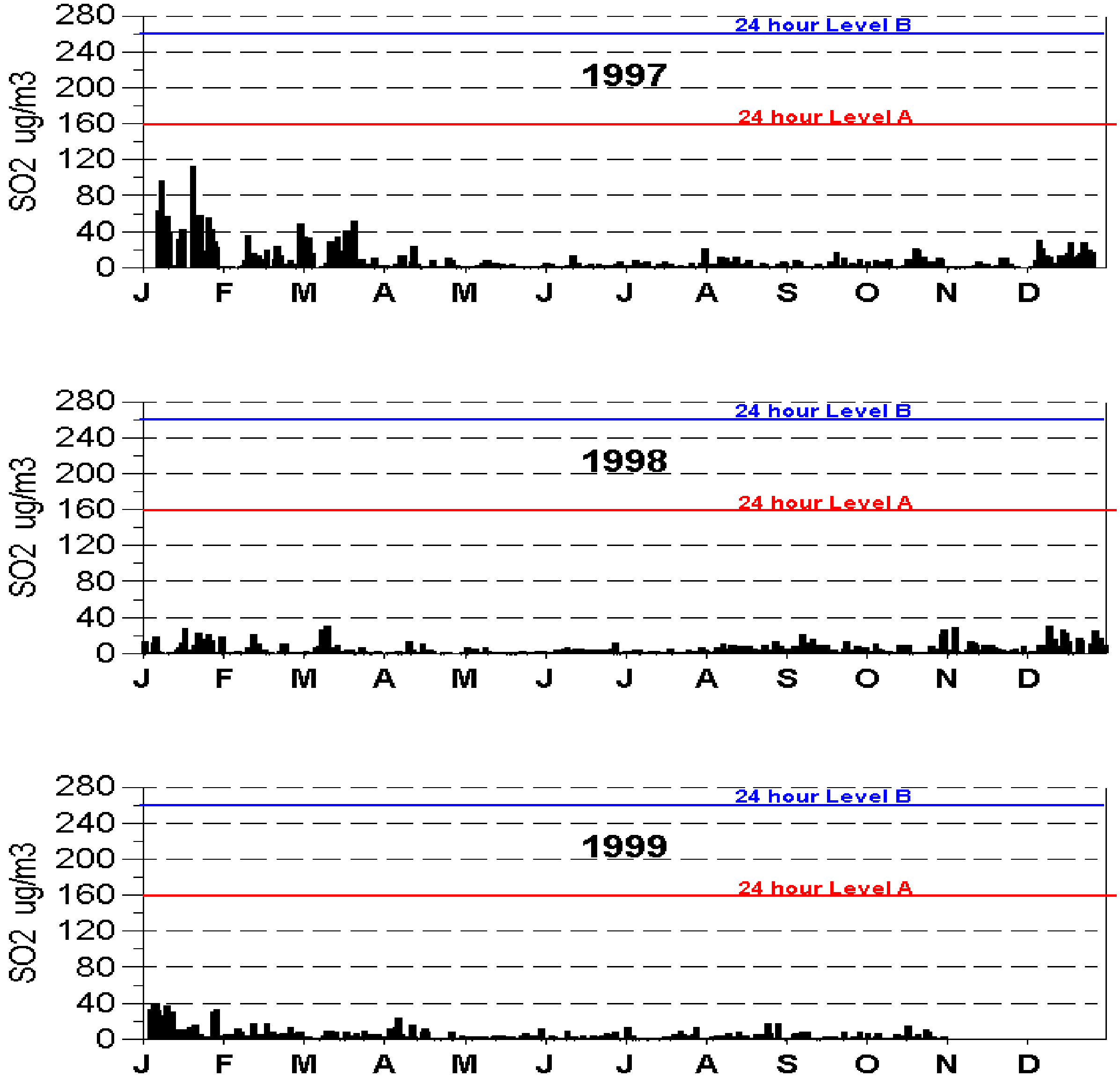


Fig 15b. Frequency Distribution
n=54,742 hourly records

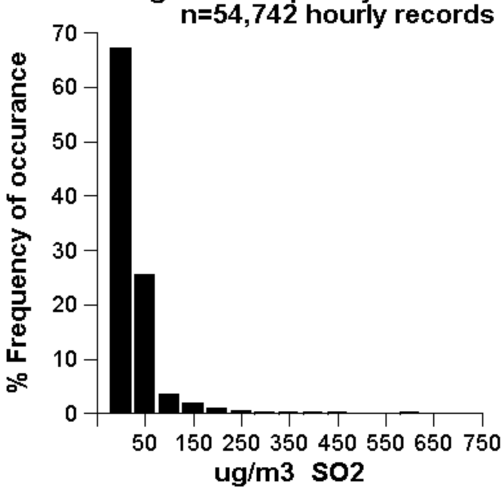


Fig 15c. Annual Averages
Based on Daily Average values.

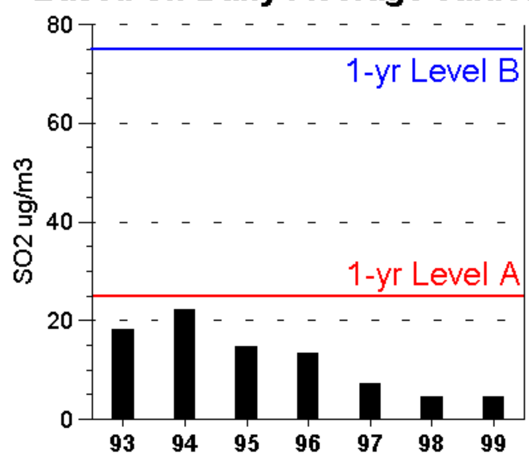


Figure 15 continued ROBSON SO_2

Figure 15d Monthly Maxima of hourly data

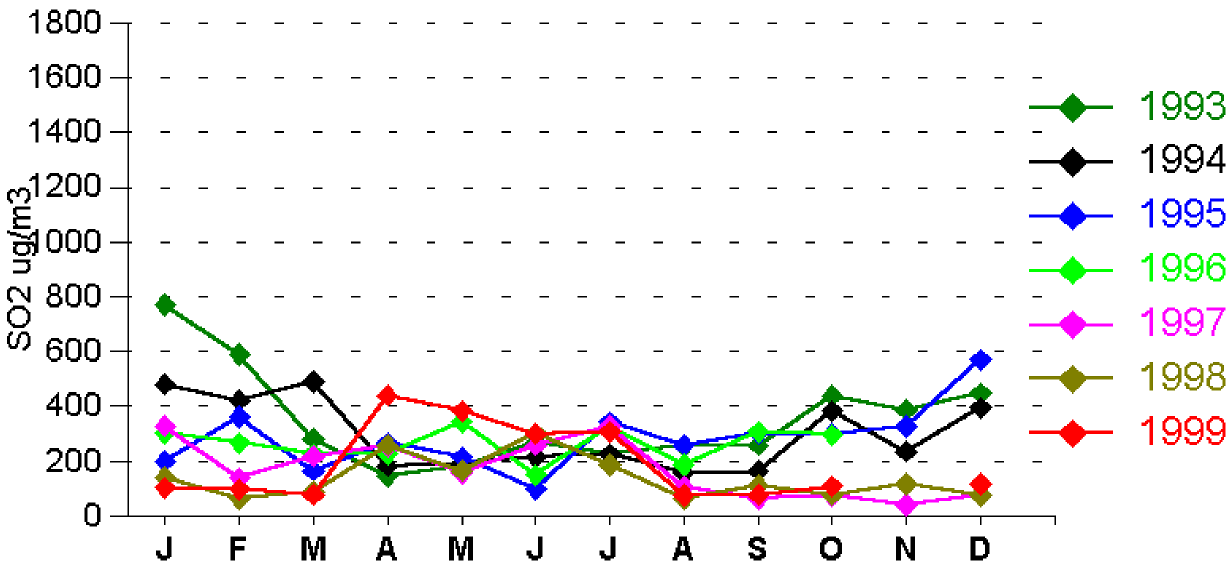
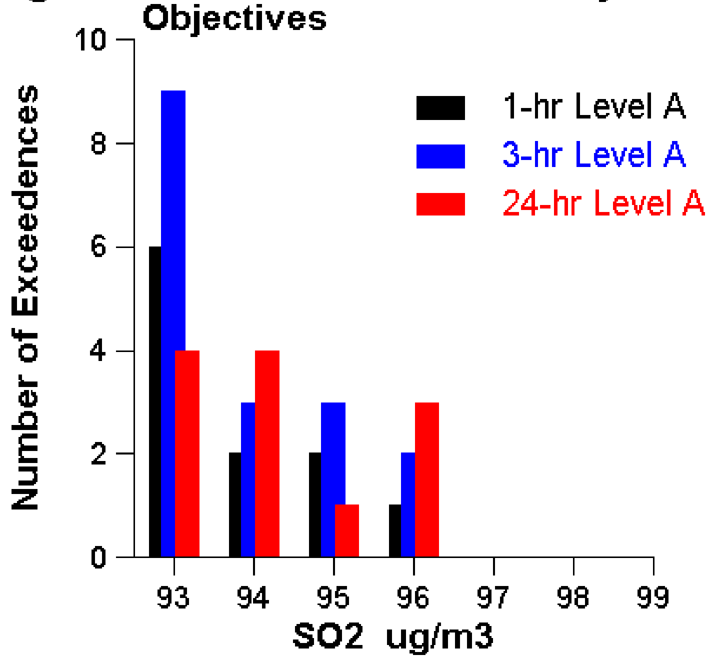


Fig 15b. Exceedences of Air Quality Objectives



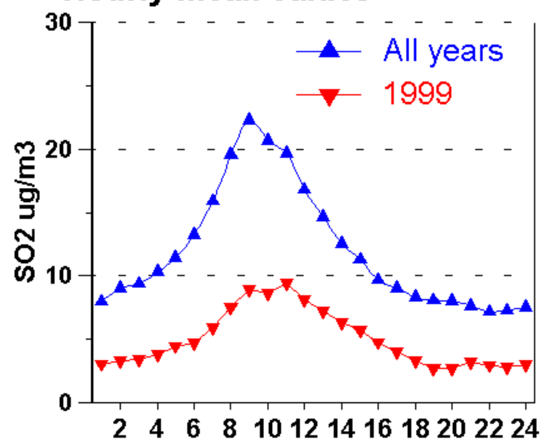
Level A objectives are the maximum concentrations compatible with 'Desirable' air quality conditions. The Level A objectives are:

1-hour	450µg/m^3
3-hours	375µg/m^3
24-hours	160µg/m^3
1 year	25µg/m^3

There were no exceedences of the 1 year Level A objective.

Level B objectives are the maximum concentrations compatible with 'Acceptable' air quality conditions. There were no exceedences of Level B objectives at Robson.

Fig 15f. Daily Cycle of SO2 Hourly mean values



7.2 TRAIL - Butler Park SO_2

The data record is largely complete except for a lengthy lapse (during local construction) from November 1995 through June1996. All years except 1996 have better than 75% data capture.

The time series plots (**Figure 16a)** show that the average SO_2 levels and the frequency and magnitude of high values have declined markedly over the 7 year period of this report. There have been no exceedences of the 24-hour Level B objective during this time, and no exceedences of the 24-hour Level A objective since 1996.

SO_2 values at Trail do not show the seasonal pattern observed at Robson – levels fluctuate within a narrow range at all seasons of the year, and occasional higher values appear to be random. This suggests that the industrial emissions of this pollutant have been successfully reduced.

The frequency distribution of the hourly readings at Trail (**Figure 16b**) shows that 44% of the data fall in the range of 0 to 50 $\mu g/m^3$; 91% of the hourly readings are ≤ 150 $\mu g/m^3$.

Average Annual SO_2 concentrations at Butler Park (**Figure 16c**) have exceeded 1-year Level A objectives for three consecutive years (1994 - 1996) but have not exceeded the 1-year Level B objective. There was a major drop in the annual average in 1997, and the annual averages for 1998 and 1999 have been less than half of the average values for 1993 - 1996.

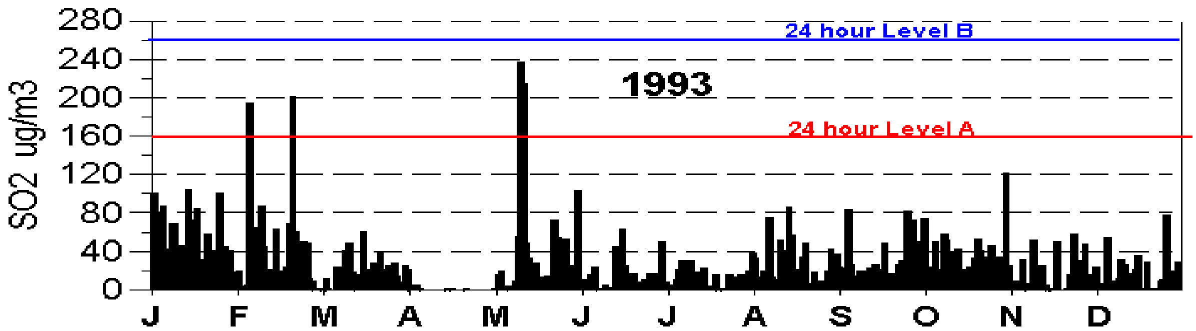
The monthly maxima of hourly values (**Figure 16d**) show variation within a range far greater than that seen at Robson. Prior to 1998 most of the monthly maxima exceeded the 1-hour Level B objectives (900 $\mu g/m^3$), but 1998 and 1999's values were much lower and there were few exceedences of the Level B objective among the maxima. Even in these recent years, most monthly maxima exceeded the Level A objective.

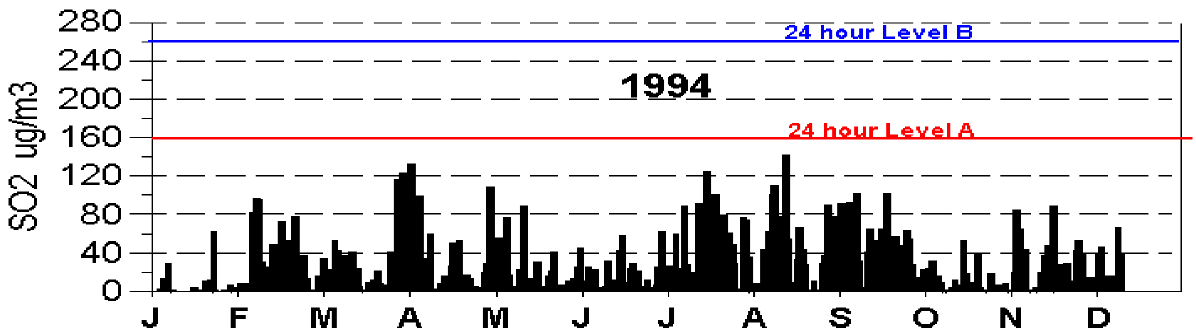
The plot of exceedences (**Figure 16e**) is accompanied by some annotation to assist in interpretation. There was a sharp drop in1996 in the frequency of 1 hour and 3 hour exceedences of the SO_2 air quality objectives, and these short duration exceedences have continued to decline since then. The 24 hour exceedences have also declined during 1993 - 1999, although not as sharply. There were no exceedences of the Level B objectives in 1999 at this site.

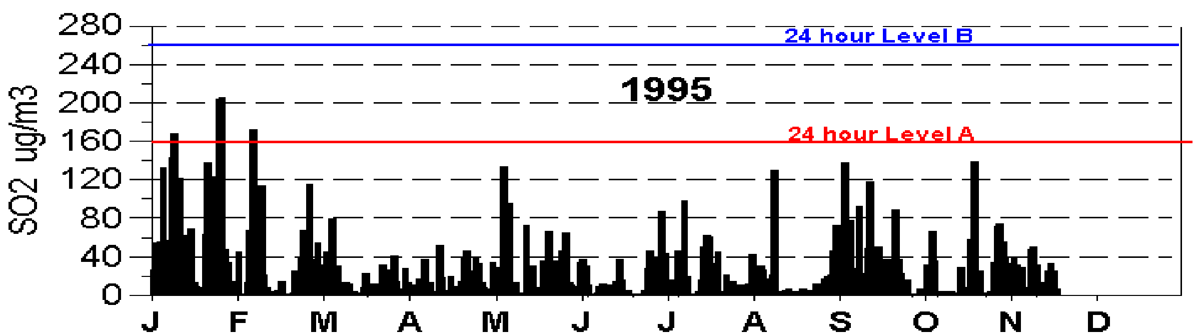
The diurnal pattern of SO_2 values at Butler Park (**Figure 16f**) shows two peaks, the first at 10 to 11 am and the second at 8 to 9 pm. Since these hourly means are strongly affected by the higher values in the earlier years of the dataset, the data from the most recent 12 months (December 1998 through November 1999) was also analysed to see if the diurnal pattern had changed as SO_2 declined. The pattern shown by the more recent data has less amplitude but it is essentially the same pattern.

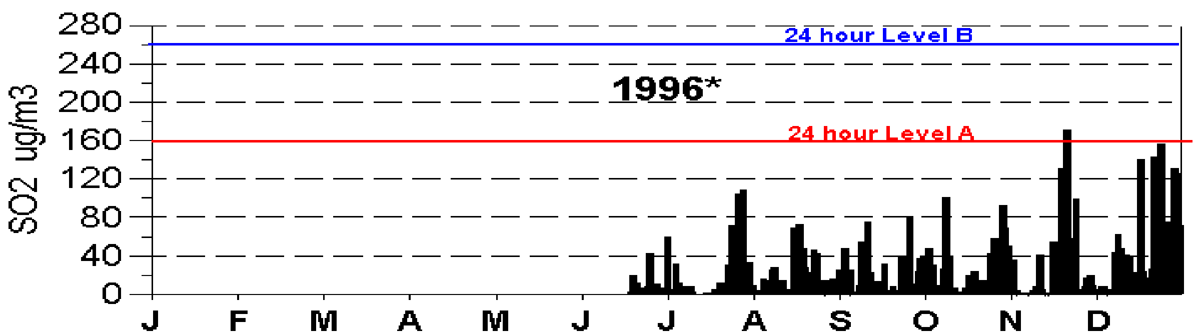
Figure 16. **Trail – Butler Park SO_2**

Figure 16a. Time Series – Daily averages by year.



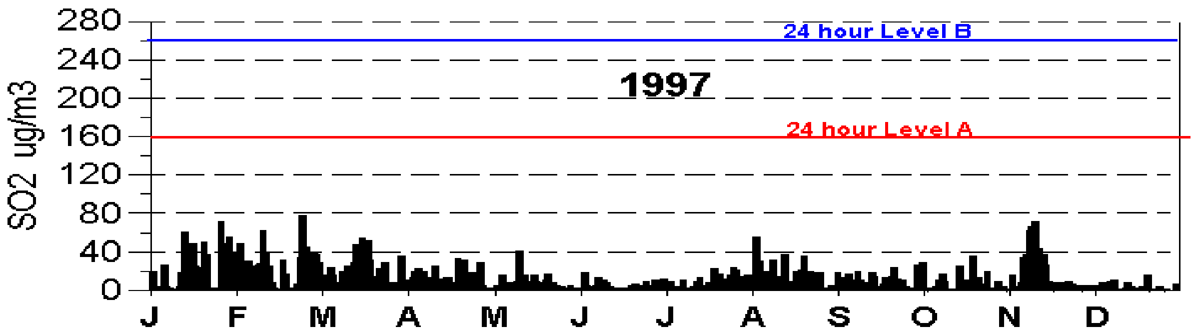


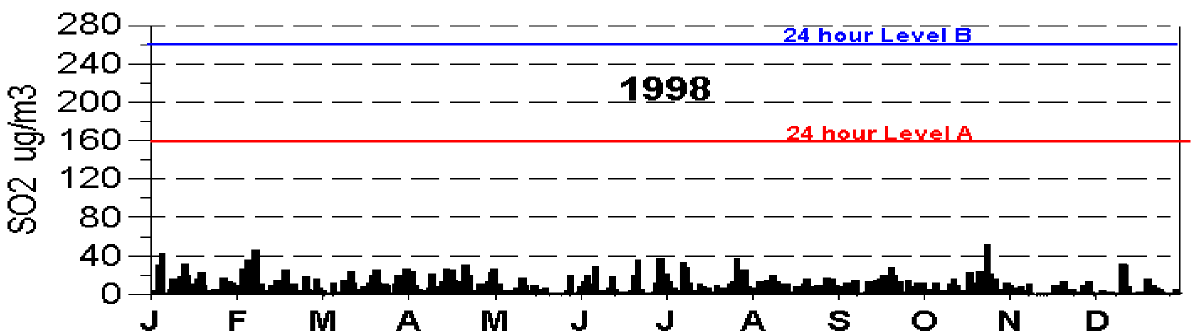




* data capture <75%

Figure 16. continued **Trail – Butler Park SO_2**





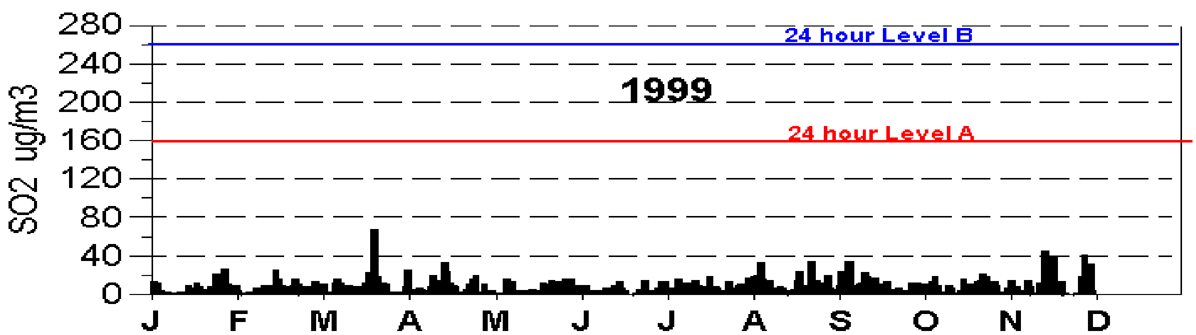


Fig 16b. Frequency Distribution
n=52,189 hourly records

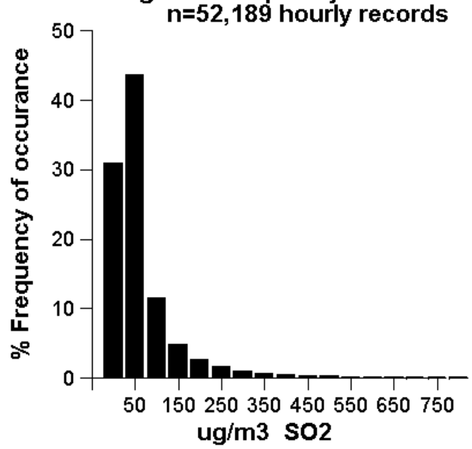


Fig 16c. Annual Averages
Based on Daily Average values.

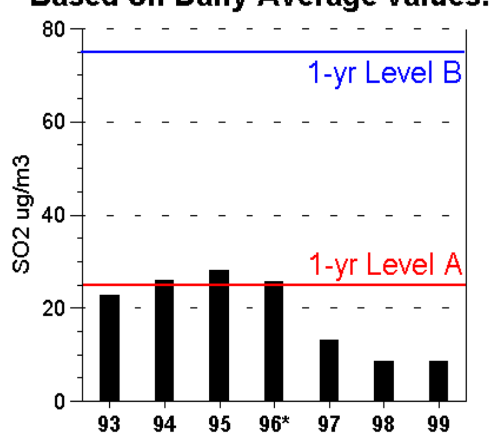


Figure 16. continued **Trail – Butler Park SO_2**

Figure 16d Monthly Maxima

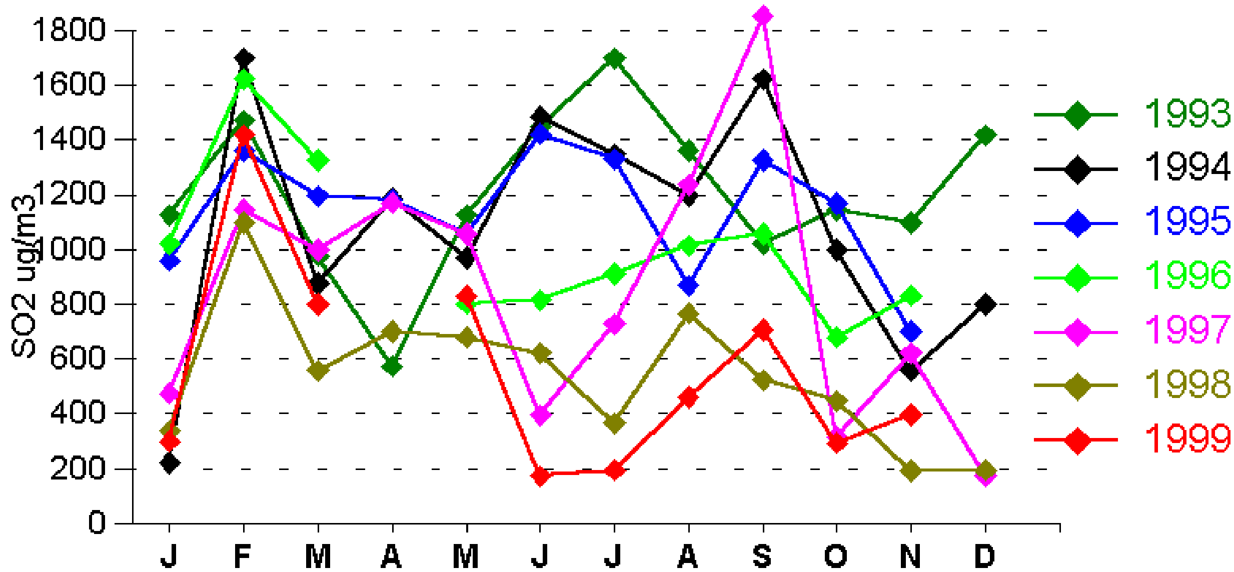
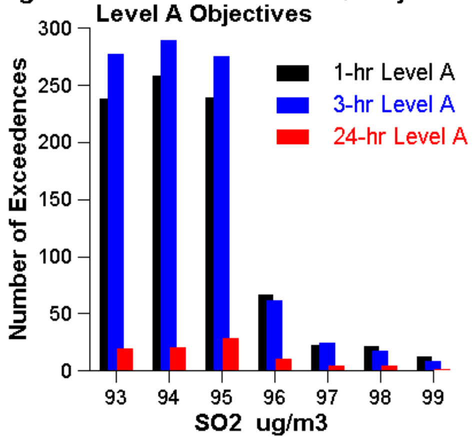


Fig 16b. Exceedences of Air Quality Level A Objectives

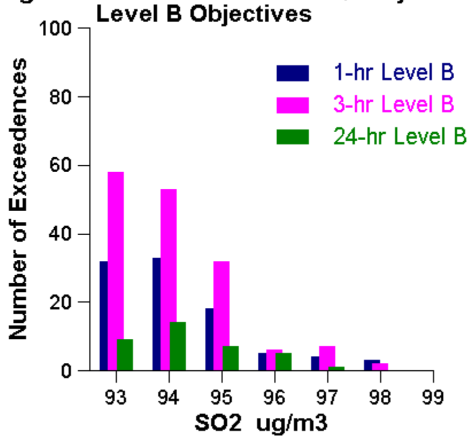


Level A objectives are the maximum concentrations compatible with 'Desirable' air quality conditions. The Level A objectives are:

1-hour	450 µg/m^3
3-hours	375 µg/m^3
24-hours	160 µg/m^3
1 year	25 µg/m^3

Exceedences of the 1 year Level A objective are shown in Figure 16c..

Fig 16b. Exceedences of Air Quality Level B Objectives

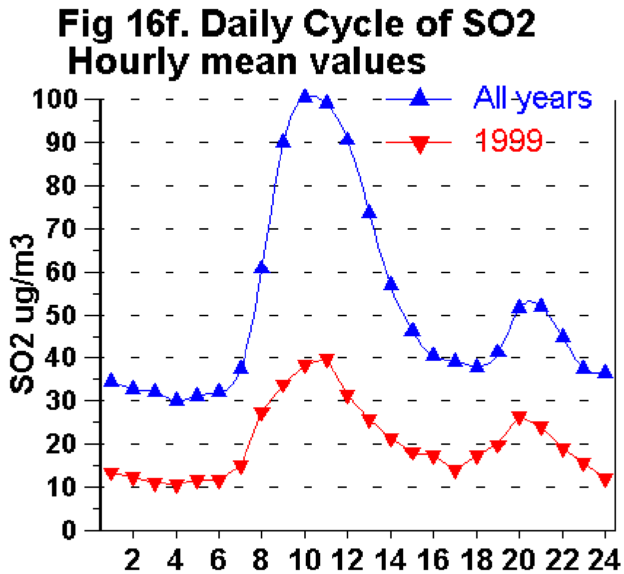


Level B objectives are the maximum concentrations compatible with 'Acceptable' air quality conditions. The Level B objectives are:

1-hour	900 µg/m^3
3-hours	665 µg/m^3
24-hours	260 µg/m^3
1 year	75 µg/m^3

There were no exceedences of the 1 year Level B objective at Butler Park.

Figure 16. continued **Trail – Butler Park SO_2**



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Appendix 1 PM10 data

Castlegar PM10 data, 1993 - 1999

Annual Means, Standard Deviations and Daily Maxima

	1993	1994	1995	1996	1997	1998	1999*
%data captu	82.0%	83.6%	95.1%	77.0%	96.7%	83.6%	47.5%
Standard De	15.2	15.5	11.6	7.4	11.8	13.4	17.1
Mean	28.1	26.2	22.0	16.6	21.8	24.4	21.2
Max	83	102	67	46	58	71	103

Exceedences

	1993	1994	1995	1996	1997	1998	1999*
BC>50	4	4	2	0	1	2	1
Can>60	2	1	1	0	0	2	1
Increments	36	31	16	4	20	22	10

6-month Period Averages

	1993	1994	1995	1996	1997	1998	1999*
Winter	28.1	32.0	21.2	20.5	23.4	22.7	25.1
Summer	27.9	23.3	23.3	15.3	15.8	29.7	15.7

Monthly Averages / **Annual Cycle – Monthly Average**

	1993	1994	1995	1996	1997	1998	1999*	Mean	Std Dev.
J	29.0	35.2	17.8	17.0	24.5	19.2	21.4	23.4	6.16
F	24.0	21.2	22.2	21.8	30.0	22.4	48.5	27.2	9.14
M	30.4	47.2	23.2	22.6	38.6	20.3		30.4	9.71
A	23.8	29.2	19.6		22.3			23.7	3.50
M		22.5	43.5	15.8	13.6	19.0	14.4	21.5	10.31
J	26.0	23.5	22.0	15.6	11.4	20.4	15.4	19.2	4.82
J	21.0	24.0	25.3	17.0	15.6	35.8	17.4	22.3	6.46
A	28.2	22.3	15.8	19.0	18.5	53.4	15.6	24.7	12.39
S	39.0	18.0	18.8	11.2	14.2	16.8		19.7	9.01
O	31.8	18.6	17.8	13.5	26.8	25.3		22.3	6.20
N	32.7	20.5	24.8	14.8	26.2	22.6		23.6	5.44
D	22.0	24.6	18.8	11.4	20.2	14.7		18.6	4.44

Monthly Maxima

	1993	1994	1995	1996	1997	1998	1999*
J	83	54	29	32	38	28	29
F	33	43	29	46	58	38	103
M	38	102	40	39	48	24	
A	64	58	29		41		
M		31	67	21	18	25	20
J	38	32	44	20	15	33	22
J	28	28	37	19	24	47	25
A	56	25	24	23	28	71	22
S	46	30	29	13	28	29	
O	47	23	29	16	41	37	
N	35	21	43	20	31	33	
D	35	44	29	15	37	24	

Appendix 1 PM10 data

Cranbrook PM10 (continuous data – hourly)

Annual Means, Standard Deviations and Daily Maxima

	1993	1994*	1995	1996	1997	1998	1999*
%data capture		66%	89%	99%	99%	90%	2%
Standard Dev.		10.98	9.14	13.31	15.03	11.71	
Mean		17.0	13.7	16.6	17.8	17.2	
Max		67	61	97	106	80	

Monthly Averages / **Annual Cycle – Monthly Averages**

	1993	1994*	1995	1996	1997	1998	1999*	Mean	Std Dev.
J			20.77	13.55	23.42	15.56		18.33	3.950
F				31.85	27.68	28.66		29.40	1.784
M			19.43	25.73	22.90	19.79		21.96	2.561
A		29.17	13.17	14.15	22.78	19.06		19.67	5.881
M		16.16	15.44	13.02	20.17	16.81		16.32	2.314
J		12.10	11.75	16.05	14.10	11.32		13.06	1.771
J		22.63	12.19	15.15	11.79	15.64		15.48	3.892
A		23.11	11.18	17.09	14.48	19.45		17.06	4.086
S		20.42	14.48	14.26	16.58	13.78		15.90	2.454
O		10.70	9.50	15.75	11.65	15.22		12.57	2.483
N		11.31	13.93	12.50	16.49	14.32		13.71	1.753
D		14.09	10.83	9.12	13.57			11.90	2.029

Monthly Maxima

	1993	1994*	1995	1996	1997	1998	1999*
J			61	69	104	58	
F				97	82	80	
M			37	60	106	36	
A		46	22	54	49	55	
M		39	26	26	44	59	
J		34	31	27	37	19	
J		67	26	27	22	30	
A		44	22	50	44	32	
S		36	28	31	50	26	
O		27	20	36	25	30	
N		35	45	34	34	37	
D		14	11	9	14		

6-month Period Averages

	93	94	94-95	95-96	96-97	97-98	98
Winter (Oct-Mar)			15.2	17.4	18.5	17.4	14.8
Summer (Apr-Sep)		19.7	13.0	15.0	16.6	16.0	

Exceedences

	1993	1994*	1995	1996	1997	1998	1999*
BC>50		2	4	14	16	9	
Can>60		2	1	7	9	3	
Increments		40	29	84	113	65	

24 hour Diurnal Cycle

Hour (am)	1	2	3	4	5	6	7	8	9	10	11	Noon
Mean	10.27	9.42	8.57	8.68	10.75	15.34	21.23	21.85	20.00	19.42	18.54	17.99
Std Deviatior	9.46	8.97	7.66	6.60	7.58	13.06	20.97	22.92	18.57	18.88	17.58	18.04
Hour (pm)	1	2	3	4	5	6	7	8	9	10	11	Midnight
Mean	16.68	16.71	17.46	17.79	19.24	19.98	21.31	21.32	19.62	16.58	13.82	11.80
Std Deviatior	17.61	16.71	18.23	18.42	25.09	27.27	27.51	23.35	21.66	16.65	13.41	11.36

Appendix 1 PM10 data

Creston PM10 (continuous data – hourly)

Annual Means, Standard Deviations and Daily Maxima

	1993	1994*	1995*	1996*	1997	1998	1999*
% data capture		13%	61%	66%	96%	89%	60%
Mean		14.9	18.6	19.5	17.1	19.4	14.8
Standard Deviation		12.12	11.64	13.15	12.86	12.91	9.23
Max		64	71	76	95	97	46

Monthly Averages / **Annual Cycle – Monthly Averages**

	1993	1994*	1995*	1996*	1997	1998	1999*	Mean	Std Dev.
J			26.28	13.48	27.23	17.26	13.60	19.57	6.03
F				29.17	29.22	32.21	17.00	26.90	5.85
M			34.09	26.12	26.34	16.90	21.50	24.99	5.72
A			17.64	14.06	15.29	19.16	15.75	16.38	1.81
M			15.77	12.93	19.12	19.80	11.81	15.88	3.20
J				21.29	11.36	12.70	10.36	13.93	4.33
J			17.23	19.93	14.04	19.43		17.66	2.32
A			13.64	29.32	15.46	20.16	25.00	20.72	5.84
S			19.59	14.50	14.39	19.90	16.43	16.96	2.38
O		10.64	18.51	25.20	14.77	21.17		18.06	5.03
N		13.63	19.25		16.56	14.92	12.30	15.33	2.41
D		16.57	18.95		13.06	11.39		14.99	2.95

Monthly Maxima (of hourly data) by Year

	1993	1994*	1995*	1996*	1997	1998	1999*
J			257	141	216	229	192
F				194	184	252	158
M			131	135	203	111	115
A			67	84	243	114	80
M			161	53	204	156	149
J				349	170	22	48
J			187	185	126	167	
A			55	151	192	96	25
S			100	99	65	116	73
O		23	89	62	128	176	
N		55	168		60	83	65
D		150	133		67	103	

6-month Period Averages

	94-95	95-96	96-97	97-98	98-99	99
Winter (Oct-I	19.5	20.8	27.5	18.2	17.0	12.3
Summer (Ap	16.1	17.4	15.0	19.6	13.9	

Exceedences

	1993	1994*	1995*	1996*	1997	1998	1999*
BC>50		2	8	10	11	8	0
Can>60		1	3	4	5	7	0
Increments		11	53	74	79	86	22

24 hour Diurnal Cycle 94 - 99

Hour (am)	1	2	3	4	5	6	7	8	9	10	11	Noon
Mean	11.25	10.35	9.42	9.08	10.04	11.7	14.07	19.94	20.23	18.77	18.29	18.05
Std Deviatior	9.51	8.76	6.98	6.69	9.04	8.21	10.49	19.25	19.52	17.17	17.61	16.29
Hour (pm)	1	2	3	4	5	6	7	8	9	10	11	Midnight
Mean	18.78	19.43	21.83	23.22	24.93	26.16	28.96	25.96	22.5	18.73	15.83	13.17
Std Deviatior	17.28	17.6	19.69	21.34	23.33	26.48	29.64	26.3	24.06	17.98	13.94	11.47

Appendix 1 PM10 data

Golden PM10 - NAPS and Continuous data

24 Hour Diurnal Cycle (for 1999 continuous data)

Hour (am)	1	2	3	4	5	6	7	8	9	10	11	Noon
Mean	23.55	19.93	18.05	17.56	20.28	27.51	30.64	30.10	24.11	20.33	19.31	17.42
Std Deviatior	26.19	20.11	15.80	14.78	17.91	24.51	26.63	31.55	22.48	20.41	22.04	20.00
Hour (pm)	1	2	3	4	5	6	7	8	9	10	11	Midnight
Mean	17.70	18.46	21.11	23.35	31.76	42.40	44.21	44.93	43.98	35.86	32.75	27.71
Std Deviatior	19.22	18.52	24.31	25.08	42.95	66.61	54.47	50.44	52.39	37.36	36.43	28.73

Monthly Averages / **Annual Cycle – Monthly Averages**

	1993	1994	1995	1996	1997	1998	1999	Mean	Std Dev.
J	57.7	47.6	40.2	26.8	40.8	30.0	34.0	39.58	9.85
F	60.0	43.5	46.4	53.6	39.4	43.4	37.6	46.28	7.37
M	54.6	80.0	51.0	53.8	51.6	72.8	67.1	61.55	10.80
A	38.2	31.8	25.0	32.0	31.5	25.8	29.9	30.61	4.08
M	32.2	19.8	28.6	24.4	20.2	23.4	19.9	24.06	4.43
J	16.0	15.6	22.0	18.6	20.1	14.4	19.4	18.01	2.55
J	12.2	30.7	14.3	23.0	14.3	40.8	17.9	21.87	9.72
A	21.3	17.0	13.0	23.5	6.4	27.4	19.5	18.29	6.46
S		20.3	36.2	22.7	5.8	33.8	20.4	23.18	10.01
O	52.8	31.8	32.2	21.3	17.0	30.8	22.4	29.75	10.87
N	47.0	31.8	28.4	22.4	34.0	28.8	21.5	30.56	7.93
D	37.3	36.8	27.0	30.5	45.0	25.5		33.67	6.73

Monthly Maxima by Year

	1993	1994	1995	1996	1997	1998	1999
J	77	70	62	51	71	35	61
F	94	86	104	108	65	69	104
M	82	160	91	137	83	114	155
A	69	36	35	54	52	49	54
M	55	27	37	48	33	35	57
J	25	21	42	25	28	27	51
J	16	56	19	34	29	62	35
A	31	24	16	35	9	32	35
S		33	65	30	10	56	40
O	59	43	49	34	36	48	39
N	96	42	39	25	53	50	39
D	49	57	40	39	59	47	

Annual Means, Standard Deviations and Daily Maxima

	1993	1994	1995	1996	1997	1998	1999
% data captu	87%	95%	93%	97%	100%	100%	n/a
Mean	39.0	33.9	30.4	29.4	27.2	33.1	28.2
Standard De	16.23	16.94	11.16	11.45	14.64	14.03	13.83
Max	96	160	104	137	83	114	155

6-month Period Averages

	93	93-94	94-95	95-96	96-97	97-98	98-99	99
Winter (Oct-I	57.6	52.3	39.8	37.0	34.3	39.6	47.7	22.0
Summer (Ap	24.8	22.9	24.3	24.1	16.4	27.6	21.1	

Exceedences Adjusted to daily values (i.e. multiplied by the number of days till next reading)

Year	1993	1994	1995	1996	1997	1998	1999
BC Exceede	99	60	42	36	54	60	37
Canadian Ex	63	42	24	18	18	24	30
Increments	562	480	336	282	312	420	304

Appendix 1 PM10 data

Invermere PM10 NAPS data 1994 - 1999

Monthly Averages / **Annual Cycle – Monthly Averages**

	1993	1994*	1995	1996	1997	1998	1999*	Mean	Std Dev
J			24.4	13.8	19.5	23.0	17.0	19.5	3.87
F			25.6	21.6	42.1	37.4	32.8	31.9	7.50
M		33.5	32.4	23.4	28.5	47.8		33.1	8.15
A		19.2	13.8	14.8	26.0	26.6		20.1	5.40
M		14.4	14.0	14.8	13.3	16.4	11.6	14.1	1.46
J		8.3	13.0	22.8		14.4		14.6	5.22
J		31.5	14.6	21.2	12.1	23.3		20.6	6.84
A		26.7	11.5	19.8	17.5	26.0		20.3	5.63
S		26.8	19.0	11.5	14.8	18.8		18.2	5.13
O		24.0	29.0	16.8	19.8	22.8		22.5	4.11
N		29.4	16.2	12.6	36.6	16.4		22.2	9.18
D		24.7	18.8	21.8	33.2	14.3		22.6	6.32

Monthly Maxima

	1993	1994*	1995	1996	1997	1998	1999*
J			31	23	33	33	35
F			77	44	65	76	51
M		54	59	29	52	62	
A		47	27	23	31	53	
M		22	26	25	20	24	20
J		11	24	32		26	
J		62	33	32	19	30	
A		36	22	31	23	26	
S		50	30	16	29	28	
O		30	52	38	28	31	
N		41	21	17	61	29	
D		30	36	45	56	24	

Annual Means, Standard Deviations and Daily Maxima

	1993	1994*	1995	1996	1997	1998	1999*
%data capture		69%	100%	100%	90%	89%	23%
Mean		24.0	19.2	17.9	24.1	23.6	19.6
Standard Dev.		13.62	13.98	9.21	14.55	15.41	12.79
Max		62	77	45	65	76	51

6-month Period Averages

	94	94-95	95-96	96-97	97-98	98-99
Winter (Oct-Mar)	33.5	26.9	20.5	23.5	32.5	19.8
Summer (Apr-Sep)	21.3	14.2	17.6	16.9	19.9	11.6

Exceedences

Year	1993	1994*	1995	1996	1997	1998	1999*
BC>50		3	4	0	7	5	1
Can>60		1	1	0	2	3	0
Increments		22	20	10	27	26	5

Appendix 1 PM10 data

Johnston Lake PM10

Monthly Averages | **Annual Cycle – Monthly Averages**

Year	1993	1994	1995	1996	1997	1998	1999*	Mean	Std Dev
J	17.0	12.8	18.5	5.2	11.8	8.2	8.6	11.73	4.47
F	15.0	10.4	6.5	8.2	6.0	6.2	6.3	8.37	3.08
M	13.3	11.8	6.6	6.6	4.0	6.0		8.05	3.34
A	8.8	10.0	5.0	2.0	4.0	25.4		9.20	7.75
M	16.5	9.2	7.0	15.8	7.4	21.6	7.0	12.07	5.42
J	8.0	5.2	7.4	28.5	7.3	10.8		11.20	7.91
J	10.2	16.0	11.0	11.5	13.7	33.8		16.02	8.16
A	13.8	14.2	14.8	12.3	8.1	28.4		15.28	6.26
S	17.7	12.4	18.4	6.6	10.6			13.14	4.42
O	21.0	8.0	7.6	8.1		13.8		11.71	5.18
N	17.8	9.6	7.2	6.5	13.0	10.4		10.76	3.80
D	12.4	9.8	8.4	4.9	7.8	7.0		8.38	2.34

Monthly Maxima

	1993	1994	1995	1996	1997	1998	1999*
J	33	21	33	7	26	13	15
F	21	16	13	11	11	9	9
M	17	19	15	9	5	11	
A	12	13	10	2	6	64	
M	27	13	9	27	13	47	14
J	14	8	14	49	15	19	
J	14	34	15	21	33	46	
A	24	23	24	17	10	43	
S	20	20	38	13	22		
O	33	11	13	15		23	
N	26	16	9	12	22	20	
D	18	16	12	9	12	10	

Annual Means, Standard Deviations and Daily Maxima

	1993	1994	1995	1996	1997	1998	1999*
%data captui	92%	98%	93%	93%	98%	90%	23%
Mean	14.4	10.9	9.8	9.6	8.8	15.1	7.4
Standard De	7.16	5.82	7.16	8.06	5.94	13.46	4.34
Max	33	34	38	49	33	64	15

6-month Period averages

	93	93-94	94-95	95-96	96-97	97-98	98-99
Winter (Oct-I	15.5	14.4	9.6	7.2	7.5	8.6	9.2
Summer (Ap	12.4	11.4	10.7	13.0	8.3	23.6	7.0

Exceedences

Year	1993	1994	1995	1996	1997	1998	1999*
BC>50	0	0	0	0	0	1	0
Can>60	0	0	0	0	0	1	0
Increments	3	1	2	2	1	15	0

Appendix 1 PM10 data

Nelson PM10 NAPS data

Monthly Averages

	1993*	1994*	1995	1996	1997	1998	1999*	Annual Cycle – Monthly Averages: Mean	Std Dev
J	5.7	20.8	17.6	20.8	15.0	13.5	21.0	16.34	5.17
F	29.8		21.2	29.4	14.1	29.4	21.8	24.27	5.79
M	19.6		18.4	28.4	36.9	47.0		30.06	10.79
A	13.0	17.2	17.8	21.6	45.6	49.5		27.46	14.48
M	21.8	14.6	11.5	15.3	20.0	23.6	18.0	17.83	3.99
J	15.6		12.7	18.2	14.2	17.2		15.57	1.99
J	14.6		15.6	23.0	19.1	56.0		25.67	15.45
A	43.0	16.0	13.2	23.5	17.6	49.2		27.08	13.92
S	31.0	14.2	17.2	11.7	8.5	17.8		16.73	7.12
O		13.6	15.0	12.5	30.8	20.6		18.50	6.75
N	12.5	11.6	10.2	10.3	20.6	16.6		13.64	3.77
D		9.0	16.6	8.9	17.4	17.0		13.78	3.95

Monthly Maxima

	1993*	1994*	1995	1996	1997	1998	1999*
J	8	45	32	52	34	31	52
F	53		37	95	29	49	49
M	35		32	43	88	51	
A	23	28	33	35	90	51	
M	37	19	16	34	34	33	23
J	26		16	24	22	27	
J	18		24	35	30	121	
A	43	20	22	39	25	65	
S	40	28	26	20	9	28	
O		24	22	18	47	37	
N	13	18	16	14	30	25	
D		14	41	12	23	49	

Annual Means, Standard Deviations and Daily Maxima

	1993*	1994*	1995	1996	1997	1998	1999*
%data captu	64%	61%	95%	98%	95%	89%	21%
Mean	19.0	14.7	15.7	18.8	22.3	27.8	20.3
Std Deviatio	11.43	8.23	8.56	14.56	17.36	20.39	14.32
Maximum	53	45	41	95	90	121	52

6-month Period Average

	93	93*-94*	94*-95	95-96	96-97	97-98	98-99
Winter (Oct-I	19.5	18.4	15.4	20.1	16.3	24.6	19.2
Summer (Ap	19.3	15.4	14.9	19.2	22.1	34.0	

Exceedences

Year	1993*	1994*	1995	1996	1997	1998	1999*
BC>50	1	0	0	2	3	5	1
Can>60	0	0	0	1	3	2	0
Increments	11	2	7	18	28	50	5

Appendix 1 PM10 data

Radium PM10

Monthly Averages | **Monthly Maxima**

	Monthly Averages 1998	Monthly Averages 1999	Monthly Maxima 1998	Monthly Maxima 1999
J		8.6		19
F		12.9		21
M				
A				
M		10.8		19
J		10.2		20
J	11.6	7.5	16	21
A	24.9	13.8	62	21
S	20.3	11.8	31	36
O	10.7	16.3	21	31
N	16.7	12.2	36	20
D	8.1	9.3	27	15

Annual Means, Standard Deviations and Daily Maxima

	1993	1994	1995	1996	1997	1998	1999
%data capture						n/a	n/a
Mean						15.3	11.3
Std Deviation						11.01	6.75
Maximum						62	36

6-month period averages

	94-95	95-96	96-97	97-98	98-99	99
Winter (Oct-Mar)					11.4	12.3
Summer (Apr-Sep)				20.8	10.9	

Exceedences and Increments

	1993	1994	1995	1996	1997	1998*	1999*
BC>50						1	0
Can>60						1	0
Increments						9	3

Appendix 1 PM10 data

Revelstoke PM10 – NAPS data

Monthly Averages / **Annual Cycle – Monthly Averages**

	1993	1994	1995	1996	1997	1998	1999*	Mean	Std Dev
J	24.8	27.2	24.6	8.4	28.3	20.0	20.6	22.0	6.24
F	41.5	29.8	28.6	25.5	23.8	26.4		29.3	5.82
M	23.6	36.2	35.0	27.0	31.2	25.4		29.7	4.75
A	13.2	11.2	11.8	15.4	25.9	25.6		17.2	6.20
M	20.0	10.3	9.4	8.8	13.1	23.8	10.8	13.7	5.40
J	16.2	8.8	8.7	12.6	14.0	16.4	13.8	12.9	2.94
J	13.2	36.5	16.6	26.5	17.7	38.8		24.9	9.90
A	29.3	15.3	9.8	16.7	15.1	26.4		18.8	6.81
S	24.0	14.0	18.0	13.3	13.3	23.0		17.6	4.48
O	23.8	14.0	12.3	13.3	51.2	22.6		22.9	13.44
N	16.0	12.0	13.0	19.2	20.6	22.5		17.2	3.86
D	13.8	12.6	11.0	16.7	22.0	13.3		14.9	3.60

Monthly Maxima

	1993	1994	1995	1996	1997	1998	1999*
J	30	44	29	12	39	30	29
F	54	54	52	53	36	44	
M	30	82	51	41	51	37	
A	21	18	17	21	33	43	
M	35	13	14	15	22	29	19
J	21	13	12	19	15	37	27
J	16	45	32	27	32	54	
A	55	21	18	34	22	51	
S	37	25	29	21	17	46	
O	33	23	14	16	83	35	
N	28	18	16	26	30	31	
D	18	18	13	21	31	18	

Annual Means, Standard Deviations and Daily Maxima

	1993	1994	1995	1996	1997	1998	1999*
%data captui	97%	85%	80%	85%	90%	95%	25%
Mean	21.6	19.0	16.6	16.9	23.0	23.7	15.1
Std Deviatior	10.88	14.25	10.54	9.43	15.46	11.56	7.64
Max	55	82	52	53	83	54	29

Exceedences

Year	1993	1994	1995	1996	1997	1998	1999*
BC>50	2	2	2	1	5	2	0
Can>60	0	1	0	0	3	0	0
Increments	10	15	6	5	22	12	0

6-month Period Averages

	93	93-94	94-95	95-96	96-97	97-98	98-99
Winter (Oct-I	28.9	24.8	20.1	16.9	22.2	28.4	19.3
Summer (Ap	18.9	14.0	12.4	14.1	16.2	25.3	12.3

Appendix 1 PM10 data

Slocan PM10 – NAPS data, irregular dataset

Annual Means, Standard Deviations and Daily Maxima

	1993*	1994*	1995*	1996*	1997*	1998*	1999*
%data captui	61%	61%	36%	0%	0%	n/a	n/a
Mean	15.1	12.5	12.1			14.9	13.0
Std Deviatior	5.0	9.7	6.6			6.0	5.6
Max	31	23	31			24	34

Monthly Averages

	1993*	1994*	1995*	1996*	1997*	1998*	1999*
J	7.0	12.7	12.0				14.0
F	18.0	13.8	10.8				10.9
M	12.7	22.3	8.0				
A	12.0		10.3				17.0
M	11.5	34.0	11.0				10.7
J	14.7	9.6	11.0				
J	16.8	26.5	10.4				
A	23.0	13.0	28.5				
S	22.0	14.0	12.0				
O	19.0	8.7					
N	16.2	5.8				15.5	
D	11.8	4.5				14.1	

Exceedences

Year	1993*	1994*	1995*	1996*	1997*	1998*	1999*
BC>50	0	0	0			0	0
Can>60	0	0	0			0	0
Increments	0	4	1			1	1

6-month Period Averages

	93	93-94	94-95	95-96	96-97	97-98	98-99
Winter	14.6	15.5	7.6				13.7
Summer (Ap	15.4	15.2	13.0				13.3

Time Series

Date	Arsenic Castlegar	Arsenic Trail	Cadmium Castlegar	Cadmium Trail	Lead Castlegar	Lead Trail	Zinc Castlegar	Zinc Trail
01-Jan-93	0.1		0.01		0.1		0.54	
07-Jan-93	0.1		0.01		0.1		0.09	
13-Jan-93	0.1		0.01		0.1		0.16	
19-Jan-93	0.42		0.39		8.71		4.32	
25-Jan-93	0.25		0.09		3.26		1.69	
31-Jan-93	0.1		0.01		0.22		0.39	
06-Feb-93	0.1		0.01		0.1		0.17	
12-Feb-93	0.1		0.01		0.1		0.2	
18-Feb-93	0.1		0.01		0.1		0.14	
24-Feb-93	0.1		0.01		0.1		0.18	
02-Mar-93	0.1		0.03		1.01		0.51	
08-Mar-93	0.1		0.02		0.66		0.39	
14-Mar-93	0.18		0.07		1.47		1.19	
20-Mar-93	0.1		0.01		0.14		0.01	
26-Mar-93	0.1		0.01		0.1		0.01	
01-Apr-93	0.1		0.01		0.28		0.33	
07-Apr-93	0.1		0.01		0.1		0.03	
13-Apr-93	0.1		0.01		0.1		0.01	
19-Apr-93	0.1		0.01		0.1		0.01	
25-Apr-93	0.1		0.01		0.1		0.01	
01-May-93	0.1		0.01		0.1		0.08	
07-May-93	0.1		0.01		0.1		0.13	
13-May-93	0.1		0.01		0.1		0.07	
19-May-93	0.1		0.01		0.1		0.09	
25-May-93	0.1		0.01		0.1		0.02	
31-May-93	0.1		0.01		0.1		0.03	
06-Jun-93	0.1		0.01		0.1		0.01	
12-Jun-93	0.1		0.03		0.47		0.22	
18-Jun-93	0.1		0.01		0.6		0.38	
24-Jun-93	0.1		0.01		0.13		0.01	
30-Jun-93	0.1		0.01		0.1		0.01	
06-Jul-93	0.1		0.01		0.23		0.06	
12-Jul-93	0.1		0.01		0.1		0.01	
18-Jul-93	0.1		0.01		0.31		0.06	
24-Jul-93	0.1		0.01		0.14		0.01	
30-Jul-93	0.1		0.01		0.1		0.07	
05-Aug-93	0.1	0.1	0.01	0.02	0.1	0.67	0.02	1.1
11-Aug-93	0.1	0.1	0.01	0.01	0.1	0.71	0.06	0.95
17-Aug-93	0.1		0.01		0.31		0.31	
23-Aug-93	0.1		0.01		0.1		0.17	
29-Aug-93	0.1	0.14	0.01	0.06	0.1	0.92	0.03	1.65
04-Sep-93	0.1	0.2	0.01	0.04	0.1	1.11	0.01	2.51
10-Sep-93	0.1	0.1	0.01	0.03	0.24	0.68	0.01	1.22
16-Sep-93	0.1	0.12	0.01	0.07	0.1	1.31	0.01	1.29
22-Sep-93	0.1	0.1	0.01	0.05	0.1	0.92	0.01	1.14
09/28/93	0.1	0.1	0.01	0.05	0.1	0.73	0.01	1.42
04-Oct-93	0.1		0.01		0.12		0.34	
10-Oct-93	0.1		0.01		0.1		0.23	
16-Oct-93	0.1		0.01		0.1		0.01	
22-Oct-93	0.11		0.03		0.48		0.69	
28-Oct-93	0.1		0.01		0.1		0.14	
03-Nov-93	0.19	0.19	0.04	0.14	0.98	0.41	1.08	0.55
09-Nov-93	0.1	0.58	0.01	0.09	0.15	2.24	0.39	1.52
15-Nov-93	0.16	0.1	0.04	0	1.21	0.12	1	0
21-Nov-93	0.1	0.1	0.01	0	0.4	0.15	0.32	0
27-Nov-93		0.1		0.06		2.04		0.55
03-Dec-93		0.1		0		0.1		0.23
09-Dec-93	0.1	0.1	0.01	0.03	0.1	1.11	0.07	0.39
15-Dec-93	0.1	0.13	0.02	0	0.89	0.42	0.4	0.34
21-Dec-93	0.1	0.1	0.02	0	0.56	0.19	0.49	0.41
27-Dec-93	0.1	0.1	0.01	0	0.1	0.13	0.01	0
02-Jan-94	0.15		0.04		0.65		0.85	
08-Jan-94	0.19	0.1	0.03	0	0.79	0	0.51	0.15
14-Jan-94	0.37	0.1	0.05	0.01	1.55	0.38	2.17	0.34
20-Jan-94	0.1	0.49	0.01	0.05	0.1	2.44	0.01	1.33
26-Jan-94	0.22	0.12	0.03	0.01	0.92	0.44	0.49	0.44
01-Feb-94	0.1	0.14	0.02	0.05	0.48	1.28	0.12	0.87
07-Feb-94	0.1		0.01		0.1		0.01	
13-Feb-94	0.1		0.04		1.08		0.34	
19-Feb-94	0.1	0.31	0.01	0.01	0.22	0.21	0.33	0.5
25-Feb-94	0.1	0.78	0.01	0.09	0.1	2.7	0.18	1.2
03-Mar-94	0.1	0.3	0.04	0.11	1.23	3.13	0.45	3.28
09-Mar-94	0.1	0.4	0.01	0.04	0.1	1.23	0.16	1.01
15-Mar-94	0.1	0.11	0.01	0.03	0.1	0.77	0.01	0.47
21-Mar-94	0.1	0.1	0.01	0.03	0.16	0.45	0.01	0.47
27-Mar-94	0.1	0.19	0.01	0.03	0.1	0.43	0.01	0.77
02-Apr-94	0.1	0.16	0.01	0.05	0.1	1.38	0.01	1.23
08-Apr-94	0.1	0.1	0.01	0.02	0.18	0.57	0.19	0.7
14-Apr-94	0.1	0.12	0.01	0.03	0.1	0.72	0.04	0.59
20-Apr-94	0.1	0.13	0.01	0.09	0.1	1.5	0.01	2.27

Appendix 2: Metals Tables

	Arsenic		Cadmium		Lead		Zinc	
Date	**Castlegar**	**Trail**	**Castlegar**	**Trail**	**Castlegar**	**Trail**	**Castlegar**	**Trail**
26-Apr-94	0.1		0.01		0.1		0.01	
02-May-94	0.1	0.12	0.01	0	0.1	0.32	0.11	0.35
08-May-94	0.1	0.15	0.01	0.06	0.1	1.33	0.01	1.55
14-May-94	0.1	0.14	0.01	0.03	0.1	0.47	0.01	0.65
20-May-94	0.1	0.11	0.01	0.02	0.1	0.55	0.01	0.37
26-May-94	0.1	0.15	0.01	0.04	0.1	0.92	0.01	0.76
01-Jun-94	0.1	0.12	0.01	0.02	0.1	0.52	0.01	0.96
07-Jun-94	0.1	0.1	0.01	0	0.27	0.19	0.4	0.64
13-Jun-94		0.1		0.05		0.9		1.02
19-Jun-94	0.1	0.18	0.01	0.09	0.1	2.23	0.01	3.65
25-Jun-94	0.1	0.1	0.01	0.03	0.1	0.55	0.01	0.85
01-Jul-94	0.1	0.1	0.01	0	0.21	0.15	0.45	0.58
07-Jul-94	0.1	0.1	0.01	0.13	0.1	1.45	0.3	1.82
13-Jul-94	0.1	0.1	0.01	0.02	0.1	0.44	0.22	1.45
19-Jul-94		0.15		0.1		1.7		4.27
25-Jul-94		0.17		0.14		1.83		2.2
31-Jul-94	0.1		0.03		0.36		0.7	
06-Aug-94	0.1		0.02		0.23		0.63	
12-Aug-94	0.1		0.01		0.1		0.18	
18-Aug-94	0.1		0.01		0.1		0.22	
24-Aug-94	0.1		0.01		0.1		0.21	
30-Aug-94	0.1	0.19	0.01	0.03	0.1	0.85	0.17	1.88
05-Sep-94	0.1	0.18	0.01	0.09	0.1	1.51	0.47	2.59
11-Sep-94	0.1	0.28	0.01	0.03	0.1	0.68	0.34	0.94
17-Sep-94	0.1	1.33	0.01	0.38	0.1	5.55	0.28	9.61
23-Sep-94	0.1		0.01		0.1		0.19	
29-Sep-94	0.1		0.01		0.1		0.27	
05-Oct-94	0.1		0.01		0.1		0.35	
11-Oct-94	0.1		0.01		0.1		0.21	
17-Oct-94	0.1	0.18	0.01	0.03	0.1	0.49	0.38	1.49
23-Oct-94	0.1	0.15	0.07	0.02	0.58	0.43	0.6	0.95
29-Oct-94	0.13	0.1	0.02	0	0.54	0	0.63	0.25
04-Nov-94	0.1	0.2	0.02	0	0.33	0.12	0.79	0.35
10-Nov-94		0.1		0.06		0.41		0.6
16-Nov-94								
22-Nov-94		0.1		0		0		0.3
28-Nov-94	0.16	0.1	0.04	0	0.39	0	0.5	0.22
04-Dec-94	0.1	0.13	0.01	0.04	0.1	0.87	0.23	0.52
10-Dec-94	0.1	0.1	0.02	0.04	0.24	0.55	1.16	3.05
16-Dec-94	0.36	0.17	0.13	0.03	3.64	0.5	2.14	0.31
22-Dec-94	0.23	0.59	0.08	0.18	2.64	5.25	0.54	1.21
28-Dec-94	0.13	0.12	0.01	0	0.27	0.16	0.46	0.28
03-Jan-95	0.1	0.39	0.01	0.04	0.1	0.91	0.18	1.18
09-Jan-95	0.1	0.8	0.01	0.05	0.1	1.51	0.19	2.62
15-Jan-95	0.3	0.1	0.06	0	1.22	0.15	0.8	0.34
21-Jan-95	0.1		0.01		0.1		0.17	
27-Jan-95	0.1	0.16	0.01	0.03	0.32	0.85	0.79	1.41
02-Feb-95	0.1	0.1	0.01	0	0.38	0.35	0.31	0.47
08-Feb-95	0.1	0.1	0.01	0.06	0.1	1.46	0.19	1.75
14-Feb-95	0.1	0.1	0.01	0.01	0.28	0.32	0.38	0.79
20-Feb-95	0.1	0.1	0.02	0.1	0.37	1.38	0.39	1.55
26-Feb-95	0.1	0.1	0.01	0.06	0.1	0.71	0.19	1.66
04-Mar-95	0.1	0.1	0.01	0.03	0.1	0.38	0.19	0.76
10-Mar-95	0.28		0.06		0.49		0.66	
16-Mar-95	0.1		0.01		0.16		0.28	
22-Mar-95	0.1	0.22	0.01	0.18	0.1	2.82	0.2	2.61
28-Mar-95	0.1	0.18	0.01	0.05	0.1	1.43	0.19	3.02
03-Apr-95	0.1	0.18	0.02	0.06	0.27	0.9	0.49	3.64
09-Apr-95	0.1	0.18	0.01	0.04	0.23	1.22	0.39	1.42
15-Apr-95	0.1	0.17	0.01	0.02	0.1	0.46	0.19	1.5
21-Apr-95	0.1	0.19	0.01	0.04	0.1	1.09	0.18	3.72
27-Apr-95	0.1	0.1	0.01	0.02	0.1	0.67	0.19	1.21
03-May-95	0.1	0.1	0.01	0	0.31	0.18	0.28	0.28
09-May-95	0.1	0.2	0.01	0.02	0.1	0.59	0.17	1.3
15-May-95	0.1	0.19	0.01	0.03	0.1	1	0.18	1.52
21-May-95		0.26		0.05		1.28		2.27
27-May-95	0.1	0.24	0.01	0.06	0.1	1.36	0.15	2.48
02-Jun-95	0.1	0.28	0.01	0.03	0.45	1.15	0.26	1.19
08-Jun-95	0.1	0.12	0.01	0.03	0.1	0.78	0.18	1.33
14-Jun-95	0.1	0.12	0.01	0.05	0.11	1.08	0.26	0.92
20-Jun-95	0.1	0.1	0.01	0	0.35	0	0.37	0.22
26-Jun-95	0.1	0.15	0.01	0.02	0.1	0.58	0.18	0.94
02-Jul-95	0.1		0.06		0.97		0.41	
08-Jul-95	0.1		0.01		0.1		0.18	
14-Jul-95		0.14		0.05		1.88		1.7
20-Jul-95	0.1	0.11	0.03	0.05	1	1.68	0.44	1.41
26-Jul-95	0.1	0.1	0.01	0.01	0.1	0	0.37	0.38
01-Aug-95	0.1	0.1	0.01	0.03	0.1	0.71	0.2	0.85
07-Aug-95	0.1	0.1	0.01	0	0.28	0.4	0.29	0.39
13-Aug-95	0.1	0.1	0.01	0.03	0.36	0.93	0.44	0.76
19-Aug-95	0.1		0.01		0.1		0.15	

	Arsenic		Cadmium		Lead		Zinc	
Date	Castlegar	Trail	Castlegar	Trail	Castlegar	Trail	Castlegar	Trail
25-Aug-95	0.1		0.01		0.1		0.31	
31-Aug-95	0.1		0.01		0.1		0.26	
06-Sep-95	0.1		0.01		0.1		0.27	
12-Sep-95	0.1		0.01		0.1		0.26	
18-Sep-95	0.1	0.1	0.01	0	0.1	0	0.31	0.49
24-Sep-95		0.1		0		0		0.41
30-Sep-95	0.1		0.03		0.89		0.71	
06-Oct-95	0.1		0.01		0.1		0.28	
12-Oct-95	0.1		0.01		0.2		0.44	
18-Oct-95	0.1		0.01		0.1		0.29	
24-Oct-95	0.17		0.04		0.96		0.8	
30-Oct-95	0.1		0.01		0.1		0.29	
05-Nov-95	0.11		0.03		0.74		0.77	
11-Nov-95	0.1		0.02		0.51		0.63	
17-Nov-95	0.1		0.01		0.1		0.55	
23-Nov-95	0.33		0.05		2.09		1.17	
29-Nov-95	0.1		0.09		1.84		1.22	
05-Dec-95	0.1		0.01		0.1		0.29	
11-Dec-95	0.1		0.03		0.48		0.57	
17-Dec-95	0.1		0.03		0.57		0.46	
23-Dec-95	0.1		0.01		0.1		0.28	
29-Dec-95	0.11		0.1		1.13		0.78	
04-Jan-96	0.1		0.03		0.3		0.28	
10-Jan-96	0.1		0.1		1.14		1.05	
16-Jan-96	0.1		0.03		0.3		0.39	
22-Jan-96	0.1		0.03		0.3		0.42	
28-Jan-96	0.1		0.03		0.3		0.15	
03-Feb-96	0.1		0.03		0.3		0.25	
09-Feb-96	0.1		0.03		0.3		0.27	
15-Feb-96	0.1		0.03		0.3		0.29	
21-Feb-96	0.13		0.04		0.52		0.8	
27-Feb-96	0.1		0.03		0.3		0.35	
04-Mar-96	0.1		0.03		0.3		0.31	
10-Mar-96	0.1		0.05		0.82		0.69	
16-Mar-96	0.1		0.03		0.66		1	
22-Mar-96	0.1		0.03		0.3		0.3	
28-Mar-96	0.1		0.03		0.3		0.3	
03-Apr-96								
09-Apr-96								
15-Apr-96								
21-Apr-96								
27-Apr-96								
03-May-96	0.1		0.03		0.3		0.28	
09-May-96	0.1		0.03		0.3		0.47	
15-May-96								
21-May-96	0.1		0.03		0.3		0.48	
27-May-96	0.1		0.03		0.3		0.38	
02-Jun-96	0.1		0.03		0.3		0.34	
08-Jun-96	0.1		0.03		0.3		0.34	
14-Jun-96	0.1		0.03		0.3		0.37	
20-Jun-96	0.1		0.03		0.3		0.34	
26-Jun-96	0.1		0.03		0.3		0.49	
02-Jul-96								
08-Jul-96	0.1		0.03		0.3		0.38	
14-Jul-96	0.1		0.03		0.3		0.42	
20-Jul-96	0.1		0.03		0.3		0.56	
26-Jul-96	0.1		0.03		0.3		0.49	
01-Aug-96	0.1		0.03		0.3		0.39	
07-Aug-96								
13-Aug-96								
19-Aug-96								
25-Aug-96	0.1		0.03		0.3		0.44	
31-Aug-96	0.1		0.03		0.3		0.88	
06-Sep-96	0.02		0.011141		0.37376		0.74763	
12-Sep-96	0.03		0.00011728		0.0046324		0.39276	
18-Sep-96	0.03		0.0062413		0.3332		0.56984	
24-Sep-96	0.02		0		0.0018764		0.35511	
30-Sep-96	0.02		0.00080438		0.011146		0.39909	
06-Oct-96	0.01		0.0013789		0.071073		0.34582	
12-Oct-96	0.01		0.0040038		0.20131		0.51891	
18-Oct-96	0.01		0.012548		0.39293		0.53073	
24-Oct-96	0.01		0.011105		0.40533		0.36031	
30-Oct-96	0.01		0		0.013725		0.32071	
05-Nov-96	0.02		0.079806		1.4683		0.54809	
11-Nov-96	0.01		0.00040878		0.012789		0.17035	
17-Nov-96	0.00		0.00040878		0.013139		0.16468	
23-Nov-96	0.00		0.00041046		0.0080334		0.15375	
29-Nov-96								
05-Dec-96		0.02		0.0077182		0.35925		0.3155
11-Dec-96		0.01		0.0093806		0.22596		0.94043
17-Dec-96		0.07		0.1633		3.7999		2.4158

	Arsenic		Cadmium		Lead		Zinc	
Date	Castlegar	Trail	Castlegar	Trail	Castlegar	Trail	Castlegar	Trail
23-Dec-96	0.00	0.17	0.0005888	0.050643	0.020196	0.76588	0.18288	1.3382
29-Dec-96	0.01	0.23	0.0018842	0.038521	0.023375	1.0946	0.19613	1.568
04-Jan-97	0.05	0.01	0.11982	0.0019193	2.0378	0.038734	1.4638	0.37611
10-Jan-97	0.05		0.12459		2.3122		1.071	
16-Jan-97	0.00	0.03	0.00047104	0.018286	0.0098919	0.48221	0.27114	1.2848
22-Jan-97	0.08		0.024951		1.0891		1.0554	
28-Jan-97	0.03	0.03	0	0.035919	0.0031795	0.77895	0.39214	1.1085
03-Feb-97		0.04		0.036335		0.56628		0.99743
09-Feb-97	0.01	0.04	0.00052992	0.048387	0.015427	0.87869	0.19183	1.0912
15-Feb-97	0.04	0.03	0.11682	0.0011874	1.7682	0.027014	0.95621	0.21593
21-Feb-97	0.06	0.02	0.034621	0.0093806	1.283	0.25636	1.6575	0.89947
27-Feb-97	0.01	0.04	0.00017664	0.027786	0.0036506	0.66317	0.22787	1.505
05-Mar-97	0.00	0.07	0.00082774	0.055452	0.019629	1.226	0.33287	1.0034
11-Mar-97	0.01		0.00017664		0.01525		0.26508	
17-Mar-97	0.18	0.07	0.018783	0.031763	0.89086	1.023	0.97859	0.74273
23-Mar-97	0.02		0.016545		0.53451		0.9568	
29-Mar-97	0.01		0.010598		0.50643		0.36258	
04-Apr-97	0.02	0.05	0.00047104	0.015258	0.01631	0.9434	0.18382	1.6832
10-Apr-97	0.00	0.04	0	0.010568	0.0030029	0.5911	0.1979	0.79379
16-Apr-97	0.02	0.05	0.00023552	0.008965	0.016015	0.30855	0.18624	0.93272
22-Apr-97	0.01	0.02	0.00011776	0.016133	0.015191	0.70656	0.24476	1.2665
28-Apr-97	0.02	0.02	0.00047104	0.0031598	0.0126	0.24098	0.23634	0.79055
04-May-97	0.01	0.02	0.0002365	0.0040372	0.020694	0.41203	0.28587	0.4983
10-May-97	0.01	0.02	0.00011776	0.0066811	0.013896	0.39424	0.22934	0.87859
16-May-97	0.01	0.03	0	0.005759	0.013189	0.55553	0.20178	0.97903
22-May-97	0.01	0.01	0	0.004257	0.0034292	0.26523	0.24223	0.62199
28-May-97	0.00	0.03	0	0.0036216	0.011187	0.19699	0.29069	0.48548
03-Jun-97	0.01	0.02	0	0.010524	0.0027335	0.67934	0.21333	1.6679
09-Jun-97	0.00	0.00	0	0.0089056	0.0072442	0.35878	0.21643	1.3133
15-Jun-97	0.01	0.01	0.00059125	0.0089869	0.01691	0.45017	0.22077	1.61
21-Jun-97	0.01	0.02	0	0.0031598	0.0074778	0.1658	0.22251	0.82453
27-Jun-97	0.01	0.03	5.9125E-05	0.0049665	0.0060898	0.30579	0.21622	0.76389
03-Jul-97	0.01		0.0027085		0.078134		0.43919	
09-Jul-97	0.00	0.01	0.0030745	0.0012468	0.087918	0.035088	0.45555	0.18185
15-Jul-97	0.01	0.00	0.00059125	0.0050465	0.003784	0.12818	0.14042	0.63467
21-Jul-97	0.01	0.02	0.00082432	0.010406	0.018901	0.47465	0.1525	0.85435
27-Jul-97	0.01	0.02	0	0.014368	0	0.89353	0.2	1.3471
02-Aug-97	0.01	0.05	0	0	0	0.89	0.1	3.3
08-Aug-97		0.02		0		0.51		0.9
14-Aug-97	0.01	0.01	0	0	0	0	0.2	0.7
20-Aug-97	0.01	0.03	0	0	0	0.59	0.3	1.4
26-Aug-97	0.01		0		0		0.3	
01-Sep-97								
07-Sep-97		0.03		0		0.35		0.9
13-Sep-97		0.04		0		0.57		1.2
19-Sep-97		0.02		0		0.53		1.2
25-Sep-97		0.03		0		0.52		1
01-Oct-97	0.01	0.01	0	0	0	0.34	0.4	1.1
07-Oct-97	0.02		0		0		0.4	
13-Oct-97	0.01	0.01	0	0	0	0	0	0.2
19-Oct-97	0.01	0.01	0	0	0	0	0.5	1.1
25-Oct-97	0.01		0		0		0.8	
31-Oct-97	0.02	0.01	0	0	0	0	0.7	0.4
06-Nov-97	0.01	0.01	0	0	0	0	0.7	0.7
12-Nov-97	0.01	0.01	0	0	0	0	0.2	0.6
18-Nov-97	0.01	0.01	0	0	0	0	0.5	0.4
24-Nov-97	0.01	0.01	0	0	0	0	0.3	0.3
30-Nov-97	0.01	0.01	0	0	0	0	0.3	0.3
06-Dec-97	0.01	0.03	0	0	0	0.45	0.2	0.7
12-Dec-97	0.07	0.01	0	0	0.38	0	0.4	0.3
18-Dec-97	0.01	0.03	0	0	0	0	0.2	0.5
24-Dec-97	0.01	0.01	0	0	0	0	0.3	0.2
30-Dec-97	0.07		0		0		0.6	
05-Jan-98	0.02		0		0		0.3	
11-Jan-98	0.01		0		0		0.2	
17-Jan-98	0.01	0.04	0	0	0	0	0.3	0.4
23-Jan-98	0.04	0.02	0	0	0	0	0.2	0.3
29-Jan-98	0.01	0.06	0	0	0	0.52	0.2	0.5
04-Feb-98	0.01	0.03	0	0	0	0.72	0.2	0.8
10-Feb-98	0.04	0.03	0	0	0	0	0.3	0.9
16-Feb-98	0.01	0.04	0	0	0	0	0.2	0.5
22-Feb-98	0.02	0.01	0	0	0	0	0.6	0.4
28-Feb-98	0.01	0.01	0	0	0	0.34	0.2	0.9
06-Mar-98	0.01	0.04	0	0	0	0.33	0.2	0.8
12-Mar-98	0.01	0.04	0	0	0	0.3	0.1	1.1
18-Mar-98	0.01	0.01	0	0	0	0	0.2	1.4
24-Mar-98		0.04		0		0		0.8
30-Mar-98	0.01	0.03	0	0	0	0	0.2	0.9
05-Apr-98	0.01	0.21	0	0	0	0.41	0.4	2.2
11-Apr-98	0.01	0.01	0	0	0	0	0.2	0.6
17-Apr-98	0.01	0.03	0	0	0	0	0.2	1.1

Appendix 2: Metals Tables

Date	Arsenic Castlegar	Arsenic Trail	Cadmium Castlegar	Cadmium Trail	Lead Castlegar	Lead Trail	Zinc Castlegar	Zinc Trail
23-Apr-98		0.11		0		0.52		1.3
29-Apr-98	0.01	0.04	0	0	0	0	0.2	0.9
05-May-98	0.01	0.01	0	0	0	0	0.2	1
11-May-98		0.03		0		0		0.9
17-May-98		0.01		0		0		0.5
23-May-98		0.01		0		0		0.5
29-May-98	0.01	0.04	0	0	0	0.4	0.2	1.9
04-Jun-98	0.01		0		0		0.2	
10-Jun-98	0.01	0.01	0	0	0	0	0.2	0.5
16-Jun-98	0.01	0.03	0	0	0	0	0.2	0.6
22-Jun-98	0.01		0		0		0.2	
28-Jun-98	0.01	0.01	0	0	0	0	0.6	0.5
04-Jul-98	0.01	0.01	0	0	0	0	0.2	0.4
10-Jul-98	0.01	0.02	0	0	0	0.34	0.3	1.5
16-Jul-98	0.01	0.01	0	0	0	0.37	0.3	1.5
22-Jul-98								
28-Jul-98	0.01		0		0		0.3	
03-Aug-98	0.01	0.01	0	0	0	0	0.4	1.3
09-Aug-98	0.01	0.05	0	0	0	0.51	0.2	3.2
15-Aug-98	0.01	0.01	0	0	0	0	0.2	0.4
21-Aug-98	0.01	0.02	0	0	0	0.33	0.2	1
27-Aug-98	0.01	0.03	0	0	0	0	0.2	0.5
02-Sep-98	0.01	0.03	0	0	0	0	0.2	0.8
08-Sep-98	0.03	0.01	0	0	0	0	0.3	0.4
14-Sep-98	0.01	0.02	0	0	0	0	0.6	0.7
20-Sep-98	0.01	0.01	0	0	0	0	0.4	0.8
26-Sep-98	0.01	0.01	0	0	0	0	0.2	0.9
02-Oct-98		0.01		0		0		0.4
08-Oct-98	0.02	0.02	0	0	0	0	0.2	0.5
14-Oct-98	0.01	0.03	0	0	0	0	0.4	0.4
20-Oct-98	0.01	0.03	0	0	0	0.51	0.2	1.1
26-Oct-98	0.03	0.06	0	0	0	0.3	0.3	0.8
01-Nov-98	0.01	0.03	0	0	0	0	0.4	0.7
07-Nov-98	0.01	0.01	0	0	0	0	0.4	0.6
13-Nov-98	0.01	0.01	0	0	0	0	0.4	0.2
19-Nov-98	0.03	0.01	0	0	0	0	0.4	0.4
25-Nov-98	0.02	0.01	0	0	0	0	0.4	0.3
01-Dec-98	0.04	0.01	0	0	0	0	0.3	0.2
07-Dec-98	0.01	0.01	0	0	0	0	0.4	0.3
13-Dec-98	0.01	0.01	0	0	0	0	0.5	0.3
19-Dec-98	0.01	0.04	0	0	0	0	0.3	0.7
25-Dec-98	0.01	0.06	0	0	0	0	0.4	0.6
31-Dec-98	0.03	0.03	0	0	0	0	0.6	0.4
06-Jan-99	0.05	0.01	0	0	0.5	0	0.6	0.3
12-Jan-99	0.01	0.01	0	0	0	0	0.4	0.3
18-Jan-99	0.03	0.01	0	0	0	0	0.4	0.6
24-Jan-99	0.01	0.02	0	0	0	0	0.2	1
30-Jan-99	0.01	0.01	0	0	0	0.41	0.2	1.3
05-Feb-99	0.02	0.01	0	0	0	0	0.3	0.5
11-Feb-99	0.01	0.01	0	0	0	0	0.3	0.7
17-Feb-99	0.01	0.01	0	0	0	0	0.4	0.5
23-Feb-99	0.01	0.01	0	0	0	0	0.4	0.4
01-Mar-99								
07-Mar-99		0.03		0		0		1.4
13-Mar-99		0.01		0		0		0.7
19-Mar-99		0.04		0		0.42		1
25-Mar-99		0.01		0		0		0.8
31-Mar-99		0.01		0		0.16		1.04
06-Apr-99		0.01		0		0.12		1.03
12-Apr-99		0.01		0		0.13		0.64
18-Apr-99		0.01		0		0.25		0.98
24-Apr-99		0.01		0.01		0.37		1.61
30-Apr-99		0.01		0.01		0.16		0.81
06-May-99	0.01	0.03	0	0.05	0	0.82	0.8	1.9
12-May-99	0.03		0		0		0.5	
18-May-99	0.01	0.01	0	0	0	0	0.5	0.6
24-May-99	0.01	0.01	0	0	0	0.48	0.6	1.4
30-May-99	0.02	0.01	0	0	0	0.31	0.7	0.7
05-Jun-99	0.02	0.06	0	0	0	0.38	1.2	0.8
11-Jun-99	0.02	0.04	0	0	0	0.33	1.3	2.3
17-Jun-99	0.01	0.01	0	0	0	0	0.7	1.3
23-Jun-99	0.03	0.03	0	0	0	0	0.8	1.9
29-Jun-99	0.01	0.01	0	0	0	0	0.8	1.5
05-Jul-99	0.01	0.03	0	0	0	0	3.8	1.1
11-Jul-99	0.01	0.05	0	0	0	0.34	3	1.2
17-Jul-99	0.03	0.03	0	0	0	0	1.4	1
23-Jul-99	0.03	0.04	0	0	0	0	4.6	0.8
29-Jul-99	0.01	0.06	0	0	0	0	1.1	1.1
04-Aug-99	0.01	0.08	0	0	0	0.45	4.6	1.5
10-Aug-99	0.03	0.03	0	0	0	0.47	0.3	2.8
16-Aug-99	0.02	0.03	0	0	0	0	0.5	1.3

Date	Arsenic Castlegar	Arsenic Trail	Cadmium Castlegar	Cadmium Trail	Lead Castlegar	Lead Trail	Zinc Castlegar	Zinc Trail
22-Aug-99	0.01	0.34	0	0	0	0	0.6	1.5
28-Aug-99	0.01		0		0		0.4	
03-Sep-99		0.10		0		0		1.5
09-Sep-99		0.04		0		0.42		1.5
15-Sep-99		0.01		0		0		1.9
21-Sep-99		0.08		0.04		0.95		3.2
27-Sep-99		0.09		0.06		0.71		2
03-Oct-99		0.12		0		0		1.1
09-Oct-99		0.02		0		0		0.4
15-Oct-99		0.10		0		0.74		3.3
21-Oct-99		0.14		0		0.43		1
27-Oct-99		0.10		0		0.42		0.9
02-Nov-99		0.10		0		0.39		1
08-Nov-99		0.07		0		0.32		0.7
14-Nov-99		0.24		0		0.53		1.6
20-Nov-99		0.01		0		0		0.3
26-Nov-99		0.15		0		0		0.8
02-Dec-99		0.01		0		0		0.3
08-Dec-99		0.05		0		0		0.6
14-Dec-99		0.03		0		0		0.5
20-Dec-99		0.01		0		0		0.3

Metals - Annual Medians and Maxima

Arsenic

	Castlegar		Trail	
	Median	Maximum	Median	Maximum
1993	0.1	0.42	0.1	0.58
1994	0.1	0.37	0.13	1.33
1995	0.1	0.33	0.12	0.8
1996	0.1	0.13	0.05	0.23
1997	0.01	0.18	0.02	0.07
1998	0.01	0.04	0.02	0.21
1999	0.01	0.03	0.03	0.34

Cadmium

	Castlegar		Trail	
	Median	Maximum	Median	Maximum
93	0.01	0.39	0.03	0.14
94	0.01	0.13	0.03	0.38
95	0.01	0.1	0.03	0.18
96	0.03	0.1	0.03	0.16
97	0.001	0.125	0.003	0.055
98	0.001	0.001	0.001	0.001
99	0.001	0.001	0.001	0.006

Lead

	Castlegar		Trail	
	Median	Maximum	Median	Maximum
93	0.1	8.71	0.70	2.24
94	0.1	3.64	0.55	5.55
95	0.1	2.09	0.85	2.82
96	0.3	1.47	0.77	3.80
97	0.0	2.31	0.35	1.23
98	0.0	0.0	0.0	0.72
99	0.0	0.5	0.0	0.95

Zinc

	Castlegar		Trail	
	Median	Maximum	Median	Maximum
93	0.09	4.32	0.75	2.51
94	0.22	2.17	0.85	9.61
95	0.29	1.22	1.3	3.72
96	0.38	1.05	1.34	2.42
97	0.29	1.66	0.87	3.3
98	0.2	0.6	0.70	3.2
99	0.6	4.6	1	3.3

Appendix 3 SO2 Tables

Robson SO2

Daily Cycle of SO2

Hour	Mean	Std Dev
1	7.97	3.05
2	9.04	3.33
3	9.38	3.46
4	10.32	3.81
5	11.44	4.46
6	13.29	4.71
7	15.91	5.88
8	19.54	7.49
9	22.25	8.95
10	20.68	8.64
11	19.69	9.40
Noon	16.82	8.16
1	14.65	7.24
2	12.56	6.36
3	11.29	5.75
4	9.68	4.75
5	9.05	4.00
6	8.29	3.35
7	8.08	2.67
8	8.01	2.72
9	7.64	3.17
10	7.18	2.96
11	7.29	2.78
Midnight	7.50	3.00

Monthly Maxima of Hourly data

	1993	1994	1995	1996	1997	1998	1999
J	770	479	200	477	328	138	101
F	589	421	362	301	136	64	96
M	280	490	165	266	216	88	77
A	144	234	344	210	123	93	133
M	181	194	122	237	59	45	35
J	266	213	96	101	107	61	48
J	224	224	341	149	59	56	69
A	253	154	258	328	104	117	104
S	258	165	301	186	61	112	53
O	439	383	298	306	75	77	107
N	386	234	325	296	40	115	
D	447	394	570		72	72	

Exceedences and Annual Average SO2

	1993	1994	1995	1996	1997	1998	1999
1-hour Level A	6	2	2	1	0	0	0
3-hour Level A	9	3	3	2	0	0	0
24-hour Level A	4	4	1	3	0	0	0
Annual Average	18.08	22.20	14.70	13.44	7.23	4.45	4.61

Trail – SO2

Daily Cycle of SO2

Hour	Mean	Std Dev
1	34.5	13.55
2	32.7	12.41
3	32.1	10.91
4	30.0	10.64
5	31.2	11.73
6	32.0	11.77
7	37.5	15.17
8	60.7	27.46
9	90.1	33.94
10	100.4	38.48
11	99.0	39.86
Noon	90.5	31.42
1	73.6	25.76
2	56.9	21.28
3	46.3	18.21
4	40.4	17.43
5	39.2	14.14
6	37.9	17.30
7	41.3	19.92
8	51.5	26.39
9	51.9	24.03
10	44.9	19.00
11	37.5	15.64
Midnight	36.5	11.94

Monthly Maxima of Hourly data

	1993	1994	1995	1996	1997	1998	1999
J	1124	221	959		474	336	298
F	1470	959	852		868	394	631
M	977	876	1241		652	929	221
A	573	1185	1180		719	1225	495
M	1126	969	1055		282	1265	559
J	1451	1486	1422	802	394	674	248
J	1699	1347	1329	815	727	365	706
A	1361	1196	868	911	1236	767	461
S	1020	1622	1326	1015	1854	522	706
O	1145	999	1169	1057	314	447	293
N	1097	557	700	679	621	192	397
D	1417	799		831	173	194	

Exceedences and Annual Average SO2

	1993	1994	1995	1996	1997	1998	1999
1-hr Level A	238	258	239	67	22	21	12
3-hr Level A	277	289	275	62	24	17	8
24-hr Level A	19	20	28	10	4	4	1
1-hr Level B	32	33	18	5	4	3	0
3-hr Level B	58	53	32	6	7	2	0
24-hr Level B	9	14	7	5	1	0	0
Annual Average	22.87	25.92	28.12	25.67	13.02	8.71	8.55

Appendix 4 AIR CONTAMINANTS and DEFINITIONS OF TECHNICAL TERMS (Mignacca, D., 1995)

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1.0 UNITS OF MEASURE OF AIR CONTAMINANTS

Contaminants may be present in ambient air as gases and as particles. The two most common types of measures that describe contaminants are the concentration of the contaminants in ambient air and the dimension of particles.

Concentration is the mass (weight) of contaminant per unit volume of air. Mass is expressed in units of micrograms (represented by `μg'); one gram consists of 1 million μg, and one μg is approximately two hundred times less than the mass of a typical grain of table salt. Volume is expressed in units of cubic metres (m^3); one m^3 consists of 1000 litres. Concentration is therefore expressed in units of micrograms per cubic metres of air, represented by $\mu g/m^3$. Since the volume occupied by any gas depends on temperature and pressure, concentrations in $\mu g/m^3$ are standardized relative to air at standard temperature (25 degree Celsius, ^{o} C) and pressure (101325 pascals).

For gaseous contaminants, an alternative measure of concentration is the volume of contaminant present in one billion volumes of air, or parts per contaminant per billion volumes of air (ppbv). This unit is similar to the concept of percentages. The advantage of the unit ppbv[1] is that it does not depend on air temperature and pressure.

The dimension of particles refers to the diameter of the particles and is expressed in units of length. The unit that is generally used is the micrometer (μm). One meter contains one million μm, and one um is approximately 50 times smaller than the width of a typical hair.

2.0 AIR CONTAMINANTS MONITORED IN CASTLEGAR

The two major industrial sources whose contaminant emissions to the atmosphere can affect ambient air quality in greater Castlegar are Celgar Pulp Company in Castlegar and Cominco Limited lead and zinc smelter in Trail. Although a large number of air contaminants are emitted by these two sources, the contaminants that are included in this report are only those that are measured. These are: inhalable suspended particulate matter (PM_{10}), sulphur dioxide (SO_2) and total reduced sulphur compounds (TRS). The level of acidity and chemical constituents of precipitation are also monitored.

2.1 Suspended Particulate Matter

Suspended particulate matter are very small liquid or solid particles that exist in a variety of dimensions, shapes and chemical compositions, and have a diameter from 0.005 to 100 μm (Hilborn and Still, 1990). Because the particles are very small, they behave as gas, which enables them to remain suspended (airborne) in the atmosphere. The period of time that particles remain airborne depend on the weight and size of the particles.

Since heavier particles are more prone to gravitational attraction, they settle out of the atmosphere sooner than the lighter particles and are thus more likely to impact locations that are closer to their sources. Lighter and smaller particles can remain airborne for longer periods; as such they can be transported over significant distances and can thus also impact locations that are further from their sources. At Castlegar, concentration of suspended particulate matter are measured for particles with diameter size less than or equal to 10 μm, represented by PM_{10}.

2.1.1 Sources

Particulate matter is a contaminant that is emitted directly into the atmosphere and it is also produced in the atmosphere from chemical and photochemical[2] reactions involving other contaminants and atmospheric substances. The two major industrial sources of particulate matter are Cominco and Celgar. Particulate matter is also a major component of wood smoke that is emitted from significant anthropogenic (due to human activities) sources such as open burnings, prescribed forest fires, lumber mill burners, wood-fired power boilers, wood stoves and fireplaces, residential backyard burning of foliage, grass and domestic refuse, agricultural burnings and agricultural-related activities. Exhaust from diesel and gasoline-fuelled vehicles are also sources of PM_{10}. Natural sources include wind-blown dust from roads and soils.

2.1.2 Effects

Health effects associated with exposure to particulate matter depend on the size and chemical composition of the particles. The greatest risk of adverse health effects is associated with PM_{10} particles because they are sufficiently small to penetrate deep into the finer structure of the lungs.
General health effects associated with prolonged exposure to elevated PM_{10} concentrations are irritations of the respiratory tract, a decrease in lung functions of healthy individuals and aggravation of asthma, emphysema, pneumonia, bronchitis and heart conditions. Depending on the exact chemical composition of the particles, exposure to PM_{10} may increase the risk of developing cancer over a life span and possibly contribute to premature mortality (United States Environmental Protection Agency (EPA), 1991). In a report to the B.C. Provincial Health Officer, it is concluded that PM_{10} from wood smoke may be causing substantial illness in some individuals (Vedal, 1993). The most susceptible to particulate matter are individuals suffering from chronic obstructive pulmonary or cardiovascular disease, asthmatics, the elderly, children, and individuals with influenza (EPA, 1991).

Potential environmental effects of PM_{10} include a general degradation of the quality of the air. As PM_{10} accumulates in air, the particles scatter and absorb light, thereby degrading visibility[3]. Visibility degradation affects the quality of scenic vistas and associated aesthetic values, which can lead to economic losses from tourists that avoid locations perceived as being polluted. For example, if PM_{10} were present in the atmosphere at concentrations of 20, 30 and 50 $\mu g/m^3$, the theoretical[1] visibility would be 25, 15 and less than 15 kilometres

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[1] Theoretical visibility is the visibility that is calculated from equations based on the physical principles of light scattering.

(km) respectively. These visibilities should be compared to pristine areas where the prevailing visibility is in the order of 300 km. Particulate matter can also affect animal health, cause vegetation damage, and soil and corrode objects.

2.1.3 Monitoring Method

Ambient concentrations of PM_{10} are commonly assessed with an instrument called a *high volume sampler* (hi-vol sampler). The operating principle is basically the weighing of a filter before and after exposure to ambient air. Ambient air is passed through a filter (at the rate of 1.4 m^3/min), on which the particulate matter accumulates, for a period of 24 continuous hour from midnight to midnight Pacific Standard Time (PST) in BC. Particulate matter concentrations are then assessed by dividing the difference in filter weight before and after exposure, by the volume of air that has passed through the filter (approximately 84 m^3 over 24 hours). Hi-vol concentrations represent an *average* concentration over the 24-hour sampling period. Studies have indicated that hourly concentrations can be up to 5 times higher than hi-vol concentrations (Chow and Watson et. al., 1993).

2.1.4 The NAPS Monitoring Schedule

The operation of hi-vol samplers requires significant resources. As a result, hi-vol samplers are not operated every day. Most hi-vol samplers operate on a pre-set schedule. The schedule that all private and governmental agencies adhere to is the schedule established by the *National Air Pollution Surveillance* (NAPS) program. Under the NAPS schedule, hi-vol samplers are operated once every sixth day. When special studies are conducted, hi-vol concentrations are also measured on non NAPS days.

2.2 Sulphur Dioxide

Sulphur dioxide (SO_2) is a colourless gas with a strong pungent odour at concentrations over 1300 $\mu g/m^3$. SO_2 is quite soluble in water or on any moist surfaces where it transforms into sulphurous acid (H_2SO_3). In the atmosphere, SO_2 can undergo chemical and photo-chemical reactions with other substances and oxidise[4] into fine particulate matter and sulphuric acid; sulphuric acid can then contribute to acidic depositions (EPA, 1991).

2.2.1 Sources

The two major industrial sources of SO_2 emissions to the atmosphere are Cominco and Celgar. The SO_2 is mainly emitted from stacks. At Cominco, SO_2 is produced as a by-product of the smelting (akin to melting) of sulphur-containing ores to obtain lead and zinc concentrates: the high temperature involved in smelting results in the oxidation of sulphur in the ores into SO_2 and other oxides of sulphur. Major stacks from which SO_2 is released into the atmosphere are the lead sintering stack, lead furnace bag-house stack, slag furnace bag-house stack and the zinc stack.

At Celgar, SO_2 is produced as an inherent by-product of kraft mill processes and as a planned alternative to increased emissions of malodorous total reduced sulphur compounds (TRS). Major SO_2 sources include the recovery boiler in which SO_2 is produced as a by-product and the lime kiln in which TRS is oxidised to SO_2 through incineration. If problems with the lime kiln occur, TRS is incinerated in # 2 power boiler.

2.2.2 Effects

The major health effects associated with SO_2 are impaired breathing, respiratory illness and symptoms, alterations in the lungs defense, aggravation of existing respiratory and cardiovascular disease and even mortality. The major subgroups of the population most sensitive to SO_2 include asthmatics and individuals with chronic lung diseases (EPA, 1991). Environmental effects include foliar damage to trees and agricultural crops; it can also soil objects and cause and accelerate the corrosion.

2.2.3 Monitoring Method

The instrument that measures SO_2 concentrations is based on the fact that when SO_2 is exposed to a beam of ultraviolet light it emits radiation (energy) with an intensity proportional to the mass of the SO_2 present. Ambient air is drawn into the instrument at a very low flow rate and is then exposed to ultraviolet light on a pulsating basis. The concentration of SO_2 is then determined based on the intensity of radiation measured.

SO_2 concentrations are measured and recorded on a continuous basis, with concentrations determined almost instantaneously (every few seconds). From these instantaneous values a 1-hour average concentration (*hourly concentration*) is calculated every hour. The hourly concentrations are assigned to the hour at which the averaging period ends. For example, the 0800 PST hourly concentration is calculated from the instantaneous concentrations measured between 0700-0800 PST.

2.3 Total Reduced Sulphur Compounds

Total reduced sulphur compounds (TRS) is a group of chemical compounds comprising sulphur in reduced chemical form; these include dimethyl disulphide, dimethyl sulphide, methyl mercaptans, and hydrogen sulphide (H_2S). TRS is characterized by a noxious odour similar to rotten eggs or rotten cabbage at concentrations as low as low as 7 $\mu g/m^3$. In ambient air H_2S can oxidise to SO_2 within a day.

2.3.1 Sources

The primary source of TRS is Celgar. TRS is emitted from the recovery boiler stack, effluent treatment lagoons and other minor sources associated with Celgar. Mainly for safety concerns, TRS scheduled for incineration is occasionally vented directly to the atmosphere. On such occasions ambient TRS concentrations can be elevated for few hours.

2.3.2 Effects

At concentrations usually present in ambient air, TRS does not constitute a health risk. TRS is mainly an odour problem, which may discomfort some individuals. The odour threshold concentration is near 7 $\mu g/m^3$. At concentrations over 1800 $\mu g/m^3$, individuals may suffer nausea and headache due to severe odour (Ontario Ministry of Environment, 1992). At concentrations of 70 $\mu g/m^3$, H_2S can discolour surfaces coated with lead base paints in several hours (Stern et. al., 1973).

2.3.3 Monitoring Method

The instrument that measures TRS concentrations is based on the fact that under very high temperature TRS oxidizes to SO_2. The instrument that measures TRS is therefore a modified SO_2 instrument. Ambient air is first passed through a scrubber to remove any SO_2 that may be present. The SO_2-free air is then passed through a very high temperature chamber in which any TRS that is present is oxidized to SO_2. The resulting SO_2 concentration is then assessed by the method described in Section 2.2.2. TRS in ambient air is then assigned the concentration of the associated SO_2. Because the original proportion of each TRS compound is unknown, the TRS concentration is expressed as an equivalent H_2S concentration since one molecule of H_2S is oxidised into one molecule of SO_2. TRS concentrations are monitored continuously, with real-time access to the data.

2.4 Acidic Precipitations and Depositions

In water, some gaseous and particulate substances dissociate and release positive hydrogen ions (H^+). The concentration of H^+ that a substance can release is expressed on a relative scale whose dimensionless unit is the pH. The pH scale ranges from 0 to 14, with 0 being the highest concentration of H^+ and 14 the lowest[5]. Each change of one unit on the pH scale actually represents a 10 fold change in the concentration of H^+; a substance with a pH of 4 contains 10 times more H^+ than a substance with a pH of 5.

Acids are defined as those substances with a pH less than seven, and *alkali* as those substances with a pH greater than seven; substances with a pH of seven are said to be neutral. Examples of acids are sulphuric acid, vinegar (pH = 2), apple juice (pH = 3). An example of an alkali is baking soda (pH = 8). Distilled water has a pH of seven.

`Acidic precipitations' refers to any type of precipitation (e.g. fog, rain, snow, hail, etc.) that has been acidified by atmospheric contaminants (Hilborn and Still 1990). Major atmospheric acidic contaminants include sulphuric acid (H_2SO_4) and nitric acid (HNO_3). Precipitation from the uncontaminated atmosphere is slightly acidic with pH ranging from 5.6 to 5.0 (Chapter 24, The State of Canada's Environment, 1991); this level of acidity mainly results from oxidation of the naturally occurring carbon dioxide into carbonic acid.

`Acidic precipitations' is the popular term for the wet deposition of acidic substances. *Deposition* is a process through which air contaminants are removed from the atmosphere and returned to earth. There are two basic types of deposition processes: dry deposition and wet deposition (Bisson, 1986). Dry deposition occurs when the contaminants are returned directly to earth. This occurs through gravitational attraction of the contaminants and through the impact and retention of the contaminants with any object or living creature on earth. In wet deposition the contaminants are first absorbed by either cloud or fog droplets, rain and snow, and are then returned to earth as part of the precipitation. `Acidic depositions' (wet or dry) refers to the return to earth of those contaminants that are acids or who have the potential of being transformed (*acid-forming*) into acids following their deposition.

2.4.1 Formation and Sources of Acidic Precipitations

Atmospheric acidic substances are not emitted directly into the atmosphere. They are formed in the atmosphere from complex chemical and photo-chemical reactions involving other contaminants and substances (*precursors*[6]). The two major anthropogenic precursors of acid precipitations are oxides of sulphur (which includes SO_2) and oxides of nitrogen (which includes NO_2).

If SO_2 and NO_2 remain in the atmosphere for sufficient time, their oxidation will eventually lead to the formation of sulphuric (H_2SO_4) and nitric acid (HNO_3) respectively. The oxidation of SO_2 and NO_2 can occur in both the gas phase (i.e. in the air) or in the liquid phase (i.e. in cloud droplets and precipitation). Depending on the type of other substances that are present in the gas and liquid phase, the oxidation can take as short as few hours to as long as few days (Chapters 2 and 4, Seinfeld, 1975; Chapter 1, Stern et. al, 1973). The H_2SO_4 and HNO_3 so produced are then eventually returned to earth either directly as fine particulate matter, or indirectly as components of precipitation. In precipitation, the H_2SO_4 and HNO_3 can dissociate in H^+ ions, sulphate ions (SO_4^{2-}) and nitrate ions (NO_3^-) respectively; these ions are then returned to earth as acidic precipitation or as fine particulates. Sulphate and nitrate can also cause environmental damages.

Because of the possible long oxidation time, SO_2 and NO_2 can be transported by regional winds over great distances as they are being oxidised. As result of this, acidic precipitations can affect areas that are great distances from the sources of the precursors. This renders the task of assessing the origin of acidic precipitations very difficult.

Celgar and Cominco are both sources of SO_2 and NO_2. These sources could both contribute to the acidity of local precipitations during persistent days with little air motion and high relative humidity. On such days the precursors are not transported at significant distances from the sources and the high relative humidity favours the formation of acidic substances.

2.4.2 Effects

Acidic precipitations can increase the naturally occurring acidity of various ecosystems such as lakes, streams, soils and vegetation. This affects not only the quality of the ecosystems but also the quality of life of organism that interact with them. The actual increase in acidity of ecosystems, and the adverse effects that it can generate, depend on the capacity (*buffering capacity*) of the ecosystems to neutralize the acids that it receives. In an Environment Canada weekly publication (*Climatic Perspective*) it is stated that environmental damage to lakes and streams is usually observed in sensitive areas regularly receiving precipitation with pH less than 4.7, while pH less than 4.0 are serious.

Acidic precipitations can also cause impaired lung function and complications in sensitive individuals, reduce agricultural productivity, contribute to forest dieback, cause and accelerate the corrosion of non protected materials and objects such as metals, brick, stone, etc. (Chapter 24, The State of Canada's Environment, 1991).

2.4.3 Monitoring Method

Precipitation samples are usually collected during a one week period. Basically, the cover of a container in which precipitation is collected opens automatically as precipitation is detected. Various chemical analyses are then performed on portions of the precipitation sample to determine the concentrations of H^+, SO_4^{2-}, NO_3^- and other contaminants.

3.0 AMBIENT AIR QUALITY OBJECTIVES

In the 1970's the Government of British Columbia published *Pollution Control Objectives* (PCO) for a number of industrial and municipal sectors. Some of these PCO recommend ambient air contaminant concentrations that are preferably not to be exceeded. In the report entitled *BRITISH COLUMBIA'S ENVIRONMENT: Planning for the Future, Ensuring Clean Air* (1992), BC Environment proposed that some of the PCO be utilized as ambient air quality objectives (*objectives*). Some of these objectives were derived from the scientific literature available in the 1970's, and as such they may not reflect new developments in the field that have occurred since then. The objectives have been assigned a similar definition as the Government of Canada National Ambient Air Quality Objectives.

The objectives specify various time-average concentrations intended to provide a specified degree of protection to humans, animals, vegetation and materials (Hillborn and Still, 1990). The definition of the objectives are presented in Table 1 and the associated time-average concentrations in Table 2; objectives have been established for only a few of the many known air contaminants. The objectives are not legally enforceable. They are used to assess the potential effects associated with the measured concentrations, and the progress, or lack thereof, in securing and maintaining acceptable air quality.

4.0 INTEGRITY OF MEASURED CONCENTRATIONS

Because of possible legal implications or other actions that may be undertaken based on measured concentrations, it is extremely important that measured concentrations are indeed valid. To ensure the integrity of measured concentrations, a series of quality assurance and quality control (QA/QC) tests are performed on both BC Environment and permittee[7]-operated monitors. BC Environment formally archives only those data for which the corresponding QA/QC tests have been passed. There is then reasonable assurance that the archived data are indeed valid and accurately represent ambient concentrations at the time of measurement.

Hi-vol samplers are subject to volumetric flow rate assessments once a year, as well as weekly visual inspections. SO_2 and TRS instruments are subject to daily automatic span checks, approximately four manual calibrations per year and at least two audits per year. In 1992 audits were performed by an agency that was independent of both BC Environment and permittees. The laboratory analyzing the hi-vol filters also performs a number of tests according to BC Environment standards.

The accepted data are archived in a VAX main-frame computer. Particulate and precipitation data are archived in the System for Environmental Assessment and Management (SEAM) database. SO_2 and TRS data are archived in the Continuous Air Monitoring Information System (CAMIS) database. Meteorological data is stored in the Meteorological Information System (MIS).

5.0 DEFINITION OF TECHNICAL TERMS

Data Capture. Data capture refers to the number of hi-vol and hourly data that have been actually archived in a year, and the number of 3 and 24-hour moving averages that can be calculated from the archived hourly data. In a leap year (1992), the maximum possible data capture for each of hi-vol data, hourly data, and 3 and 24-hour moving averages are 61, 8784, 8782 and 8761 respectively.

% Data Capture. The % data capture is the data capture expressed as a percentage of the maximum possible data capture for the year. For example, if the SO_2 hourly data capture is 7500, then the % hourly data capture for 1992 is 85% (= 7500*100÷8784).

Average (Avg). Given a set of concentrations, the average of these concentrations is the sum of all concentrations in the set divided by the number of individual concentrations in the set. Caution is recommended in interpreting annual averages that are based on less than 75% data capture (for hi-vol data measured on the

NAPS schedule, a 75% data capture corresponds to 46 hi-vol concentrations).

Standard Deviation (Std). The standard deviation is a number that gives a measure of the difference (variation) between the individual concentrations in a set and their average. In this report, standard deviations are only used in conjunction with 1992 annual averages and they are represented by a vertical line through the average (see Figure 1). The length of this line represents concentrations within the range from (Avg - Std) to (Avg + Std); this range is expressed as Avg +/- Std. At least 75% of the individual concentrations in a set have a value in the range Avg +/- 2*Std.

Frequency. The term *frequency* is an alternate expression for percentage. The frequency expresses the number of times that a particular event occurred as a percentage of the total number of events.

95% Confidence Interval. A 95% confidence interval is a range of concentrations for which there is a 95% probability that the true value of the average of a set of concentrations could be any of the values within that range. In this report, 95% confidence intervals are only used in conjunction with annual average concentration trends and they are represented by a vertical line through the average (see Figure 14).

Statistically Significant Change in Concentrations. Changes between any two annual average concentrations are said to be statistically significant at the 95% level of confidence if their respective 95% confidence intervals do not overlap. A statistically significant change suggests that the change was probably due to factors other than random (chance) variations.

Pth Percentile Concentration. The Pth percentile concentration (e.g., 75th percentile) is the concentration that is not exceeded by P% (e.g. 75%) of all concentration in a given set.

Linear Correlation Coefficients (r). Given a set of values (e.g. concentration values) of two parameters (e.g. SO_2 and TRS) that are measured at the same time. The linear correlation coefficient (r) is a measure of the degree of correlation (i.e. relation) of the values of the two parameters. r ranges from negative one to positive one. The values are 100% correlated if r is found to be 1. A positive r indicates that the values follow the same trend (*positive correlation*); a negative r indicates that the values follow an inverse trend (*negative correlation*). The greater the absolute value of r, the greater is the degree of correlation of the values. An absolute value of one (1) indicates that the values are 100% correlated, and a value of zero indicates no correlation.

The value of 100*r^2 (the square of r multiplied by 100), is the percent of the total variation of the values of one parameter that are explained by a relation with the other parameter. Therefore, a correlation of r = 0.80 (r^2 = 0.64) is twice as strong as a correlation of r = 0.57 (r^2 = 0.32). If 100*r^2 =1, then the variation of the values of one parameter are totally explained by a relation with the other parameters. It should be understood that the linear correlation coefficient does not provide any details on the sources of the variation. It only indicates whether two parameters are related or not.

Wind Rose and Air Contaminant Pollution Rose. A wind rose is a chart that presents the joint frequency of occurrence of measured wind direction and wind speed categories; wind direction is the direction from which the wind is blowing. An air pollution rose is simply a chart that presents the average contaminant concentration according to wind direction and wind speed categories. Air pollution roses are very useful in inferring sources that may contribute to ambient concentrations since the plume is transported in the same general direction as that of the prevailing wind.

DEFINITION OF THE BRITISH COLUMBIA AMBIENT AIR QUALITY OBJECTIVES	
Level A (Maximum Desirable)	Level A concentrations are intended to provide long-term protection. For polluted areas, the air quality may be subject to a general improvement if measured concentrations are persistently below Level A. For unpolluted areas, the air quality may be subject to a general degradation if measured concentrations are persistently above Level A.
Level B (Maximum Acceptable)	Level B concentrations are intended to provide adequate protection against effects on human health, vegetation and animals. Effects on personal comfort, especially in sensitive individuals, may become noticeable if measured concentrations exceed Level B.
Level C (Maximum Tolerable)	Level C concentrations denote concentrations beyond which, due to a diminishing margin of safety, appropriate action is required without delay to protect the health of the general population.

Table 1: Definition of the British Columbia ambient air quality objectives. In brackets are the corresponding terms of the National Ambient Air Quality Objectives.

BRITISH COLUMBIA AMBIENT AIR QUALITY OBJECTIVES				
AIR CONTAMINANT	AVERAGING TIME-PERIOD	CONCENTRATIONS ($\mu g/m^3$)		
		Level A	Level B	Level C
PM_{10}	24-hours		50	
SO_2	1-hour	450	900	
	3-hours	375	665	
	24-hours	160	260	800[3]
	1-year	25	75	
TRS	1-hour	7	28	
	24-hours	3	6	

Table 2: The British Columbia ambient air quality objectives. Concentrations in $\mu g/m^3$ are at standard temperature (25^o C) and pressure (101325 pascal). *Averaging time-period* means that concentrations are averaged over the indicated period. In this report the BC ambient air quality objectives and the associated time-averaging period are simply denoted as 1-hour, 3-hour, 24-hour and 1-year *objective* (e.g. the SO_2 24-hour Level B objective).

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1. The equation that converts ppbv to μg/m³ is: $C_{\mu g/m3} = (P*M_w*C_{ppbv}) \div (T*8330)$. In this equation, $C_{\mu g/m3}$ represents the contaminant concentration in μg/m³, C_{ppbv} is the contaminant concentration in ppbv, M_w is the molecular weight of the contaminant in grams/mole, P is the atmospheric pressure in pascal and T is the air temperature in degree Kelvin (^{o}K; ^{o}K = 273 + ^{o}C). At standard temperature and pressure the equation simplifies to: $C_{\mu g/m3} = 0.0408*M_w*C_{ppbv}$.

2. Photo-chemical reactions are reactions that only occur when the substances absorb sunlight. These reactions can therefore only occur under the presence of sunlight.

3. Visibility is defined as the maximum distance at which it is just possible to distinguish a large black object against the horizon sky.

4. Oxidation is a process through which a substance gains oxygen atoms, thereby transforming into a different chemical substance.

5. The pH value represents the number of times that 0.1 must be multiplied by itself (i.e. the exponent) in order to obtain the actual concentration (in moles/litre) of H^+ present in a substance. For example, precipitation with a pH of 5 means that the H^+ concentration is 0.1 to the power of 5 (= 0.1*0.1*0.1*0.1*0.1) moles/litre.

6. *Precursors* are substances that eventually transform into other chemical substances.

7. Permitees are industries that have been granted a waste discharge permit by BC Environment.