Air Quality in the Capital Regional District 2007

Prepared for:

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EXECUTIVE SUMMARY

Air quality is monitored in the Capital Regional District (CRD) to assess ambient air quality and to track trends. The monitoring is conducted under the long term monitoring program (LTMP), which is a partnership between the CRD and the British Columbia Ministry of the Environment (MoE), Royal Roads University and Environment Canada. SENES Consultants Limited (SENES) was contracted to provide an analysis and summary report of the monitoring data collected in 2007, including analysis of supporting meteorological information that was available over the same time period.

There are six air quality stations in the CRD that measure either gaseous contaminants and/or fine particulate matter. One station, on Saturna Island, is managed by Environment Canada, and records only gaseous pollutants. In addition, there are three 'Hi-Vol' stations that measure fine particulate matter only.

Ambient air concentrations of six air contaminants, collectively referred to as common air contaminants (CACs), are sampled on a frequent basis at the monitoring stations. The six CACs are carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ground-level ozone (O_3), particulate matter smaller than or equal to 10 microns (PM_{10}) and particulate matter smaller than or equal to 2.5 microns ($PM_{2.5}$).

Data collection was less successful for 2007 than in previous years, hampering data analysis for the annual report. Data were missing at all six monitoring sites for the following periods:

Monitoring Location	CO	NO/NO_2	SO_2	O_3	$PM_{2.5}$
Victoria Topaz	**Jan 1 - 2, Jun 22 – Jul 12, Aug 11 - 22, Oct 24 - 30, Nov 17 – 19**	**Jan 1 - 4, Jul 11 - 12, Sep 6 - 7, Dec 2, Dec 4**	**May 1-31, Jul 11 - 12, Dec 2, Dec 4**	**Jan 1 - 2, May 30 – Jun 12, Jul 12, Dec 4-5**	**Mar 26 - 27, Jul 11 - 12, Oct 16, Dec 2**
Royal Roads		**Jan 1 - Aug 15, Aug 26, Sep 13**		**Jul 11 - Aug 14**	**Jun 13, Jul 10 – Aug 15, Aug 26**
Stellys	**Jan 1-25, Mar 2 - Jun 20, Dec 1-9**	**Jan 1 - 5**		**Jan 1 - 4, Jul 1 - 5, Dec 4**	**May - Dec**
Langford	**Mar 10 – May 2**	**Jan 1- Feb 13 Jul 5 – 25 Aug 26 - 28**	**Jan 11 - 12, Mar 27 - 28, Aug 1**	**Jan 1 – May 2**	**Jan 11, Mar 27 - 28, May 1 - 3, Aug 1**
Christopher Point	**Jan 1 – Feb 12**	**N/A**	**Jan 1 – May 10, Oct 19**	**Jan 1 – May 2, Oct 4 - 14**	**Jan 1 – Feb 13, Aug 26 - 28**
Saturna Island			**N/A**	**Feb 7-13**	

N/A – not available

A primary focus of the annual air quality report is to assess the annual monitoring data with a set of CRD ambient air quality guidelines that were developed in 2004. In addition, comparisons to provincial and federal objectives and standards were made. Further temporal and spatial analyses were completed to examine trends in community air concentrations and to establish potential links between ambient concentrations and emission sources.

For the vast majority of the time in 2007, air quality remained relatively good in the CRD. The CRD guideline for PM_{10} was exceeded once at the Braefoot station. The CRD guideline for $PM_{2.5}$ was also exceeded once at Stellys Cross Road station. There was also one exceedence of the CRD guideline for ground level ozone at Saturna Island, meaning that exposure to elevated ozone concentrations was very low for CRD residents.

- The exceedence of the PM_{10} guideline of 50 µg/m^3 occurred at the Braefoot monitoring station on April 12th of the year, with a 24-hour average concentration of 69 µg/m^3. Concentrations recorded at each of the other PM_{10} monitoring stations in the CRD on that date were much lower, indicating that the higher PM_{10} concentration at Braefoot was not experienced throughout a large portion of the CRD. The likely cause of the high concentration at the Braefoot site on this date could not be determined.

- An exceedence of the CRD guideline for $PM_{2.5}$ occurred at the Stellys monitoring site on February 3rd, with a 24-hour average concentration of 25.4 µg/m^3, which was only slightly over the CRD guideline value. Concentrations recorded at each of the other $PM_{2.5}$ monitoring stations in the CRD on that date were much lower, indicating that the high $PM_{2.5}$ concentration was limited to the Stellys site. The likely cause of the high concentration at the Stellys site on this date could not be determined.

- The maximum 8-hour average ozone concentration recorded at Saturna Island on May 30th of 133.8 µg/m^3 was over the guideline having a value of 120 µg/m^3. Although peak springtime ozone concentrations at Saturna Island have been previously documented by Environment Canada and been attributed to the influence of background ozone levels, the pattern of increased ozone concentrations in the afternoon hours of May 30th also suggests the influence of photochemical production of O_3 on this occasion. While the onset of the ozone episode saw similar, simultaneous increases in O_3 levels at other monitoring locations in the CRD except for Christopher Point, elevated levels persisted well into the evening hours only at Saturna Island.

Due to the limited temporal and spatial extent of exposure to both the PM_{10} and ozone exceedences, related health effects for community members could not be determined with confidence.

A statistical tool was developed for the CRD in 2006 for the purpose of assessing trends in air quality concentrations over a period of five or more years. The tool assesses whether a statistically significant trend (increase or decrease) in annual mean and 98th percentile concentrations exists over the period. In addition, a trend in the proportion of measurements above the applicable CRD guideline is assessed. There were no statistically significant trends found for NO_2 or respirable particulate matter ($PM_{2.5}$) concentrations for any of the monitoring locations. The exceptions were for CO and SO_2 monitoring data at Victoria Topaz over the period 1998-2007, O_3 at Saturna Island for 1998-2007, for which trends were determined to be as follows:

- a decrease of 12%/year in annual mean concentrations of SO_2 at Topaz;
- a decrease of 13%/year in annual 98th percentile concentrations of SO_2 at Topaz;
- a decrease of 4%/year in the annual 98th percentile concentration of CO at Topaz; and,
- an increase of 26%/year in the annual frequency of O_3 values over the CRD guideline at Saturna Island.

It should be noted that the 26%/year increase in ozone concentrations above the CRD guideline at Saturna Island still only represents a low frequency of occurrence of one 8-hour average episode per year. Nevertheless, the trend analysis suggests that the frequency of guideline exceedances may increase in the future.

In summary, ambient concentrations of the common air contaminants monitored in the CRD remain relatively low compared with all provincial and federal guidelines objectives and standards, and the CRD was in attainment of the Canada Wide Standards (CWS) for ground level ozone and $PM_{2.5}$ in 2007. Overall, the majority of CAC show no upward or downward trends over time, with the exception of decreasing trends for sulphur dioxide and carbon monoxide at the Victoria Topaz site. On the other hand, the frequency with which ground-level ozone exceeds the CRD guideline value at Saturna Island appears to be increasing.

1.0 INTRODUCTION

The Capital Regional District (CRD) has been in partnership with the B.C. Ministry of Environment (formerly the Ministry of Water, Land and Air Protection – MWLAP) and others in conducting an ambient air quality monitoring program in the CRD area since 1996. One of the initial goals of the Long Term Monitoring Program (LTMP) was to investigate the contribution of solid waste burning to regional particulate matter (PM) air concentrations. It is also recognized that solid waste burning releases many other air contaminants, including common air contaminants (CACs) and toxic compounds. All CACs are monitored under the LTMP. An additional goal of the LTMP was to establish a reliable baseline of air quality data for all CACs to enable trend analysis. The CRD has committed to reporting on the air quality data collected within the monitoring network.

Meteorological data is collected to support the LTMP at some stations. In addition, other meteorological stations in the CRD are used to characterize weather and climate in the region, or to assess local winds for industrial or other purposes. As well, the University of Victoria facilitates the operation of a school-based weather network that includes data from up to 74 individual stations[1].

Air Quality data are collected and analysed for several reasons, including the following:

- to provide information on air quality to the public;
- to conduct long-term trend analysis;
- to fulfill Federal reporting requirements (re: Canada Wide Standards); and,
- to compare ambient concentrations to air quality objectives.

The CRD monitoring network is designed to characterize the air quality in the region and to support the initiatives described above. Air quality monitoring locations are chosen to capture air concentrations that are representative of either larger geographic areas, or 'areas of interest' where higher contaminant air concentrations are suspected, or other reasons. Local topography and the location(s) of pollutant sources can indicate how well a monitoring location represents an area. In most cases, a monitoring location should not be overly influenced by a single emission source. With the advent of the Canada Wide Standards (CWS) for ozone and particulate matter, to be implemented by 2010, 'community-oriented' monitoring sites are necessary. These sites are described as locations where people live, work and play[2].

[1] See http://www.victoriaweather.ca/.
[2] Canadian Council of Ministers for the Environment, 2000. Guidance Document on Achievement Determination: Canada Wide Standards for Particulate Matter and Ozone. www.ccme.ca.

1.1 MONITORING STATIONS

Air contaminants are sampled at six air quality monitoring stations in the Capital Regional District (CRD). Each station samples all or some of the common air contaminants (CACs), namely: carbon monoxide (CO), nitrogen oxide (NO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ground-level ozone (O_3) and particulate matter (PM). There are two sub-fractions of particulate matter sampled; $PM_{2.5}$ (particles with a diameter of less than or equal to 2.5 microns) as respirable PM, and PM_{10} (particles with less than or equal to 10 microns) as inhalable PM.

All of the air quality and meteorological stations in the CRD are included in Table 1.1. The contaminants and meteorological parameters monitored at each location are also listed. Their locations are indicated in Figure 1.1.

The Victoria Topaz station has the longest record of continuous data capture of all the CRD stations. It is operated as part of the National Air Pollution Surveillance program (NAPS). Victoria Topaz, Christopher Point and Langford record all of the common air contaminants. Royal Roads University collects particulate matter in the form of $PM_{2.5}$, nitrogen oxides and ground level ozone. The monitor at Stellys Cross Roads in Central Saanich records all CACs except SO_2. Data from these stations were made available by the B.C. Ministry of Environment.

The Saturna Island monitoring station is part of the Canadian Air and Precipitation Monitoring (CAPMON) network of primarily rural monitoring stations.

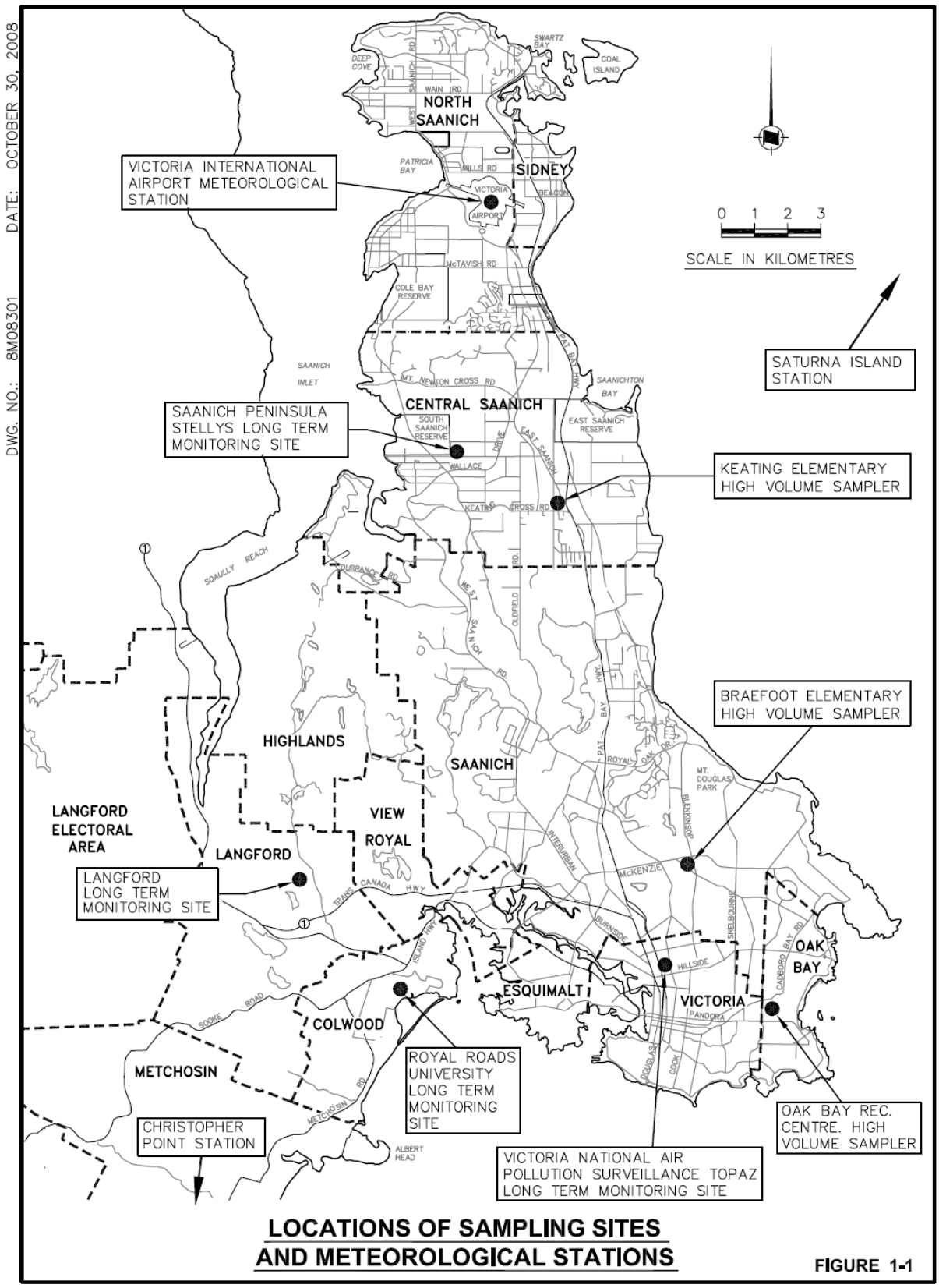
There are three high volume sampler (Hi-Vol) equipped stations that collect PM_{10} data in the CRD at the Oak Bay Recreational Centre, and at the Braefoot and Keating Elementary Schools. In addition, beginning in 2007, two Hi-Vol samplers were installed at both Stellys and Langford to sample $PM_{2.5}$ or PM_{10} as a check against the continuous $PM_{2.5}$ sampler data. Measurements are collected on a one-in-six day cycle. This type of sampling technique requires PM to be collected on filters which are sent to a laboratory for measurement.

Table 1.1
Air Quality Monitoring Stations in the Capital Regional District, 2007

Monitoring Location	Type of Site	Parameters Monitored		
		Gaseous	Particulate Matter	Meteorology
Victoria, Topaz Avenue	NAPS[1] Long Term Monitoring Site	CO, NO, NO_2 SO_2 & O_3	PM_{10} & $PM_{2.5}$ (Dichot) $PM_{2.5}$ (C-TEOM)	WS, WD, T, RH
Royal Roads University	Long Term Monitoring Site	NO, NO_2, & O_3	PM_{10} (S-Hi-Vol) $PM_{2.5}$ (C-TEOM)	WS, WD, T, RH
Stellys, Saanich Peninsula[3]	Long Term Monitoring Site	CO, NO, NO_2 & O_3	PM_{10} (Partisol) $PM_{2.5}$ (C-TEOM)	WS, WD
Christopher Point[4]	Long Term Monitoring Site	CO, SO_2 & O_3	$PM_{2.5}$ (C-TEOM)	WS, WD, T, RH, others
Langford[2]	Long Term Monitoring Site	CO, NO, NO_2 SO_2 & O_3	$PM_{2.5}$ (C-TEOM) PM_{10} (S-Hi-Vol)	WS, WD
Saturna Island	CAPMoN[5] Site	SO_2 & O_3		WS, WD
Oak Bay Recreational Centre[6]	PM sampling site (Hi-Vol)		PM_{10} (S-Hi-Vol)	
Braefoot Elementary School[7]	PM sampling site (Hi-Vol)		PM_{10} (S-Hi-Vol)	
Keating Elementary School[8]	PM sampling site (Hi-Vol)		PM_{10} (S-Hi-Vol)	
Victoria International Airport	Environment Canada metteorological station			WS, WD, T, RH, others
Hartland Landfill	Local meteorological station			WS, WD, RH

Notes:

WS – wind speed; WD – wind direction; T – temperature; RH – relative humidity
S-Hi-Vol - sequential sampling using a High Volume sampler
Dicot - sequential sampling using a dichotomous sampler
Partisol – sequential sampling using constant air flow Partisol sampler
C-TEOM – continuous sampling using Tapered Element Oscillating Microbalance samplers
1- National Air Pollution Surveillance
2- Station began operating in November 2002 and was moved in August 2005
3- Station began operating in August, 2003
4- Station began operation in September 2005
5- Canadian Air and Precipitation Monitoring Network
6- Particulate matter sampling site since October 1996
7- Particulate matter sampling site since November 1999
8- Particulate matter sampling site since November 1999



LOCATIONS OF SAMPLING SITES AND METEOROLOGICAL STATIONS

FIGURE 1-1

1.2 CRD AIR QUALITY GUIDELINES

The Canada Wide Standards (CWS) include regulatory air quality criteria for ground-level ozone and fine particulates ($PM_{2.5}$). In addition, there are National Ambient Air Quality Objectives (NAAQOs) for other CACs. However, jurisdictions within British Columbia have the flexibility to define ambient air quality guidelines that are more stringent than the national criteria. There is a growing awareness of the need to update existing national and provincial air quality objectives and guidelines in Canada. The current provincial objective level for PM_{10} was established in 1995, and the provincial and national objectives for CO, SO_2 and NO_2 have not been reviewed since the mid-1970's. Consequently, the existing provincial and national objectives for these pollutants may not reflect the current knowledge and understanding of the health effects of these air pollutants.

The CWS reflect a more recent federal initiative to update ambient air quality criteria, in particular for air contaminants that may have higher potential to adversely affect human or environmental health. The CWS are expressed as standards to be achieved by 2010. However, the CWS also has requirements beyond the numeric targets for O_3 and $PM_{2.5}$. These requirements are identified as *keeping clean areas clean* and *continuous improvement*, which are meant as guidance for those areas that are already in attainment of the CWS. The concept of keeping clean areas clean has been described [3] as a framework on managing ambient concentrations of particulate matter and ozone below the CWS to minimize any increase in ambient concentrations and, ideally, maintain or reduce ambient concentrations.

The CRD established a set of ambient air quality guidelines for each of the CACs in 2004. The upper-bound guidelines are protective of human and environmental health and are equal to or lower (more stringent) than applicable provincial or federal ambient air quality objectives or standards. Any exceedences of the CRD guidelines are identified and investigated each year.

The CRD guidelines are specified in Table 1.2. Analysis of ambient monitoring data in the following sections specifically addresses the CRD guidelines. In addition, adherence to the CWS is discussed for $PM_{2.5}$ and ozone. Appendix B provides a discussion of all relevant provincial and federal objectives, including a compliance analysis of CRD ambient CAC concentrations.

[3] Schutte, A, and I. Liepa 2003. *Continuous Improvement and Keeping Clean Areas Clean: An Issues Paper*. Prepared for the Air Pollution Prevention Directorate, Transboundary Air Issues Branch, Environmental Protection Service, Environment Canada and the Canadian Council of Ministers of the Environment by Levelton Engineering Limited, Richmond, BC.

Table 1.2
Air Quality Guidelines for the Capital Regional District

Averaging Period	Guideline Concentration (µg/m^3)					
	NO_2	**SO_2**	**CO**	**O_3**	**PM_{10}**	**$PM_{2.5}$**
1-hour	200					
8-hour			5500	120		
24-hour		125			50	25

note: all averaging periods are sequential, with the exception of O_3, which uses rolling averages

2.0 METEOROLOGY IN THE CRD

Meteorological data were collected at seven monitoring stations in the CRD during 2007. Each station is identified in Table 2.1 below, along with the general parameters collected each hour. The data were collected from the MoE data archives, with the exception of Saturna Island (not available from Environment Canada at the time of report preparation) and the Hartland Landfill (this station does not submit data to the MoE archives).

Table 2.1
Meteorological Stations in the CRD

STATION	OPERATION*	METEOROLOGICAL DATA COLLECTED**	WIND CAPTURE RATE (%)
Royal Roads University (Colwood)	Royal Roads University	WS, WD, T	99.4
Victoria Topaz	MoE, EC NAPS	WS, WD, T, RH	99.8
Stellys	MoE	WS, WD, T	99.6
Hartland Landfill	CRD Landfill Staff	WS, WD	not assessed for 2007
Christopher Point	MoE	WS, WD, T, RH, P, Rad	82.7
Victoria Airport	EC	WS, WD, T, RH, Precip, P, Cloud, Ceil	100
Saturna Island	EC CAPMoN	WS, WD	Not available for 2007

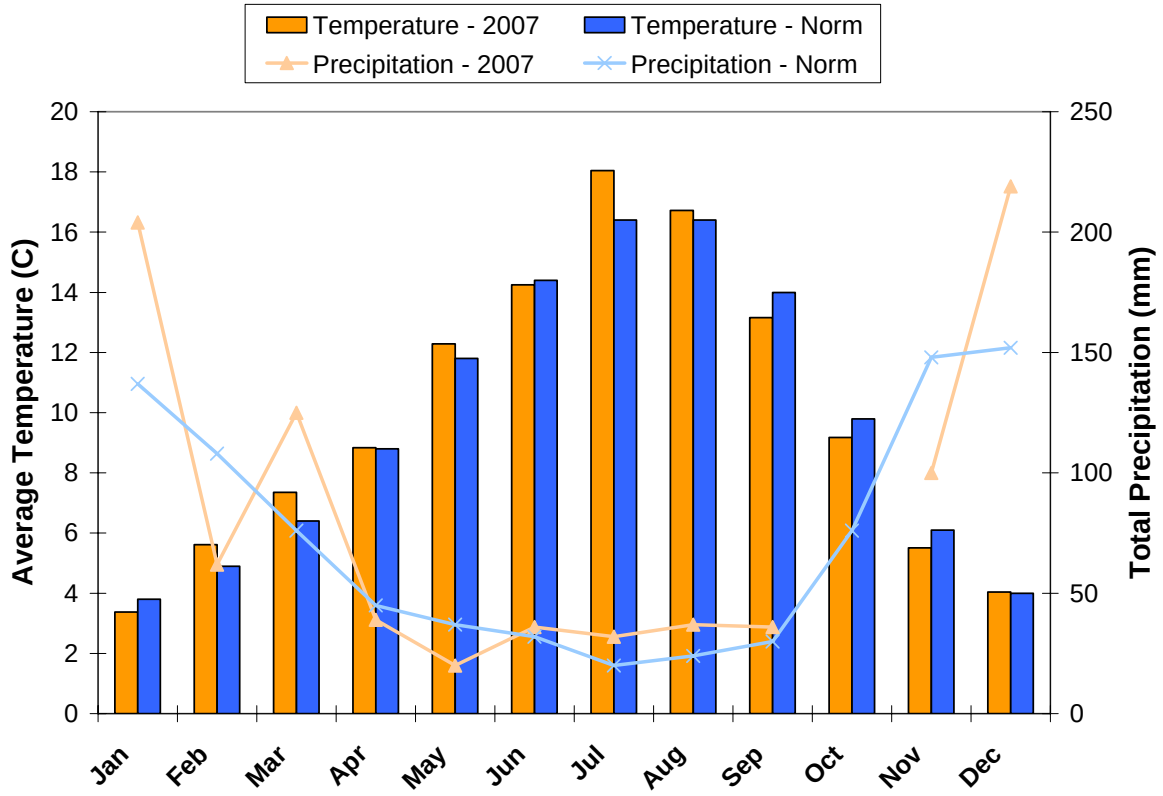
* EC = Environment Canada, CAPMoN = Canadian Air and Precipitation Monitoring Network, NAPS = National Air Pollution Surveillance.

** WS = wind speed, WD = wind direction, T = dry bulb temperature, RH = relative humidity, Precip = precipitation (rain+snow) amounts, P = pressure, Rad = radiation, Cloud = cloud cover, Ceil = ceiling.

Meteorological monitoring data were available from Christopher Point for the first time in 2007, although the data record was sporadic until March 28. From this date on, the rate of data capture was high.

The monthly average temperatures and monthly total precipitation levels for 2007 are compared to the climate norm (1971 – 2000) in Figure 2.1. Average temperatures tended to be slightly higher than the climate norm in the spring and summer months, and slightly lower in the fall and early winter months during 2007. December and January experienced higher precipitation than the norm.

Figure 2.1
2007 Monthly Average Temperature and Precipitation at the Victoria Airport



A wind rose diagram shows the frequency of wind direction (direction ***from*** which the wind blows) and wind speed at a station. Wind rose diagrams are included in Appendix A for the five stations with available data for 2007 (Royal Roads, Topaz, Stellys, Christopher Point and Victoria Airport).

3.0 GASEOUS POLLUTANTS

The gaseous air contaminants that are sampled at the monitoring stations in the CRD are carbon monoxide (CO), nitric oxide (NO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and ozone (O_3). Ambient air concentrations are measured by gas samplers that take a representative volume of the ambient air every few seconds. However, the complete, continuous record for each of the gases tends to be highly variable and difficult to interpret with respect to both emission sources and health or environmental effects. Because of this, the data records are re-averaged to produce 1-hour average concentrations, which are recorded and archived. From these 1-hour averages, further analysis allows determination of 8-hour, 24-hour, monthly and annual average concentration amounts.

The gas samplers automatically recalibrate frequently to ensure accuracy. Occasionally, due to recalibration, hourly concentrations can be missed. For each pollutant, the percent of missing data is recorded. For monitoring sites administered by the B.C. Ministry of Environment, gaseous pollutants recorded in parts per billion (ppb) or parts per million (ppm) are converted by the Ministry to micrograms per cubic metre ($\mu g/m^3$) at 20^0C and 1 atmosphere (atm). Conversely, CAPMoN ozone data for Saturna Island recorded by Environment Canada are reported in ppb at 0^0C and 1 atm. In this report, the Saturna Island ozone data have been converted to $\mu g/m^3$ by multiplying ppb by a factor 2, without accounting for hourly differences in temperature and pressure because these were not available for the report.

A statistical analysis was conducted on each station's datasets. The mean, maximum, minimum, standard deviation and percentile concentrations were calculated to determine the variability among stations and the variability in concentration amounts throughout the year in 2007. The 98^{th} percentile concentration represents the value that is only exceeded 2% of the time during the year.

The data obtained for each sampling location were analysed to obtain 1-hour, 8-hour, 24-hour, annual average concentrations and appropriate percentile distributions for comparison with CRD ambient air quality guidelines and provincial and federal objectives and standards, as well as for trend analysis. Where there were missing data in the record, analysis was limited to only those periods when there was more than 80% data capture (e.g., at least 18 hours of data for a 24-hour average and 6 hours of data for an 8-hour average). Similarly, for comparisons of month-to-month variability in concentrations, only those months with at least 80% data capture[4] in each

[4] Note that the Canadian Council of Ministers of the Environment (CCME) considers an annual $PM_{2.5}$ data set to be complete if at least 75% of the scheduled sampling in each quarter of the year have valid data. For ozone, the CCME, the requirement is that an ozone monitoring day must have valid data for 75% of possible hours in a day (i.e., 18 out of 24 hours) to compute a valid 8-hour average, and that the annual data set must have valid monitoring days for at least 75% of the days from April through September.

were considered. For pollutants where there was less than 80% data capture for the year, no trend analysis is presented because a representative analysis cannot be produced when 20% of the data are missing.

3.1 CARBON MONOXIDE (CO)

Carbon monoxide is produced by both natural and anthropogenic sources (e.g., automobile emissions, home heating). Natural sources include volcanic eruptions, forest fires and the decomposition of materials. Human emissions of CO are primarily caused by the incomplete combustion of fossil fuels. CO is an odourless, colourless, tasteless gas.

CO data is collected at Victoria Topaz, Stellys, Langford and Christopher Point. The monitor at Christopher Point did not operate from March 10th to May 2nd. The CO monitor at the Stellys station did not operate from January 1st to 25th and from March 2nd to June 20th. The monitor at Langford station did not operate from January 1st to February 12th. As indicated in the following tables and figures, the CO data for Christopher Point appear to be unreliable, and may indicate drift in the monitoring signal. Similar data issues with CO monitoring have been noted at other monitoring sites in British Columbia.[5]

The hourly concentrations are summarized in Table 3.1. Eight-hour sequential average concentrations for Topaz, Stellys, Langford and Christopher Point, are summarized in Table 3.2. There were no exceedences of the CRD 8-hour guideline of 5500 µg/m³ in 2007, and generally values were well below the guideline level.

Table 3.1
Hourly Averaged CO Concentrations in the CRD

Percentile Values						Max	Min	Mean	Std. Dev.	Missing Values
5	25	50	75	98	99	µg/m³	µg/m³	µg/m³	µg/m³	% of Total Hours
Victoria Topaz										
100	300	500	600	1600	2000	3400	0	517.9	335.5	17.3
Stellys										
0	0	0	200	800	900	1500	0	156.4	250.3	42.6
Christopher Point*										
300	600	700	900	1200	1200	1500	0	718.2	234.4	19.1
Langford										
100	100	200	300	700	900	2100	0	249.7	177.4	15.9

*possible zero-drift issue

[5] R. Vingarzan, Pacific & Yukon Region, Environment Canada, personal communication, November 12, 2008.

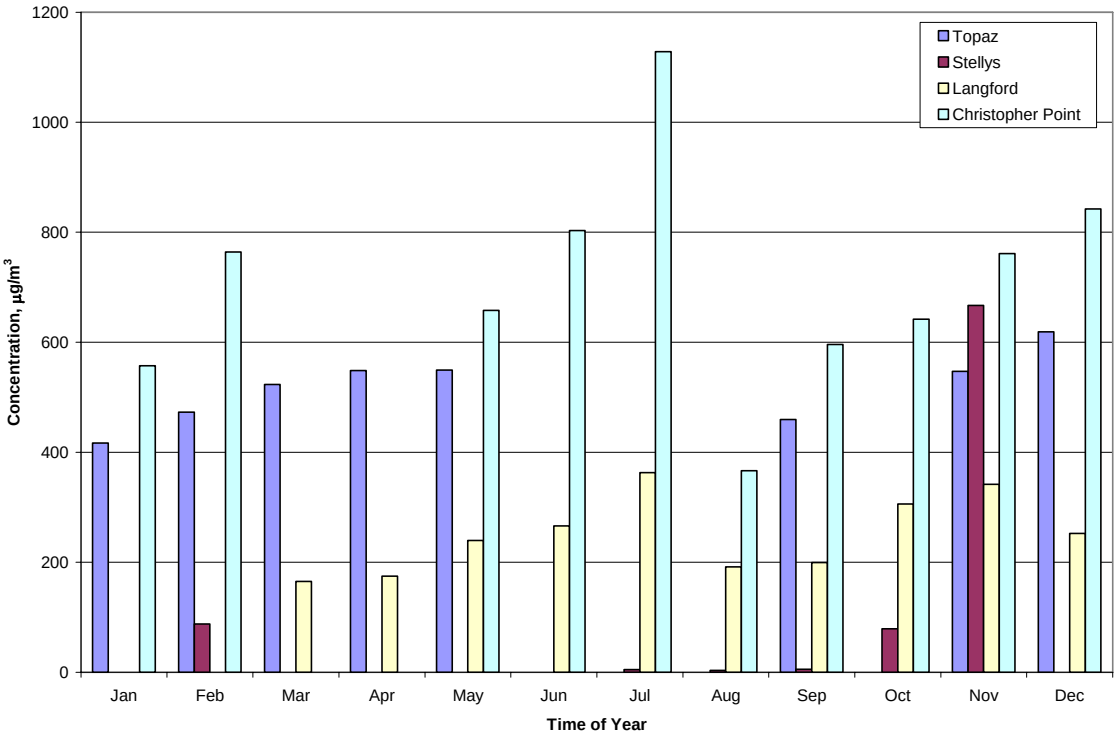
Table 3.2
8-Hour Sequentially Average CO Concentrations in the CRD

Percentile Values						Max µg/m^3	Min µg/m^3	Mean µg/m^3	Std. Dev. µg/m^3	Percent of 8-h Averages > CRD Guideline (5500 µg/m^3)	Missing Values[a] % of Total 8-h Averages
5	25	50	75	98	99						
Victoria Topaz											
163	388	500	600	1284	1495	2062.5	0	517.4	249.9	0	14.4
Stellys											
0	0	25	213	775	819	1000	0	156.9	241.9	0	40.5
Christopher Point*											
350	557	700	871	1200	1233	1325	62.5	719	227	0	16.1
Langford											
75	150	214	325	637	731	937.5	0	249.5	141.4	0	12.8

Notes:
[a] An 8-hour average concentration was determined for every interval having 6 or more hours of data available.
*possible zero-drift issue

Figure 3.1 shows the mean monthly 8-hour average carbon monoxide concentrations at Christopher Point, Stellys, Langford and Victoria Topaz. Concentrations were highest in summer (i.e., July) at both Christopher Point and Langford, but the Christopher Point data appear to be unreliable (i.e., the CO concentrations at Christopher Point, a remote location, are twice as high as those at Topaz even at the 5th percentile level, despite the fact that the Topaz site is located in proximity to high vehicle traffic volumes on Blanshard Street). Data for Topaz were constant throughout the months that valid data were available. Data for Stellys were not representative as only 6 months of monitoring data were valid.

Figure 3.1: Mean Monthly 8-Hour Average CO Concentrations at Christopher Point, Langford, Stellys and Victoria Topaz



The average diurnal patterns of CO concentrations at Victoria Topaz during the warmer (April to October) and cooler (November to March) months are shown in Figure 3.2. Rush hour traffic emissions in the morning in all months of the year (warm and cool months) are indicated by the peak concentrations at approximately 8:00 am PST in cooler months, and 7:00 am PST in warmer months (i.e., the difference in time of day for the peak value is due to daylight savings time). This morning peak in concentrations can be accounted for by the increase in vehicle emissions during this time of day combined with a lower mixing layer in the atmosphere.

A more gradual increase in CO concentrations in the late evening in hours is due to a lowering of the atmospheric mixing height towards the end of the day. CO concentrations are higher during the cooler months than the warmer months because the decrease in the depth of the mixed layer is, on average, more pronounced in the winter than in the summer, and because residential heating contributes to increased CO emissions at night during cooler months.

Figure 3.3 shows the diurnal pattern of CO concentrations at Christopher Point. The data show little diurnal variation, as would be expected at a remote location. However, the overall concentrations are much higher than at the Topaz site, which is not logical given the proximity of the Topaz monitor to high traffic levels on Blanshard Street. As such, it is concluded that the CO data at Christopher Point should be disregarded.

Figure 3.2: Average Diurnal CO Pattern for Victoria Topaz During Cold Months (November – March) and Warm Months (April – October)

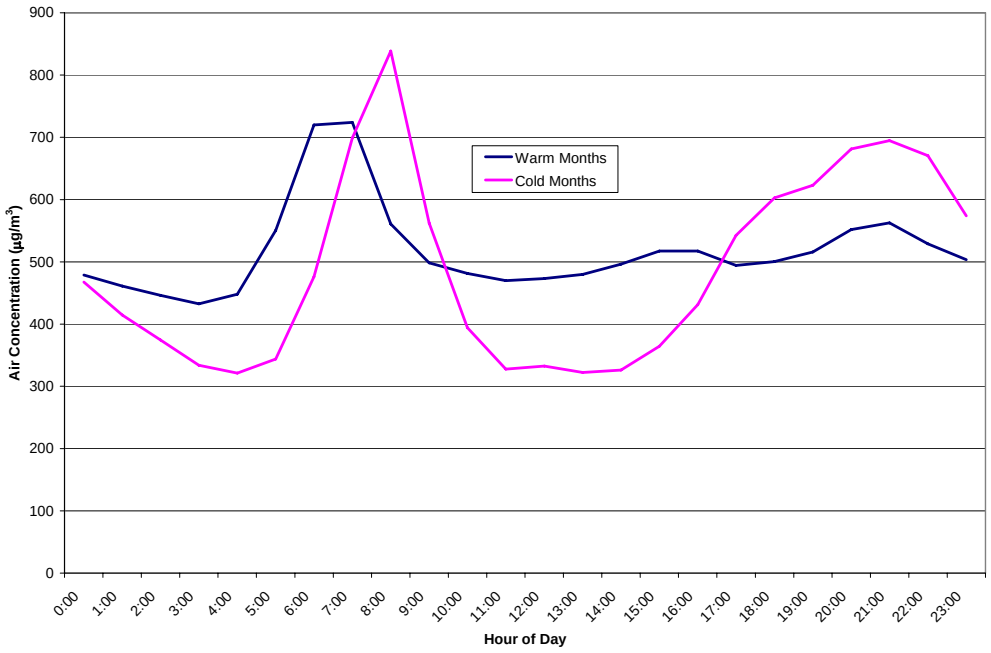
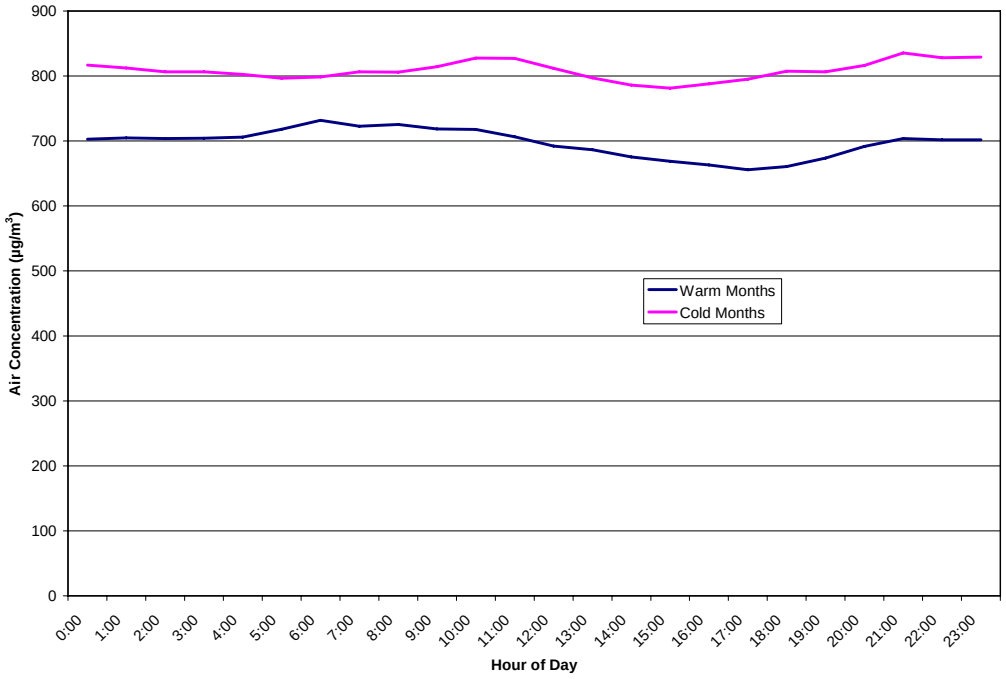


Figure 3.3: Average Diurnal CO Pattern for Christopher Point During Cold Months (November – March) and Warm Months (April – October)



3.2 NITROGEN OXIDES

The reaction of nitrogen with oxygen results in the production of nitrogen oxides (NO_x). NO_x can be produced through biological or atmospheric processes, but monitoring of NO_x in urban areas is generally associated with concerns about emissions from combustion processes. In particular, monitoring is generally conducted for two oxides of nitrogen: nitric oxide (NO) and nitrogen dioxide (NO_2). NO and NO_2 are released in significant quantities during combustion and have been identified as important pollutants in the lower atmosphere.

NO_2 acts mainly as an irritant affecting the mucosa of the eyes, nose, throat, and respiratory tract. Nitrogen dioxide (NO_2) has an orangey-red colour and irritating odour at high enough concentrations. NO_2 is corrosive due to its high potential for oxidation and can cause a reduction in visibility in its role as a smog-forming constituent.

NO_x is monitored at Victoria Topaz, Royal Roads University, Stellys and Langford. Note that NO_x monitoring at Royal Roads did not begin until August 16, 2007.

3.2.1 Nitric Oxide (NO)

Table 3.3 summarizes the NO levels measured at four locations in the CRD in 2007. The reason for the lack of NO and NO_2 data at the Christopher Point station is unclear. The high percentage of missing data at Royal Roads is due to the fact that the station did not begin recording data until August 16th.

As indicated in Table 3.3, the Victoria Topaz station had the greatest maximum hourly concentration and the highest hourly mean concentration of NO, while Stellys had the lowest. This is likely because of the Topaz station's location in close proximity to Blanshard Street. There are no CRD guidelines or other regulatory criteria for NO.

Table 3.3
Hourly Averaged NO Concentrations in the CRD

Percentile Values						Max µg/m³	Min µg/m³	Mean µg/m³	Std. Dev. µg/m³	Missing Values % of Total Hours
5	25	50	75	98	99					
Victoria Topaz										
1	2	4	11	96	133	302	0	12.7	25.2	6.2
Royal Roads University										
0	1	1	4	31	45	126.4	0	4.4	8.9	63.9
Stellys										
0	1	2	4	23	30	85.6	0	3.9	6.1	5.7
Langford										
0	1	2	5	44	66	180	0	5.7	12.7	21.6

3.2.2 Nitrogen Dioxide (NO_2)

Tables 3.4 and 3.5 provide hourly and 24-hr averaged NO_2 concentrations, respectively. There were no exceedences of the CRD 1-hour NO_2 guideline of 200 µg/m³, and values were generally well below the guideline value. Victoria Topaz experienced significantly higher 1-hour and 24-hour average NO_2 concentrations over those measured at Langford, Stellys and Royal Roads. As with the NO concentrations, the higher NO_2 levels at Topaz were likely due to the station's close proximity to a main thoroughfare. Hourly and 24-hour average NO_2 concentrations were fairly similar between all three stations.

Figure 3.4 shows monthly 24-hour average NO_2 levels in 2007. There is no obvious seasonal pattern to NO_2 concentrations at the Victoria Topaz site, except that levels were highest in January. Again, only 4 months of data were valid for the Royal Roads site, as the data collection did not begin until August 16.

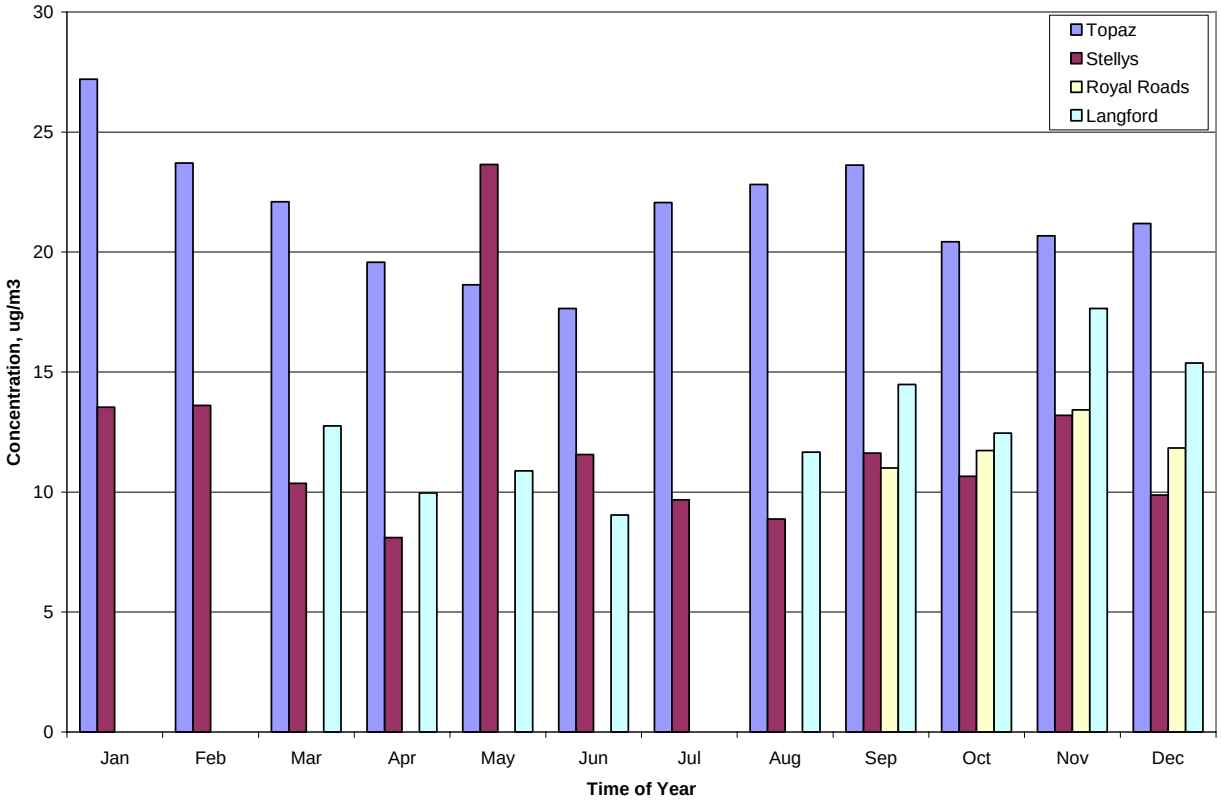
Table 3.4
Hourly Averaged NO_2 Concentrations in the CRD

Percentile Values						Max µg/m³	Min µg/m³	Mean µg/m³	Std. Dev. µg/m³	Percent of 1-h Averages > CRD Guideline (200 µg/m³)	Missing Values % of Total Hours
5	25	50	75	98	99						
Victoria Topaz											
5	12	19	29	54	59	79.2	0	21.6	12.8	0	6.2
Royal Roads University											
2	5	10	17	32	36	52.4	0	11.6	8.2	0	63.9
Stellys											
2	5	10	18	33	37	54.5	0	12	9.1	0	5.7
Langford											
3	6	11	17	36	40	65.8	0	12.6	8.8	0	21.6

Table 3.5
24-Hour Sequential Averaged NO_2 Concentrations in the CRD

Percentile Values						Max µg/m³	Min µg/m³	Mean µg/m³	Std. Dev. µg/m³	Missing Values % of Total 24-h Averages
5	25	50	75	98	99					
Victoria Topaz										
11	17	21	26	38	41	43.5	5.2	21.6	6.9	2.7
Royal Roads University										
4	7	12	15	22	23	23.3	1.8	11.7	5.2	62.7
Stellys										
4	7	11	15	30	33	35.6	2.1	12	6.5	1.6
Langford										
5	9	12	16	25	26	26.6	2.1	12.6	5.3	18.9

Figure 3.4
Mean Monthly 24-Hour Average NO_2 Concentrations at Victoria Topaz, Royal Roads, Langford and Stellys



Figures 3.5 and 3.6 show the average diurnal pattern of hourly NO_2 concentrations during the cooler and warmer months of the year, at Victoria Topaz, Royal Roads University, Stellys, and Langford. There is a distinct concentration peak in the morning and another later in the evening in the cooler months. In the warmer periods of the year, concentrations gradually increased to a peak in the evening hours. The diurnal patterns for the Royal Roads data are less certain as they were determined from an incomplete data set, (i.e., based on data from August through December only).

The early morning peak at around 8:00 am PST at all sites is likely related to the morning traffic rush of commuters going to work or school. This peak in morning NO_2 concentrations is most pronounced at the Victoria Topaz site. The late evening peak is present for all sites as well in both warm and cold months. The late evening peak occurred around 6:00 pm in the cold months and around 8:00 pm in the warm months.

Figure 3.5
Average Diurnal NO_2 Pattern for all Stations during Cooler Months (November-April)

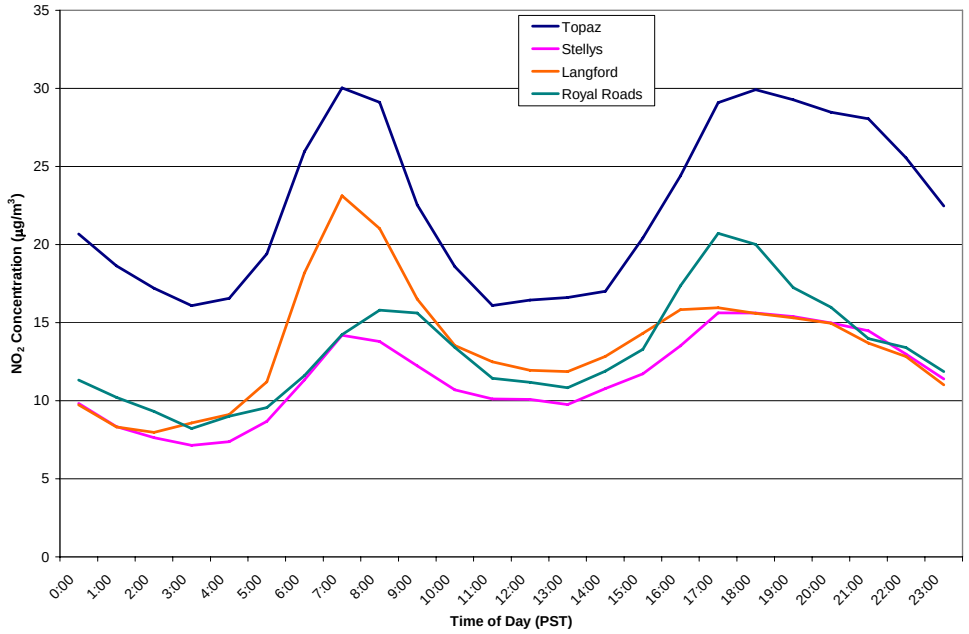
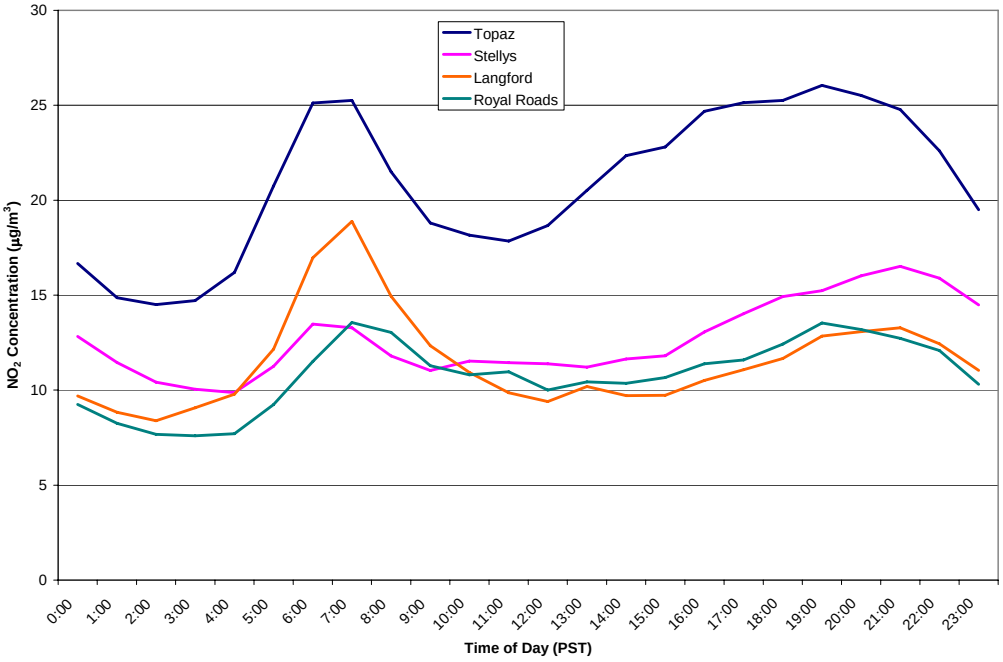


Figure 3.6
Average Diurnal NO_2 Pattern for all Stations during Warmer Months (May-October)



A more gradual increase in NO_2 concentrations in the late evening hours is due to a lowering of the atmospheric mixing height towards the end of the day. NO_2 concentrations are higher during the cooler months than the warmer months at 3 of the sites (Victoria Topaz, Langford and Royal Roads) because the decrease in the depth of the mixed layer is, on average, more pronounced in the winter than in the summer, and because residential heating contributes to increased NO_x emissions at night during cooler months. It is worth noting that the evening increase in NO_2 levels is not present at Stellys.

3.3 SULPHUR DIOXIDE (SO_2)

Sulphur oxides (SO_x) are released during the combustion of sulphur bearing fuels. Sulphur dioxide (SO_2) makes up the great majority of SO_x in the lower atmosphere. Due to a significant lowering of sulphur levels in gasoline and on-road diesel, SO_2 emissions from motor vehicles have declined considerably over the past decade. Sulphur levels in on-road diesel were reduced to 15 parts per million (ppm) in 2006 which will further lower mobile source SO_2 emissions. A similar sulphur reduction initiative for marine fuels may occur in the near future.

Sulphur dioxide is a colourless gas, with an irritating odour at sufficiently high concentrations. Emissions of SO_2 can lead to the formation of sulphuric acid (H_2SO_4) in the atmosphere. Background levels of SO_2 tend to be very low, meaning measurable concentrations are usually connected to anthropogenic activity, and occur in or near urban areas. Ambient levels of SO_2 tend to be relatively low in the CRD, due to the absence of large scale emission sources.

The major sources of emissions are fossil fuel combustion, industrial processes and geothermal activity. SO_2 can produce acid rain when it dissolves in water vapour in the atmosphere. Particulate matter ($PM_{2.5}$) concentrations in the atmosphere can increase when sulphates combine with other compounds in the atmosphere.

Table 3.6 lists the average hourly SO_2 concentration at Christopher Point, Langford and Victoria Topaz, the three locations in the CRD network with hourly data available in 2007. Table 3.7 lists the 24-hr sequential average SO_2 concentrations at these three locations.[6] Data for Saturna Island in 2007 were not available for the annual report.

Table 3.6 indicates that hourly averaged SO_2 concentrations are essentially undetectable at Victoria Topaz at least 50% of the time. Table 3.7 indicates that all 24-hour average levels at all locations during 2007 were well below the CRD guideline value of 125 µg/m³. Monitoring data for the Langford station is less reliable due to an incomplete data set (35% data is missing).

[6] SO_2 monitoring data at Saturna Island is only available for 24-hour averages. Although the data record dates back to 1998, the data has not been included in previous CRD annual air quality reports.

Table 3.6
Hourly Averaged SO_2 Concentrations in the CRD

Percentile Values						Max µg/m³	Min µg/m³	Mean µg/m³	Std. Dev. µg/m³	Missing Values % of Total Hours
5	25	50	75	98	99					
Victoria Topaz										
0	0	0	3	11	13	88	0	1.7	3.8	13.2
Christopher Point										
0	1	2	3	9	11	42	0	2.2	2.3	5.1
Langford										
1	2	2	4	11	14	89	0	3.2	2.9	38.5

Table 3.7
24-Hour Sequentially Averaged SO_2 Concentrations

Percentile Values						Max µg/m³	Min µg/m³	Mean µg/m³	Std. Dev. µg/m³	Percent of 24-h Averages > CRD Guideline (125 µg/m³)	Missing Values
5	25	50	75	98	99						% of Total 24-h Averages
Victoria Topaz											
0	0	1	2	6	7	23.3	0	1.7	2	0	9.6
Christopher Point											
1	1	2	3	6	7	8.6	0.1	2.2	1.3	0	1.4
Langford											
1	2	3	4	8	9	14.5	0.3	3.3	1.7	0	35.9

Figure 3.7 shows monthly averaged SO_2 concentrations at the Victoria Topaz, Langford and Christopher Point stations. The Langford station had highest concentrations in August and September during the months that valid data is available (June to November). The Christopher Point station consistently had higher concentrations than the Topaz station. However, given the very low concentrations, this variability in month-to-month concentrations is not particularly significant.

Figure 3.7
Mean Monthly 24-hour Average SO_2 Concentrations
at Victoria Topaz, Langford and Christopher Point

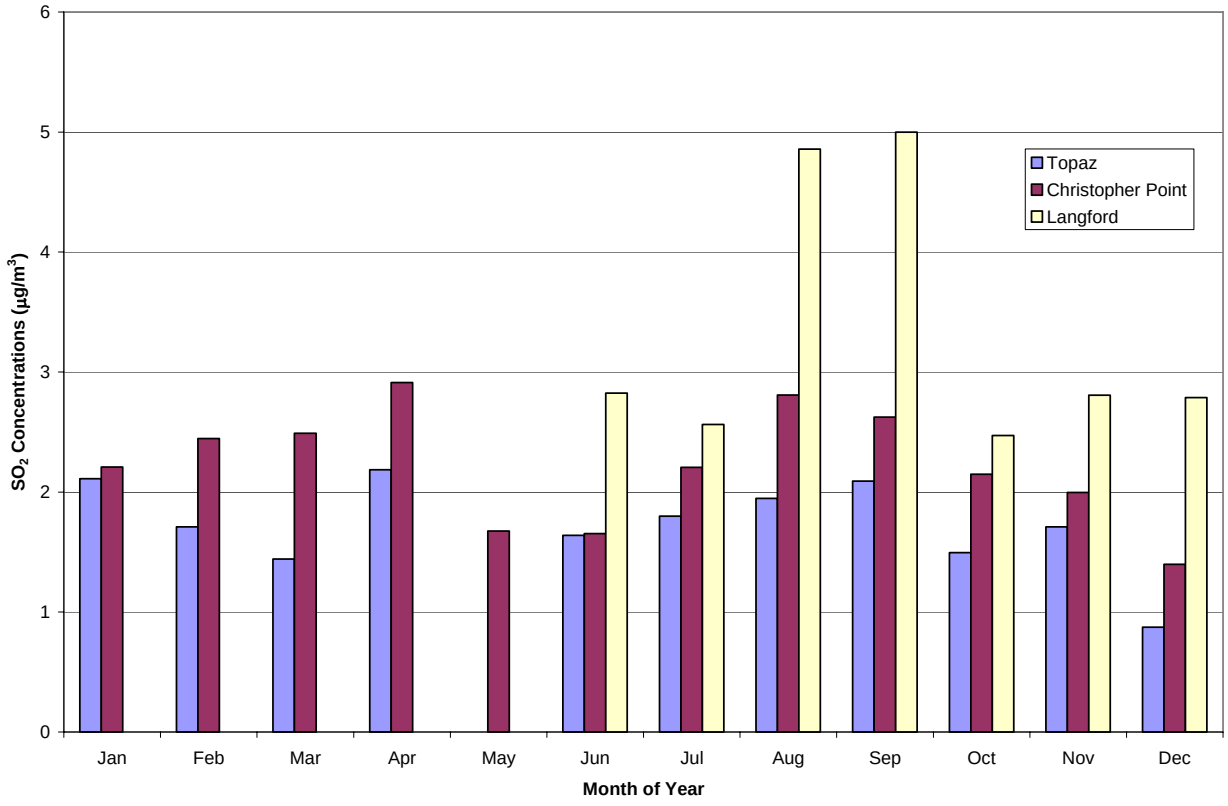


Figure 3.7 shows the average diurnal SO_2 concentrations for Victoria Topaz, Langford and Christopher Point during the cooler months (November to April), while Figure 3.8 shows the pattern for the warmer months (May to October) of the year. Note that the pattern for Langford station during the cooler months is less certain as the only data available during the cooler months are November and December. During the cooler months of the year, the Topaz site has a pronounced peak in SO_2 levels in the morning (8:00 am PST), with a lower peak in the evening at 9:00 pm PST. In the warmer months of the year, the pattern is reversed, with a more prominent peak in SO_2 levels in the evening (5:00 pm PST), and a lower peak in the morning (7:00 am PST). By comparison, the SO_2 levels at Christopher Point are more evenly distributed throughout the day in all seasons, with slightly higher levels during the midday hours in the warmer months.

In Figures 3.8 and 3.9, all months show a morning peak coinciding with rush hour commuting traffic. This peak is again significantly larger at the Topaz station for the cooler months. There is a second peak in the evening in all months of the year for Topaz. At the Christopher Point and Langford stations, no significant evening peak is observed.

Figure 3.8
Average Diurnal SO_2 Pattern for Victoria Topaz, Langford and Christopher Point for the Cooler Months (November to April)

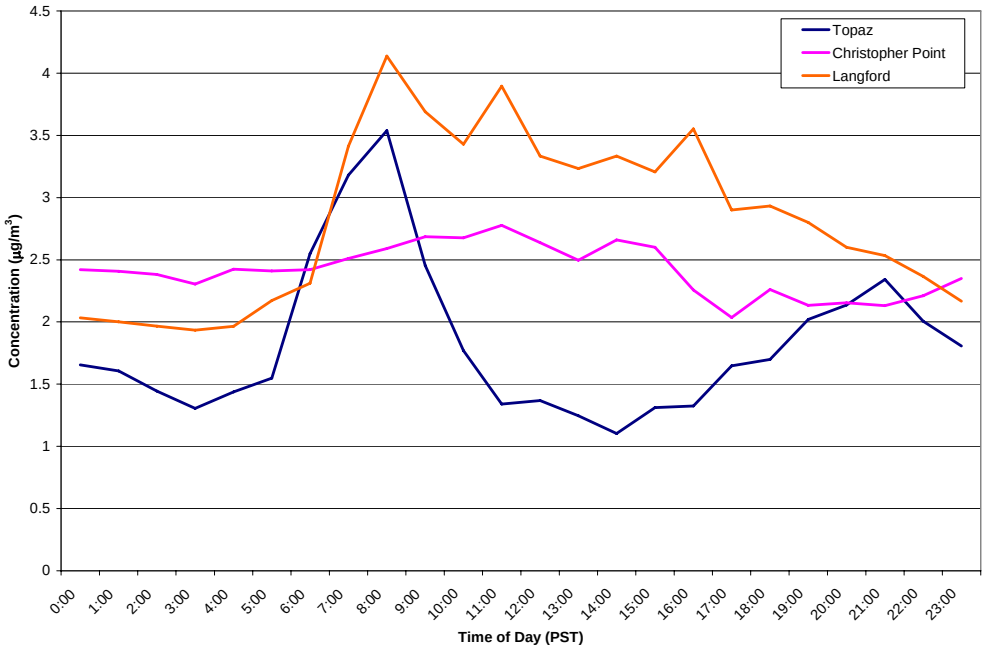
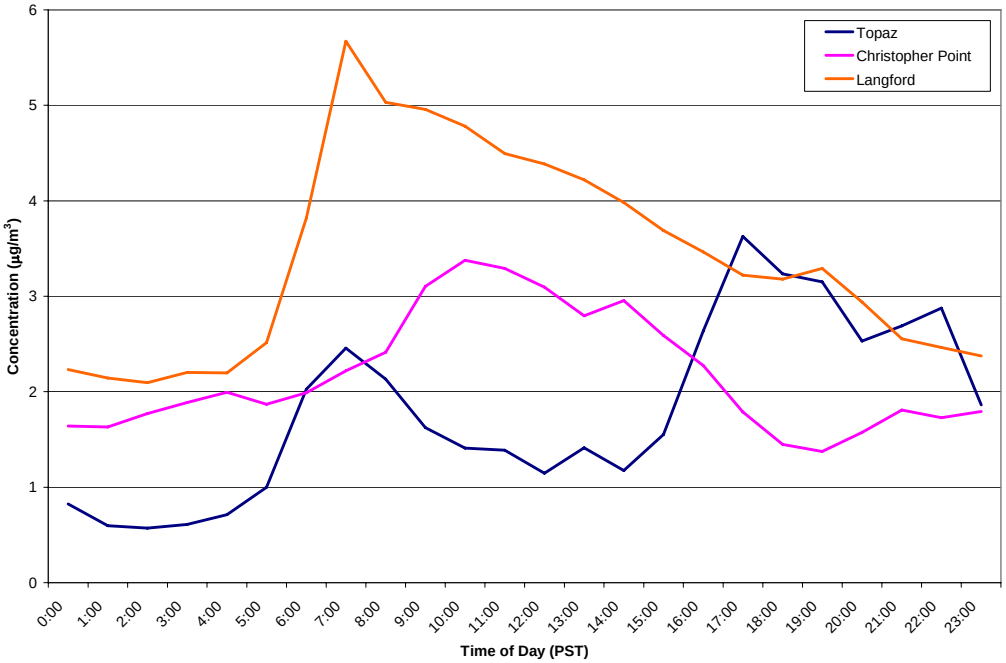


Figure 3.9
Average Diurnal SO_2 Pattern for Victoria Topaz, Langford and Christopher Point for the Warmer Months (May to October)



3.4 GROUND LEVEL OZONE (O_3)

Ozone is a photochemical oxidant that is formed in the atmosphere from chemical reactions involving NO_x, ultraviolet radiation (sunlight), oxygen and hydrocarbons (HC). Ozone is a natural component of the atmosphere, with peak concentrations experienced in the lower stratosphere. In the lower troposphere, ground level zone (O_3) is a secondary pollutant and can be formed at considerable distances from the origin(s) of the primary pollutants. Relatively high ground level concentrations can be caused by anthropogenic emissions of NO_x and HC, or by natural processes, such as stratospheric intrusion. Stratospheric intrusion involves atmospheric motions that bring ozone-rich air from very high altitudes to the surface.

Variations in weather patterns from year to year can have a large effect on community concentrations of ground level ozone. Currently, it is believed that springtime weather conditions favour the potential for stratospheric intrusion. Higher temperatures and solar insolation in the summer favour production of ozone from NO_x and HC released in urban areas. The formation of ozone depends on a rather complex set of reactions that are sensitive to relative concentrations of pollutant precursors. Ozone can be removed ('scavenged') by destructive reactions with NO_x. It is common in many urban areas to observe a decrease in ground-level ozone concentrations during periods of peak NO_x emissions.

The Federal air quality objectives for ground-level ozone are considered to be outdated, and the 24-hour average objective level is commonly exceeded in many urban and rural locations throughout Canada. The CWS for ozone is based on more up-to-date scientific, health and environmental information. Comparison of CRD ground-level ozone concentrations to the CRD guideline and the CWS is shown in the tables and discussion that follows. Comparison of CRD concentrations to provincial and federal objectives is provided in Appendix B.

Ozone is monitored at Victoria Topaz, Royal Roads University, Stellys, Christopher Point, Langford and Saturna Island. Hourly average ozone concentrations are summarized in Table 3.8. There is no CRD guideline value for hourly averaged ozone concentrations. The comparison of hourly maximum concentrations in 2007 to federal/provincial objectives is discussed in Appendix B.

Table 3.9 shows the 8-hour rolling average concentrations at Christopher Point, Stellys, Topaz, Langford, Royal Roads and Saturna Island. Although ozone levels were generally well below the CRD guideline value of 120 µg/m³ (8-hour average), Saturna Island measured ten consecutive hours where concentrations exceeded 120 µg/m³, for a peak 8-hour average of 133.8 µg/m³. By comparison, in 2006 there were two such exceedences, with Christopher Point and Saturna Island each recording one. During 2007, the Royal Roads monitoring station had missing data during the critical period of July 11th to August 14th, when elevated ozone

concentrations were most likely to have occurred. Data recording for both the Christopher Point and the Langford monitoring stations did not begin until May 3rd.

Table 3.8
Hourly Averaged Ozone Concentrations in the CRD

Percentile Values						Max µg/m³	Min µg/m³	Mean µg/m³	Std. Dev. µg/m³	Missing Values % of Total Hours
5	25	50	75	98	99					
Victoria Topaz										
0	12	28	52	90	94	117.7	0	33.5	25.8	10.2
Royal Roads University										
2	18	38	62	88	92	111.7	0	40	26.1	14.1
Stellys										
2	20	40	58	90	94	129.7	0	40.1	24.8	8
Christopher Point										
22	40	56	68	96	102	135.7	0	54.5	20.4	37
Langford										
2	16	36	54	88	94	127.7	0	36.6	24.3	39.8
Saturna Island										
26	44	56	70	96	102	140	4	56.6	19.4	4.8

Table 3.9
8-Hour Rolling Average Ozone Concentrations in the CRD

Percentile Values						Max µg/m³	Min µg/m³	Mean µg/m³	Std. Dev. µg/m³	% of 8-h Averages > CRD Guideline (120 µg/m³)	Missing Values % of Total 8-h Averages
5	25	50	75	98	99						
Victoria Topaz											
3	15	28	50	86	90	109	0	33.5	23.5	0	6.7
Royal Roads University											
6	21	37	59	85	88	103	0	39.9	23.7	0	10.8
Stellys											
6	22	39	56	85	89	115	0	40.1	22.2	0	4.5
Christopher Point											
23	42	55	66	95	101	120	0.9	54.5	18.9	0	34.3
Langford											
4	20	36	51	84	91	109.2	0	36.6	21.3	0	37.6
Saturna Island											
28	45	57	68	91	97	133.8	6	57.6	17.7	0.1	4.1

The ozone concentration exceedance recorded at Saturna Island occurred on May 30th. The maximum hourly concentration recorded was 140 µg/m^3 on May 30th, for a maximum 8-hour average of 133.8 µg/m^3. Although the monitoring data showed simultaneous increases in ozone concentrations at other monitoring sites in the CRD at the start of the episode as indicated in Figure 3.10, elevated levels persisted well into the evening hours at Saturna Island while concentrations at the other CRD monitoring sites declined during the afternoon hours (note that data for the Victoria Topaz station were not available during this episode).

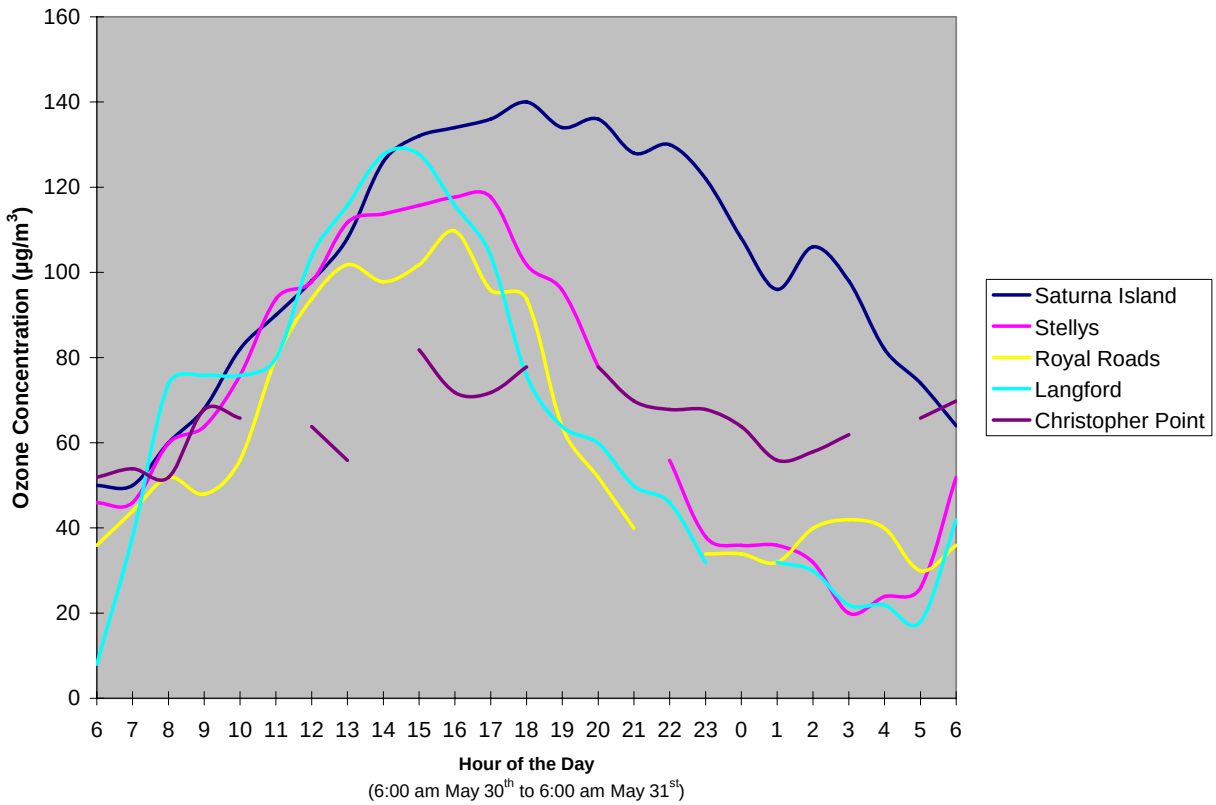
This episode was an instance of photochemical ozone production, rather than the product of stratospheric ozone being brought to the surface, as has been reported for elevated springtime ozone episodes in previously published studies for Saturna Island (Vingarzan and Thomson 2004)[7]. The fact that ozone levels did not increase at Christopher Point indicates that the increase in ozone levels was not of stratospheric origin. Similar increases in ozone levels were also recorded on this date in the Lower Fraser Valley, indicating that this ozone episode was not confined to the CRD. However, whereas the ozone levels at Stellys, Royal Roads and Langford (as well as at all stations in the Lower Fraser Valley) began to decline in the afternoon hours, those at Saturna Island remained elevated throughout the evening hours of May 30th, and into the morning hours of the following day.

According to Steyn[8], the strong diurnal signal in ozone all over the Lower Fraser Valley is dominated by ozone production in the morning, and then NO titration in the afternoon and through the night. This is enhanced by strong low level stability (in episode conditions) over land which isolates O_3 and NO in the lowest tens of metres, reducing ozone to low levels. In the absence of local NO emissions (as is the case on Saturna Island), and surface based inversions, O_3 will remain high through most of the night. It does this at elevated sites in the Lower Fraser Valley, as well as on Saturna Island (elevation of the monitoring site is 178 m ASL).

Due to the limited temporal, and uncertain spatial extent of available monitoring data, community exposure to ground-level ozone concentrations above the CRD guideline value and any related health effects cannot be determined within a suitable degree of confidence.

[7] Vingarzan, R. and B. Thomson 2004. Temporal Variation in Daily Concentrations of Ozone and Acid-Related Substances at Saturna Island, British Columbia. Journal of the Air & Waste Management Association, 54:459-472.
[8] Dr. D. Steyn, Professor, Atmospheric Science, Department of Earth and Ocean Sciences, University of British Columbia, personal communication 7 November 2008.

Figure 3.10
Ozone Episode in the CRD May 2007



CWS compliance requires that the annual 4th highest, daily maximum 8-hour average concentration, averaged over three consecutive years, does not exceed 65 parts per billion (which is equivalent to 127.6 µg/m³). CWS guidelines state that achievement of the CWS standard should be based on data from monitoring stations that are representative of "neighbourhood" or "urban scale" exposure levels where people live, work or play. The lowest ozone concentrations in a metropolitan area may occur near the urban centre where scavenging by traffic-derived NO_x emissions can reduce ozone levels, while maximum ozone concentrations may occur downwind of the urban fringe.

Table 3.11 lists the maximum and annual 4th highest 8-hour average ozone concentrations recorded at each of the ozone monitoring locations in the CRD, except Christopher Point and Langford due to the large amount of missing data for 2007 (34% and 38%, respectively). The year-to-year variations in the maximum 8-hour average ozone concentrations for the period 1998-2007 are depicted in Figure 3.10. The data indicate that maximum ozone levels at Saturna Island have frequently been at or above the CRD guideline value of 120 µg/m^3, while the levels at Royal Roads have exceeded the guideline value once during this period. The period of record

at Stellys is short, but indicates that levels can reach as high as the CRD guideline level. By comparison, the ozone levels at Victoria Topaz have never exceeded the CRD guideline at any time during this period.

Figure 3.11
Maximum 8-Hour Average Ozone Levels in the CRD (1998-2007)

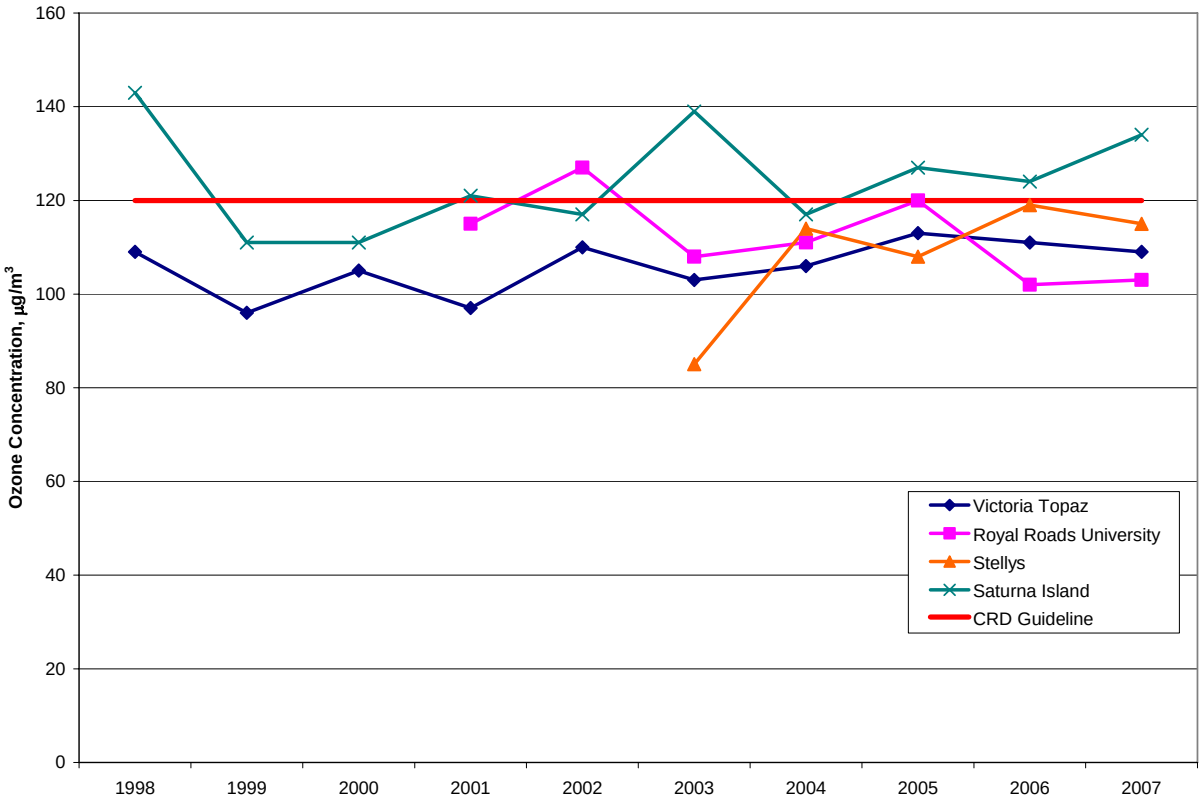


Table 3.10
Summary of 8-Hour Ozone Levels (µg/m^3) in the CRD (1998-2007)

Year	Victoria Topaz			Royal Roads University			Stellys			Saturna Island		
	Max.	4th Highest	3-year Average of 4th Highest	Max.	4th Highest	3-year Average of 4th Highest	Max.	4th Highest	3-year Average of 4th Highest	Max.	4th Highest	3-year Average of 4th Highest
1998	109	85								143	111	
1999	96	89								111	96	
2000	105	91	88.3							111	97	101.3
2001	97	86	88.6	115	97					121	109	100.7
2002	110	86	87.7	127	96					117	104	103.3
2003	103	85	85.7	108	100	97.7	85[b]	79[b]		139	113	108.7
2004	106	86	85.7	111	94	96.7	114	95		117	104	107.0
2005	113	85	85.3	120	101	98.3	108	94		127	103	106.7
2006	111	95	88.7	102[a]	93[a]	96.0	119	101	96.7	124	114	107.0
2007	109[c]	106[c]	95.3	103[d]	100[d]	98.0	115[e]	109[e]	101.3	134[f]	130.8[f]	115.9
CRD Guideline	120			120			120			120		
CWS			127.6			127.6			127.6			127.6

Notes:

[a] Missing data from March 2 to July 13, 2006

[b] Monitoring from September 16 to December 31, 2003

[c] Missing data from January 1 to 2, May 30 to June 12, July 12, and December 4-5, 2007

[d] Missing data from July 11 to August 14, 2007

[e] Missing data from January 1 to 4, July 1 to 5 and December 4, 2007

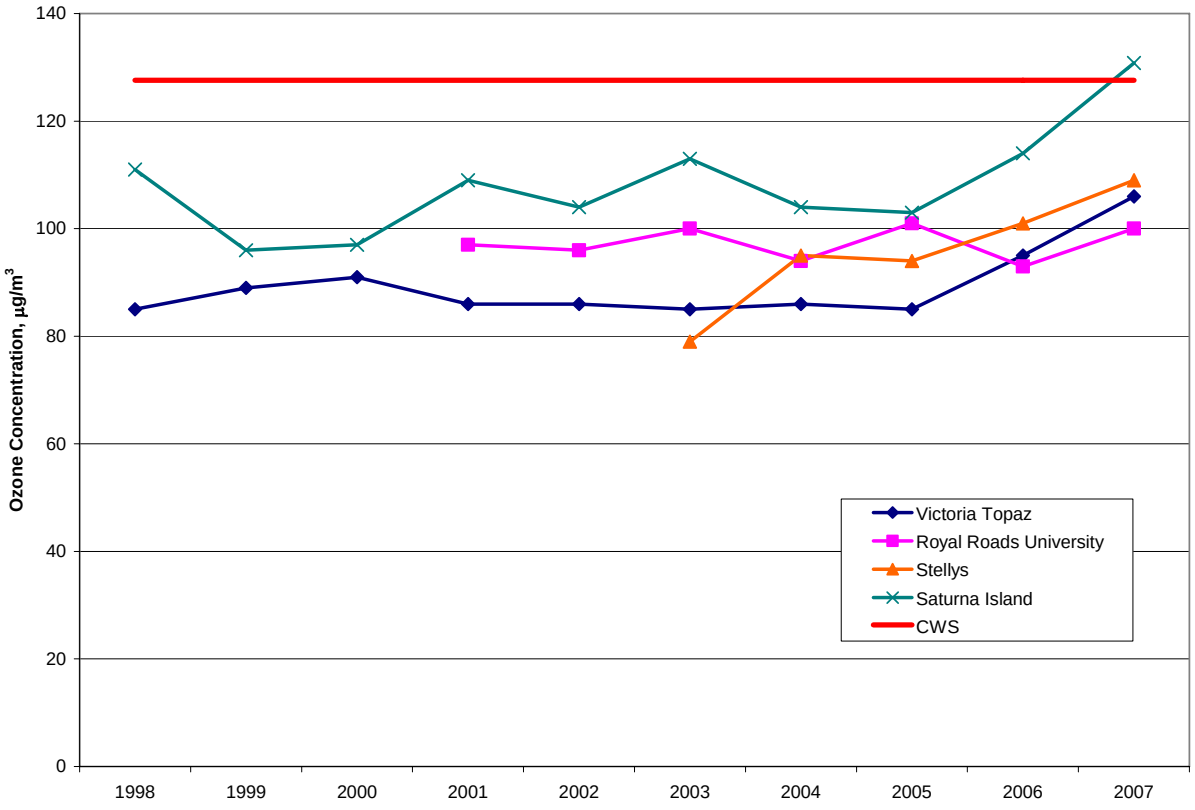
[f] Missing data from January 6, January 10 and February 8 to 13, 2007

Max. – Maximum 8-hour average concentration for the year

4th High – 4th highest 8-hour average concentration for the year

Figure 3.12 shows the trend in 4th highest ozone concentrations over the period 1998-2007. The data indicate that there is relatively little year-to-year variation in 4th highest concentrations, especially at Victoria Topaz. Saturna Island has had the highest fluctuations, while the period of record at Stellys is still too short to make definitive conclusions. Nevertheless, the annual 4th highest ozone concentrations at all four monitoring stations are well below the CWS value of 127.5 µg/m^3. At Saturna Island in 2007, the annual 4th highest ozone concentration was 130.8 µg/m^3. However, when averaged over the past three years, the annual 4th highest ozone concentration is 115.9 µg/m^3, well below the CWS value of 127.5 µg/m^3.

Figure 3.12
4th Highest 8-Hour Average Ozone Levels in the CRD (1998-2007)



Previously, the Saturna Island ozone data have been used to demonstrate CWS compliance, as this station has had the highest concentrations experienced at the ozone monitoring stations in the CRD. This station is not representative of the concentrations experienced in metropolitan areas, and therefore use of the station to demonstrate compliance is conservative. Similarly, the location of the station at Christopher Point is not representative of areas where many people in the CRD are likely to be exposed. Instead, attainment of the CWS was based on the data collected at the Topaz, Stellys and Royal Roads sites.

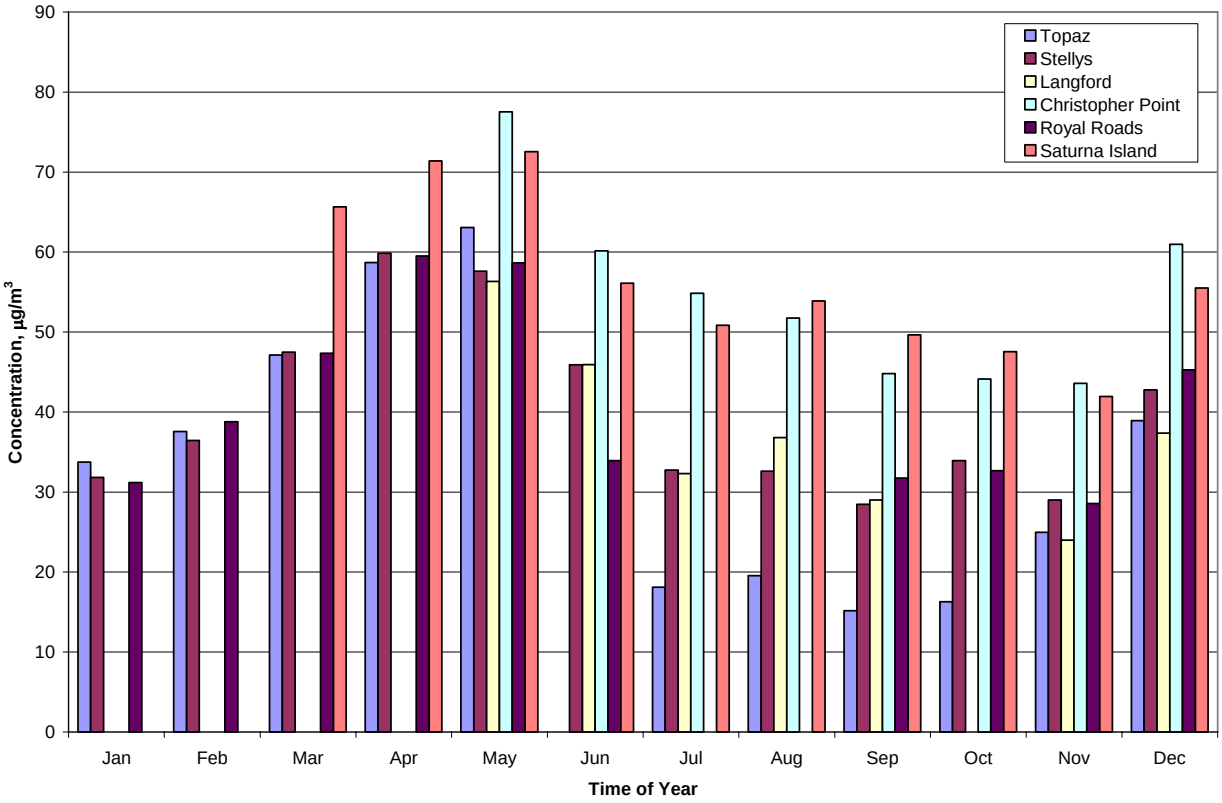
Over the three year period of 2005-2007 at Stellys, the 4th highest daily 8-hour rolling average maximum concentration did not exceed 65 parts per billion (127.5 µg/m^3) (Table 3.11). The averages over the three years for the three stations were 95.3 µg/m^3, 101.3 µg/m^3 and 98.0 µg/m^3, indicating that the CRD satisfies the CWS for ground-level ozone.

Table 3.11
4th Highest Daily Maximum 8-hour Average Ozone Concentrations at Topaz, Stellys and Royal Roads, 2005-2007

Year	Concentration at Topaz (µg/m^3)	Concentration at Stellys (µg/m^3)	Concentration at Royal Roads (µg/m^3)
2005	85	94	101
2006	95	101	93
2007	106	109	100
3-year average	95.3	101.3	98.0

Figure 3.13 shows mean monthly 8-hour average ozone concentrations for Christopher Point, Royal Roads, Topaz, Langford, Stellys and Saturna Island. Ozone concentrations are generally highest during the spring months of March, April and May. This is consistent with patterns observed in previous years, and the higher concentrations in March and April are generally considered to be due to stratospheric ozone being brought to the surface rather than to photochemical ozone production in the troposophere. Ozone concentrations are generally lower from September to November. It has generally been assumed that the spring maximum is caused by intensification of stratosphere-troposphere exchange (i.e., down-welling of stratospheric ozone into the troposphere) rather than from the photochemical generation of ozone in the troposphere from precursor emissions of NO_x and volatile organic compounds (VOC).

Figure 3.13
Mean Monthly 8-Hour Averaged Ozone Concentrations at Christopher Point, Royal Roads, Topaz, Langford, Stellys and Saturna Island



Figures 3.14 and 3.15 show average daily ozone concentrations during the warmer and cooler months of the year for Topaz, Royal Roads, Stellys, Langford, Christopher Point and Saturna Island. For each station, in both the warmer and the cooler months, there is a trough in concentration levels at around 6:00 am PST (warmer months) or 7:00 am PST (cooler months) and a peak in concentration levels at around 2:00 pm PST (warmer months) or 3:00 pm PST (cooler months). During the warmer spring and summer months (Figure 3.13), the afternoon peak in ozone levels is likely caused by increased solar insolation and warmer temperatures needed to drive the chemical transformation of NO_x and VOC to form ozone. The trough present in the morning relates to increased NO_x emissions from traffic during the morning rush hour. The higher NO_x levels chemically react with ozone, resulting in lower ozone levels. The morning trough in ozone levels in the cooler months is likely due to the same mechanism. The remainder of the diurnal variation during the cooler months results from similar ozone/NO_x interaction, with lower NO_x levels during the daytime hours (see Figures 3.4 and 3.5), and higher NO_x levels in the evening hours.

Figure 3.14: Average Diurnal Ozone Pattern During Cooler Months (November - April)

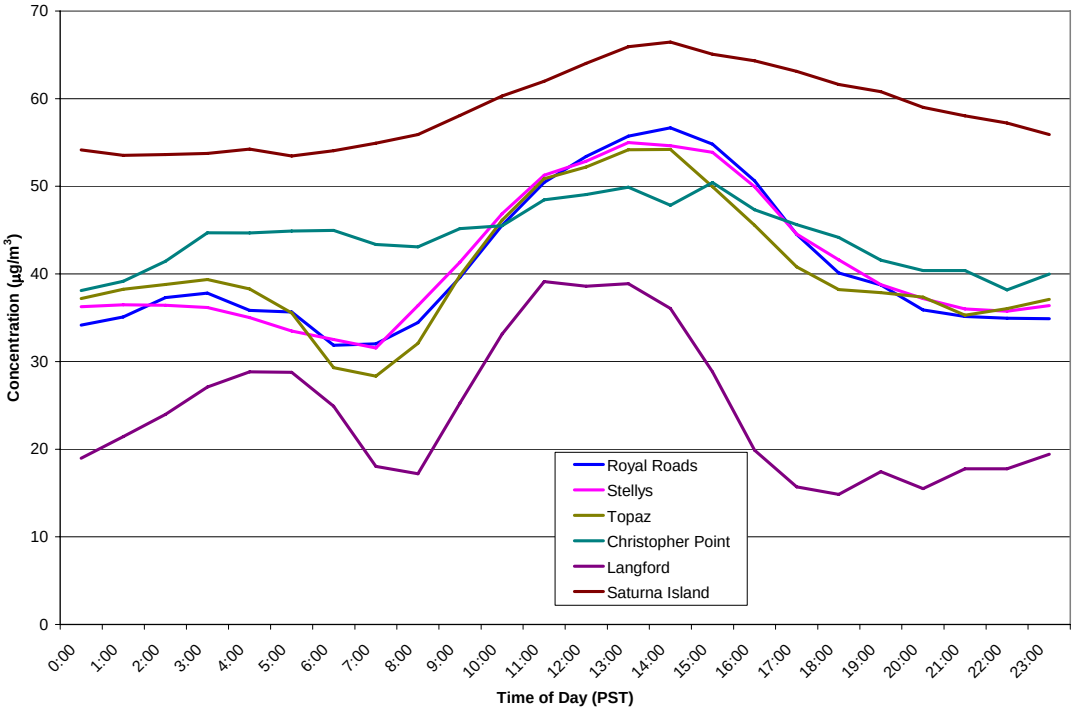
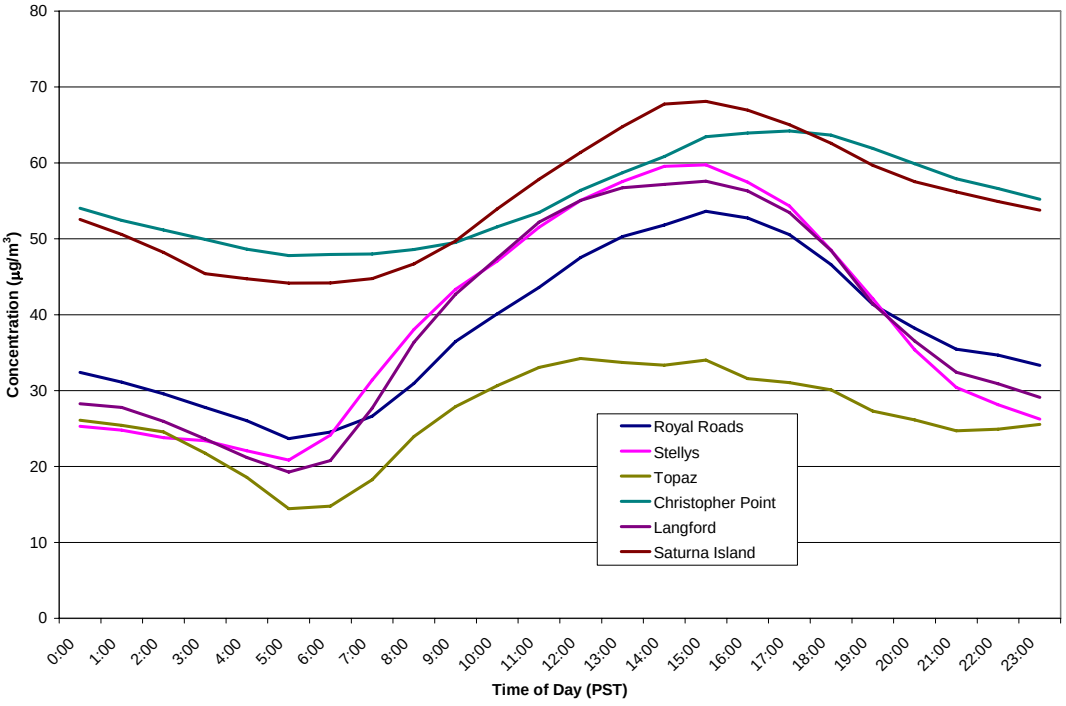


Figure 3.15: Average Diurnal Ozone Pattern During Warmer Months (May - October)



4.0 PARTICULATE MATTER

Suspended particulate matter (PM) can originate from natural sources such as dust disturbed by the action of wind, and from anthropogenic sources, such as the combustion of fuels. Fuel combustion tends to produce smaller PM, whereas dust tends to be of a larger size fraction. PM can remain suspended in air for as little as a few seconds to as long as several days or even weeks and longer. Precipitation tends to effectively remove PM from the air. Ambient PM is measured in the CRD as both 'inhalable' particulate matter, which is the fraction of suspended particles with diameters of 10 micrometres (μm) or less and 'respirable' particulate matter, which have diameters of 2.5 μm or less. These fractions are denoted as PM_{10} and $PM_{2.5}$ respectively.

There is significant interest in community levels of $PM_{2.5}$, as health research has indicated the smaller size range of suspended particles can have negative effects on human health at concentrations typically observed in urban areas. For this reason, $PM_{2.5}$ is one of two common air contaminants (with ground level ozone) with CWS criteria. Exposure to $PM_{2.5}$ can aggravate pulmonary and cardiovascular disease, increase the occurrence of asthmatic attacks and increase the risk of premature mortality. An additional adverse effect that can be related to ambient PM concentrations is the reduction of visibility.

Primary PM describes matter emitted directly to the atmosphere, whereas secondary PM describes solid (or liquid) particles that are formed in the atmosphere from the chemical reactions of other compounds. Since there are few significant industrial emission sources in the CRD, much of the PM is released by motor vehicle and marine vessel exhaust, roadway emissions (dust) due to traffic activity, residential home heating and residential burning. The contribution of residential ('backyard') burning to monitored $PM_{2.5}$ concentrations in the CRD during allowed burn days was assessed in the 2004 air quality assessment[9].

Four different ambient PM sampling (measuring) devices are currently used in the CRD. Tapered Element Oscillating Microbalance (TEOM) samplers are used to collect air concentrations of $PM_{2.5}$ that are recorded as hourly averaged concentrations. These samplers run continuously, with periodic maintenance depending on how quickly the sampling filter reaches capacity. Sequential high volume (Hi-Vol) samplers are used to determine 24-hour concentrations of PM_{10} on a cycle of one in every six days. One Partisol sampler is used to collect PM_{10} sequentially on the same schedule as the Hi-Vols, but utilizes a low-volume of airflow for sample collection.

[9] SENES Consultants Ltd, 2005. *Air Quality in the Capital Regional District 2004.* Prepared for the Capital Regional District.

There is also one dichotomous (Dichot) sampler, which produces 24-hour concentrations of both PM_{10} and $PM_{2.5}$ on the same one-in-six day rotation cycle. The Dichot sampler is part of the National Air Pollution Surveillance network managed by Environment Canada.

The three types of sequential samplers collect particulate matter on a filter, from midnight of one day to midnight of the next. Once a collection period has ended, the filter is analyzed in a lab to determine the 24-hour concentration.

It should be noted that each type of sampling instrument has its own bias, in that measured amounts may be over- or under-estimated by a small amount simply due to the process the instrument uses to determine an ambient concentration. This means that two co-located PM_{10} or $PM_{2.5}$ samplers may produce ambient PM concentrations that differ. In addition, each PM sampler may be influenced by positional bias that exists due to the location of the air quality station within the community.

4.1 INHALABLE PARTICULATE MATTER (PM_{10})

Table 4.1 provides a statistical summary of 24-hour average PM_{10} concentrations at five monitoring stations that are equipped with Hi-vol samplers: Langford, Oak Bay, Braefoot Keating Elementary school and Royal Roads University. Note that Hi-Vol PM_{10} sampling was discontinued at the Topaz site in 2007.

Table 4.2 shows the measured 24-hr PM_{10} concentrations recorded at Stellys using a Partisol sampler. The data at Stellys were collected on the same 6-day cycle as the Hi-Vol samplers.

Table 4.1
Measured 24-Hour Hi-Vol PM_{10} Concentrations in the CRD

Statistic	Langford	Oak Bay	Braefoot	Royal Roads	Keating
Mean ($\mu g/m^3$)	10.9	10.9	11.3	11.1	12.1
Std. Dev. ($\mu g/m^3$)	5.5	6.1	9.1	6.5	6.0
Maximum ($\mu g/m^3$)	23	32	69	41	33
98^{th} percentile ($\mu g/m^3$)	22	31	25	28	28
# > CRD Guideline (50 $\mu g/m^3$)	0	0	1	0	0
# of Samples	27	58	58	58	59
Percent Missing (%)	56	5	5	5	3

Table 4.2
Measured 24-Hour PM_{10} Concentration for Stellys

Statistic	Stellys
Mean (µg/m^3)	9.8
Std. Dev. (µg/m^3)	4.8
Maximum (µg/m^3)	23
98th percentile (µg/m^3)	21
# > CRD Guideline (50µg/m^3)	0
# of Samples	31
Percent Missing (%)	49

It should be noted that the large amount of missing data at Stellys was due to electrical supply problems at the station.

During 2007, the CRD 24-hour average guideline value of 50 µg/m^3 was exceeded once at Braefoot. On April 12th, Braefoot recorded a 24-hour average PM_{10} concentration of 69 µg/m^3. On this date, PM_{10} levels recorded at the other monitoring locations were much lower: 10 µg/m^3 at Stellys, 11 µg/m^3 at Royal Roads, 8 µg/m^3 at Oak Bay, 9 µg/m^3 at Keating Elementary, and 14 µg/m^3 at Langford. Therefore, the elevated PM_{10} levels at Braefoot were not experienced in other parts of the CRD. The reason for the elevated levels at the Braefoot station are unkown.

PM_{10} data for the dichotomous sampler at Victoria Topaz are summarised in Table 4.3. The average PM_{10} concentrations were higher at this location than at the other PM_{10} monitoring sites, but the large proportion of missing data (41%) may have skewed the results.

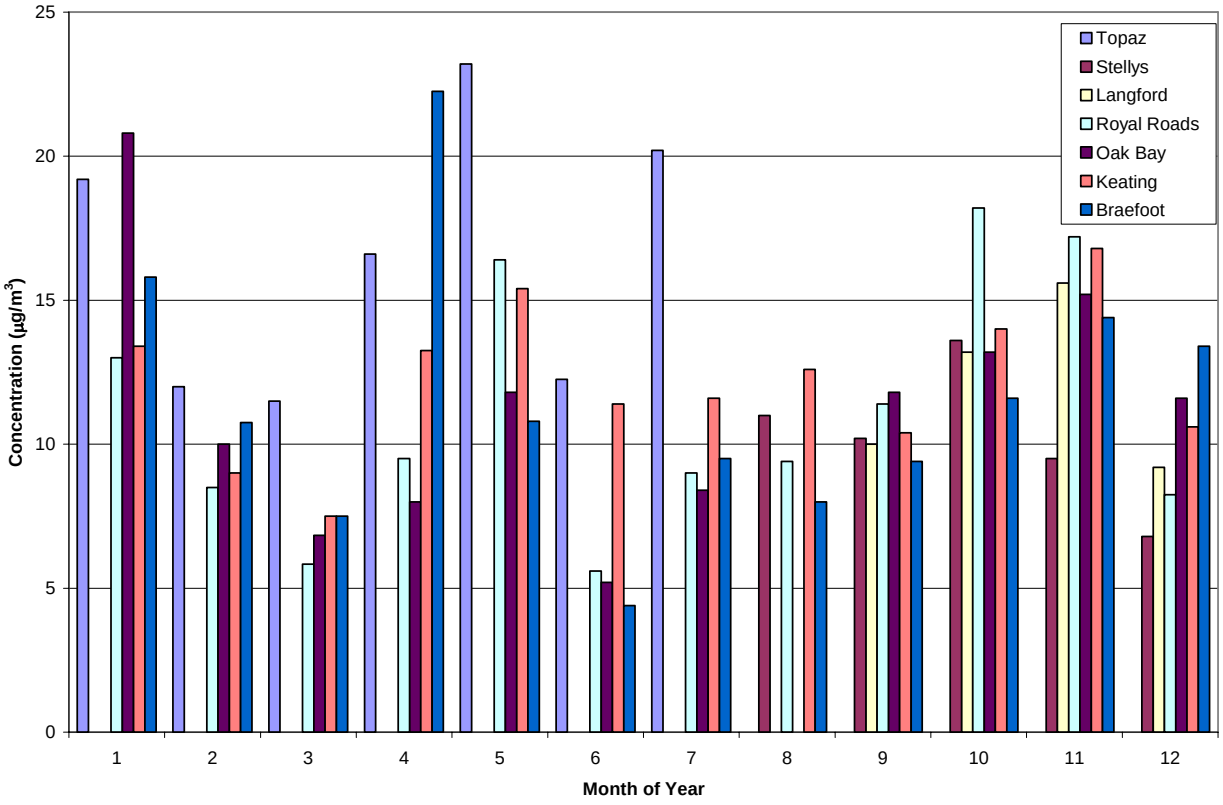
Table 4.3
2007 Dichot Sequential 24-Hour Mean PM_{10} (Victoria Topaz)

Statistic	PM_{10}
Mean (µg/m^3)	16.6
Std. Dev. (µg/m^3)	8.1
Maximum (µg/m^3)	38
98th percentile (µg/m^3)	37
# > CRD Guideline (50 µg/m^3)	0
# of Samples	36
Percent Missing (%)	41

Figure 4.1 shows the monthly averaged 24-hour PM_{10} concentrations in the CRD at each of the seven monitoring sites. There was no particular pattern to the PM_{10} concentrations in 2007.

Some of the lowest levels occurred in March and June, with more elevated levels in January, April, May, July (at Topaz), October and November. No overall conclusions can be drawn from this distribution of monthly average PM_{10} levels, except that peak monthly averages in 2007 were somewhat lower than in 2006, generally higher than in 2004-2005, and about the same as in 2003.

Figure 4.1
Mean Monthly 24-Hour Average PM_{10} Concentrations in the CRD



4.2 PARTICULATE MATTER ($PM_{2.5}$)

Table 4.4 shows the hourly averaged $PM_{2.5}$ concentrations at five TEOM-equipped monitoring stations in the CRD: Victoria Topaz, Royal Roads University, Christopher Point, Stellys and Langford. Data for the Stellys station were limited due to the large amount of missing data caused by power supply problems at the station.

There is no CRD guideline for hourly averaged $PM_{2.5}$ concentrations, nor any provincial or federal objectives or standards. However, the use of ambient air quality objectives for averaging periods shorter than 24 hours has been raised in a comprehensive review of objectives, standards and guidelines in other jurisdictions[10]. For this reason, the hourly averaged $PM_{2.5}$ values should continue to be reported for the CRD.

Table 4.4
Hourly Averaged $PM_{2.5}$ Concentrations at TEOM Sites in the CRD

Percentile Values						Max µg/m³	Min µg/m³	Mean µg/m³	Std. Dev. µg/m³	Missing Values % of Total Hours
5	25	50	75	98	99					
Victoria Topaz										
0	2	4	6	22	28	69	0	5	5.4	1.5
Royal Roads University										
0	1	3	6	16	18	52	0	4	4	11.9
Christopher Point										
0	1	3	4	11	13	36	0	3.2	2.8	2.5
Stellys										
1	4	6	9	23	27	78	0	7.1	5.7	67.3
Langford										
0	1	2	4	12	16	39	0	3	3.2	13

Table 4.5 provides a statistical summary of the 24-hour averaged $PM_{2.5}$ concentrations at five monitoring locations. The $PM_{2.5}$ concentration recorded at Stellys on February 3rd was 25.4 µg/m³, slightly over the guideline value by 0.8%.

[10] SENES Consultants Limited 2005. Development of Options for a New Provincial $PM_{2.5}$ Air Quality Objective. Prepared for the British Columbia Lung Association, Vancouver, BC.

Table 4.5
24-Hour Sequentially Averaged $PM_{2.5}$ Concentrations in the CRD

Percentile Values						Max µg/m³	Min µg/m³	Mean µg/m³	Std. Dev. µg/m³	Percent of 24-h Averages > CRD Guideline (25 µg/m³)	Missing Values
5	25	50	75	98	99						% of Total 24-h Averages
Victoria Topaz											
2	3	4	6	15	18	21.5	0.4	5	3.3	0	1.6
Royal Roads University											
1	2	3	5	12	13	18	0.1	4.1	2.6	0	10.7
Christopher Point											
1	2	3	4	9	11	13.5	0.2	3.2	2	0	1.9
Stellys											
3	5	7	9	17	19	25.4	2.2	7.1	3.5	0.8	67.1
Langford											
1	2	3	4	9	10	13.1	0.1	2.9	2	0	12.9

For the purposes of demonstrating compliance with the $PM_{2.5}$ CWS, the CCME considers an annual $PM_{2.5}$ data set to be complete if at least 75% of the scheduled sampling in each quarter of the year have valid data. Compliance with the CWS for $PM_{2.5}$ (30 µg/m³, 24-hour average) is determined by calculating 24-hour $PM_{2.5}$ concentrations each midnight-to-midnight period during the year from monitoring sites that meet the "neighbourhood" or "urban" criteria as defined in the CWS Guidance Document on Achievement Determination[11]. The consecutive three year average 98th percentile concentration must meet the CWS criteria of 30 µg/m³. It should be noted that the Stellys station likely does not meet the siting requirement, as it is situated in a rural setting. Furthermore, as has been previously noted, power supply problems resulted in a large amount of missing data at the Stellys monitoring site in 2007. Therefore, Stellys was not included in the determination of CWS achievement.

Table 4.6 lists the 98th percentile $PM_{2.5}$ concentrations for 2005, 2006, and 2007 at the Topaz and Royal Roads monitoring sites. The average 98th percentile over the 3 consecutive years were 14.3 µg/m³ and 11.3 µg/m³ for Topaz and Royal Roads, respectively. Therefore, the CRD is currently in compliance with the CWS for respirable particulate matter.

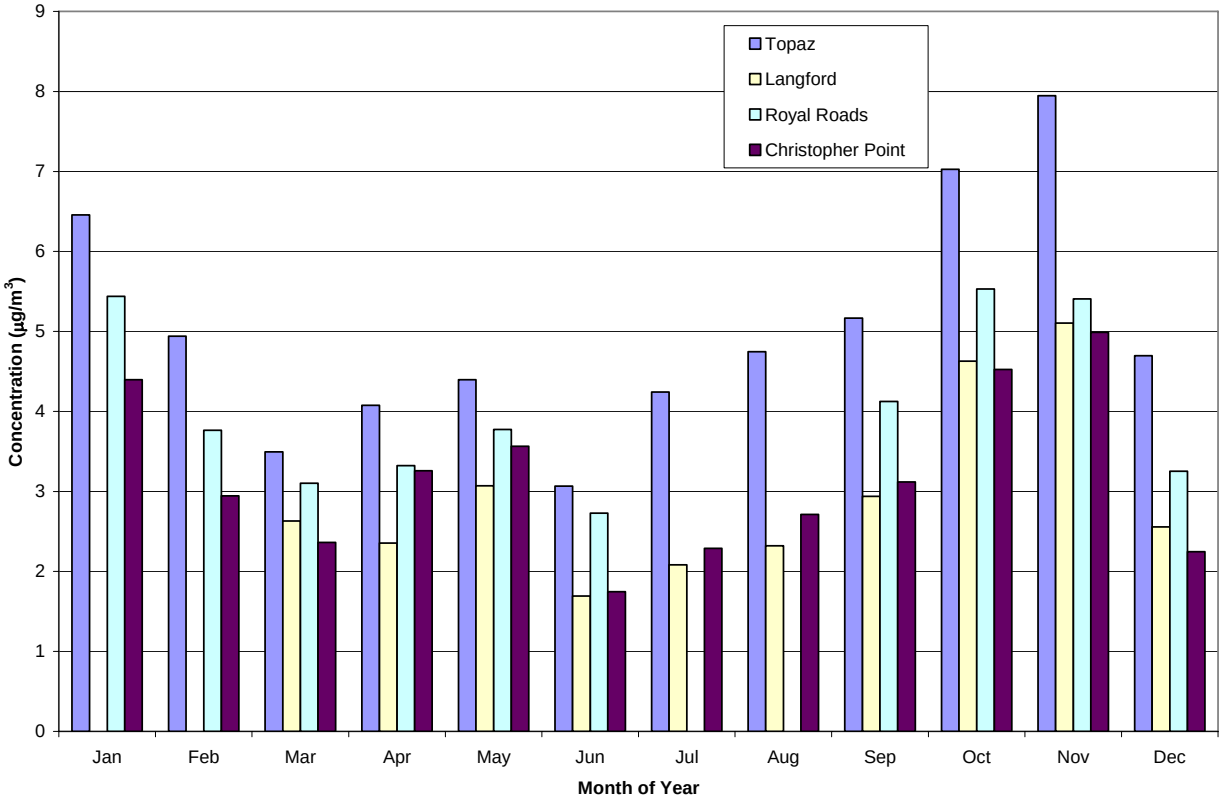
[11] Canadian Council of Ministers for the Environment, 2000. Guidance Document on Achievement Determination: Canada Wide Standards for Particulate Matter and Ozone. www.ccme.ca.

Table 4.6
98th Percentile $PM_{2.5}$ Concentrations for Topaz and Royal Roads (2005-2007)

Station	2005 (µg/m³)	2006 (µg/m³)	2007 (µg/m³)
Victoria Topaz	14	14	15
Royal Roads University	11	11	12

Figure 4.2 shows the monthly average $PM_{2.5}$ concentrations from the TEOM samplers at Topaz, Langford, Royal Roads and Christopher Point. The data for Stellys was not included in the figure as data was limited (only January to April available). The $PM_{2.5}$ levels at all four sites show similar trend, with summer months (June to July) being lowest. Topaz had slightly higher concentrations than Langford, Christopher Point and Royal Roads University. This is probably due to higher traffic levels near the Topaz station (i.e., increased road dust and vehicle emissions on Blanshard Street).

Figure 4.2
Mean Monthly 24-Hour Average $PM_{2.5}$ Concentrations in the CRD



Figures 4.3 and 4.4 show the monthly average diurnal $PM_{2.5}$ concentrations for the TEOM sites during the cooler (November-April) and warmer (May-October) months of the year. Data for Stellys was not included in the figures as data was missing for May – December. The patterns indicate pronounced morning and evening peaks in $PM_{2.5}$ concentrations at both Victoria Topaz and Royals Roads during all seasons. The morning peaks are attributable to rush hour traffic as well as the breakup of morning inversion layers in the atmosphere, while the evening peaks are more likely to be associated with the re-establishment of a lower mixed layer in the atmosphere. At Christopher Point, there is a smaller increase in $PM_{2.5}$ levels in the evening during cooler months of the year, but not so during the warmer months.

Figure 4.3: Average Diurnal $PM_{2.5}$ Pattern in the CRD during the Cooler Months (November – April)

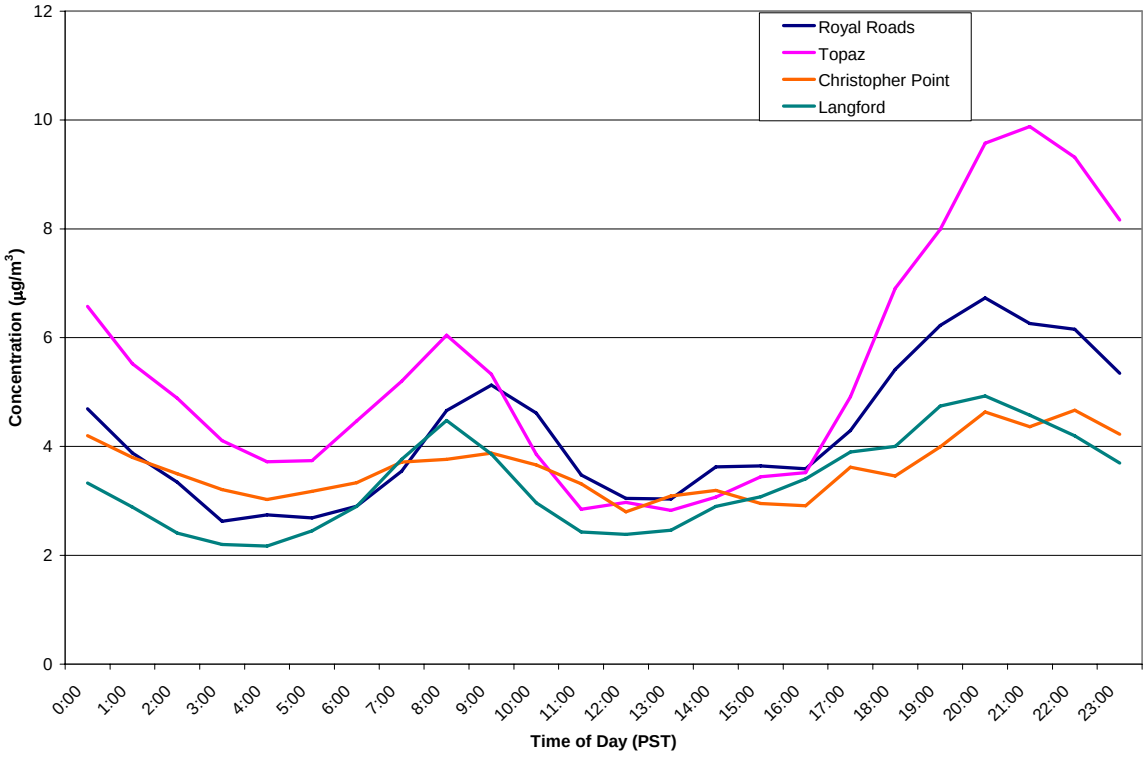
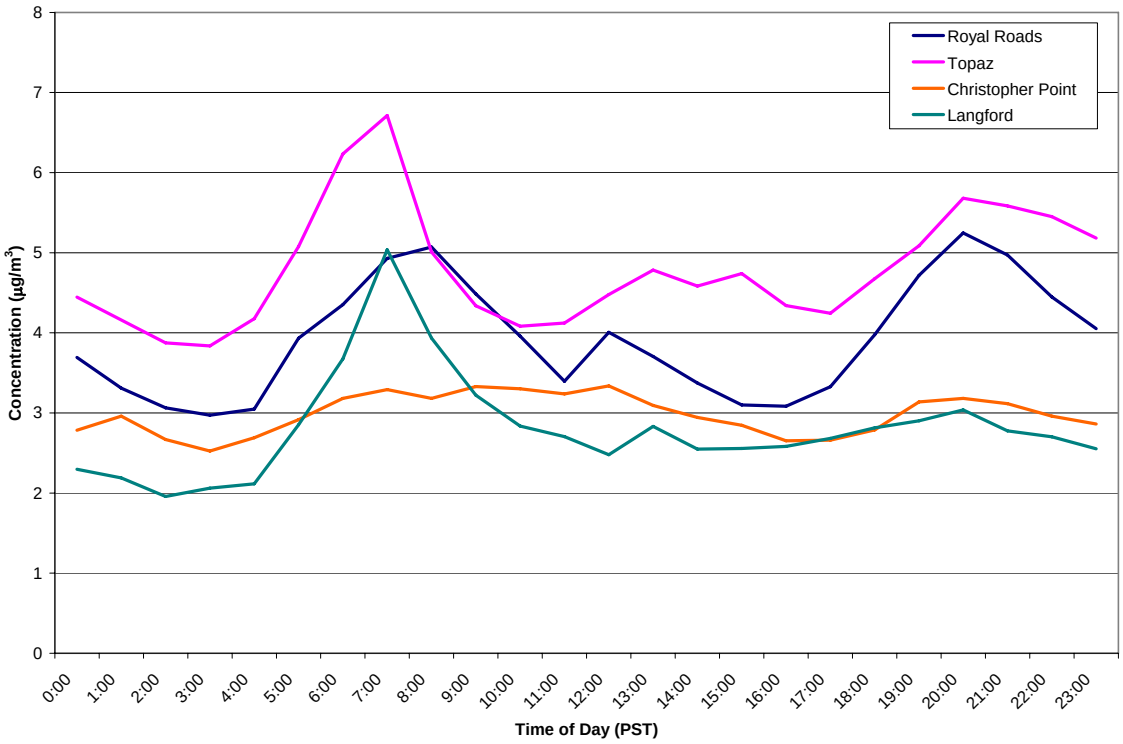


Figure 4.4: Average Diurnal $PM_{2.5}$ Pattern in the CRD during the Warmer Months (May – October)



4.3 COMPARISON BETWEEN CONTINUOUS AND SEQUENTIAL SAMPLING DATA

This section presents comparisons between continuous TEOM sampled data and sequential sampled data (i.e., Dichot and Hi-vol samplers) at two locations (Victoria Topaz and Langford). This analysis is being performed starting from 2007 as a check of data quality. A comparison was not made for the Stellys station as the TEOM and Partisol sampler data only overlap for only 2 sampling events in 2007.

Figure 4.5 shows that the $PM_{2.5}$ data collected at Victoria Topaz using the continuous TEOM and the sequential Dichot sampler agree well for the months of August to October, but not for the rest of the sampling period. Overall the Dichot sampler gives higher $PM_{2.5}$ concentrations than the TEOM, in some cases by a factor of 2-4 times higher for peak $PM_{2.5}$ concentrations measured using the Dichot sampler in May and July.

Figure 4.6 shows the comparison between Hi-Vol and TEOM sampler $PM_{2.5}$ levels at Langford Lakewood elementary School. The data indicate that the Hi-Vol sampler gave higher $PM_{2.5}$ concentrations than the TEOM overall, but especially during the period April-July, similar to the observation for the differences between Dichot sampler and TEOM sampler data at Victoria Topaz.

Figure 4.5: Comparison of $PM_{2.5}$ and PM_{10} Data at Victoria Topaz

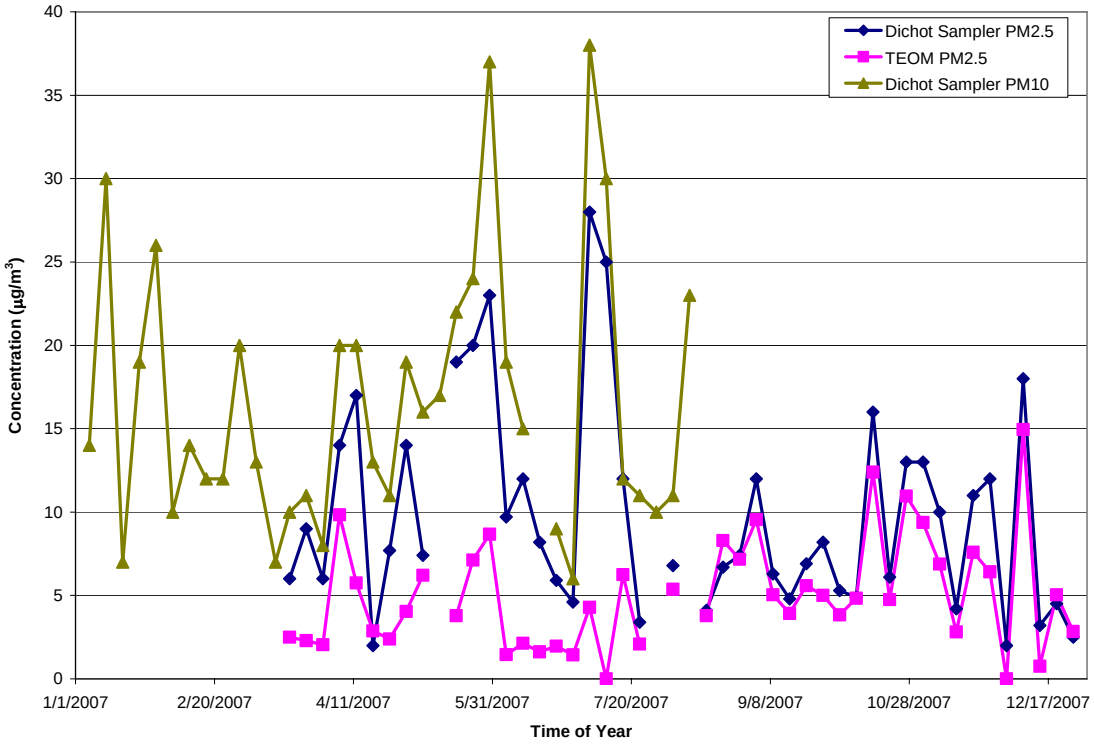
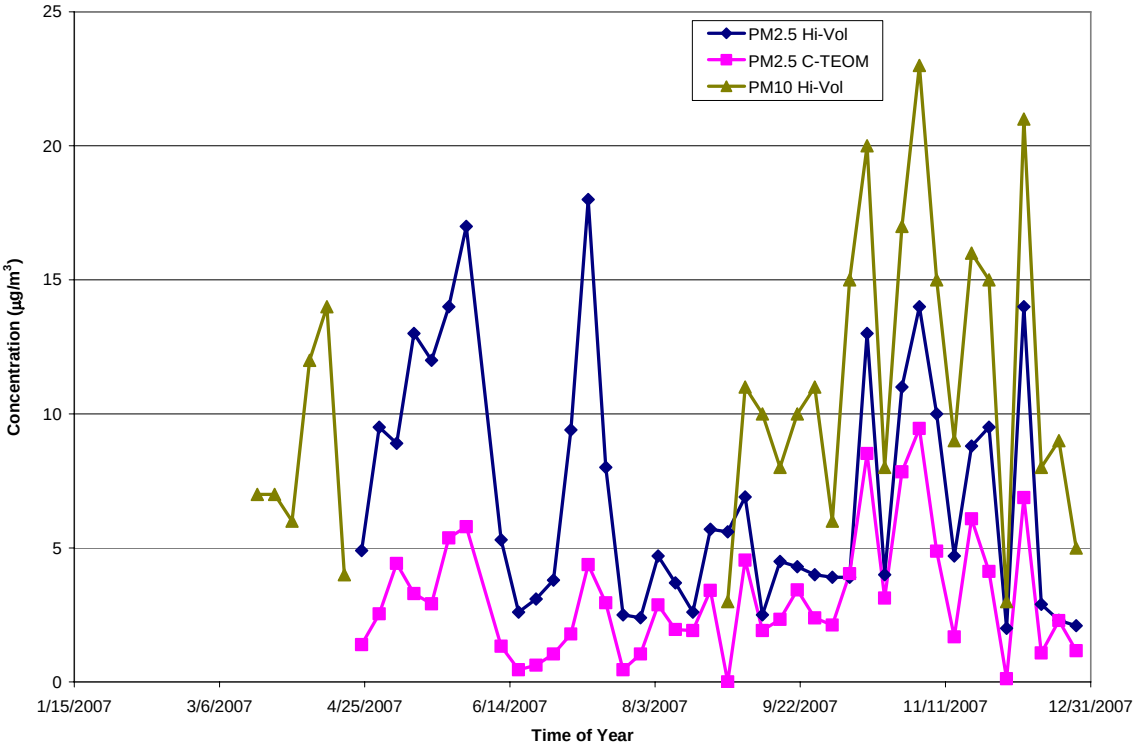


Figure 4.6: Comparison of $PM_{2.5}$ and PM_{10} Data at Langford



Since the Dichot and Hi-Vol filter samples were analyzed by different laboratories, the disparities between the two sequential filter-based samplers and the TEOM samplers at the two sites cannot be explained as being due to errors in laboratory procedures, particularly as the largest differences occurred simultaneously during the same period. Therefore, no conclusions can be drawn about the $PM_{2.5}$ levels measured at these two locations in 2007. There is a suggestion that the TEOM samplers may be underestimating actual $PM_{2.5}$ levels, but this issue requires further investigation by the MoE as part of quality assurance/quality control for the monitoring network.

5.0 AIR QUALITY TRENDS IN THE CRD

SENES developed a statistical tool in 2006 to recognize and assess significant trends in air quality monitoring data from year-to-year in the CRD. The statistical variables this tool measures are the annual mean and 98th percentile concentration. The tool also identifies the annual number of CRD guideline exceedences.

Averaging periods suitable to the CRD guideline are used for each air contaminant. There must be at least 10 years of continuous data available for each station, for small trends to be effectively assessed. If the number of continuous years of available data is limited to less than 5 years, small trends may still be recognized, but may not be considered statistically significant. However, larger trends may be identified as significant even with a data record of less than 10 years.

Victoria Topaz and Satruna Island are the only two stations that have enough continuous data for the tool to determine whether potential trends exist. Table 5.1 shows the trend analysis summary for 10 continuous years (1998-2007) at these two stations. The data indicate that SO_2 concentrations at Victoria Topaz have been steadily declining over this period. The decline at Victoria Topaz was detectable in both the 98th percentile 24-hour average concentrations, as well as for the annual average concentrations. In addition, there has been a weaker trend to lower CO concentrations at the 98th percentile level at Victoria Topaz. This trend was also observed at Saturna Island at the 98th percentile over the period 1998-2005, as reported in the annual air quality report for 2006. While these trends are statistically significant, it should be noted that the absolute values of the SO_2 concentrations at both locations are relatively small.

Table 5.1
Summary of Trend Analysis for Victoria Topaz and Saturna Island

Measure	CO	NO_2	SO_2	O_3	$PM_{2.5}$	PM_{10}
	Victoria Topaz (1998- 2007)					
Annual mean	No trend	No trend	-12%/year	No trend	No trend	No trend
Annual 98th Percentile	-4%/year	No trend	-13%/year	No trend	No trend	No trend
	Saturna Island (1998-2007 O_3; 1998-2005 SO_2)					
Annual mean	--	--	-5%/year	No trend	--	--
Annual 98th Percentile	--	--	-13%/year	No trend	--	--
% over CRD Guideline	--	--	--	26%/year	--	--

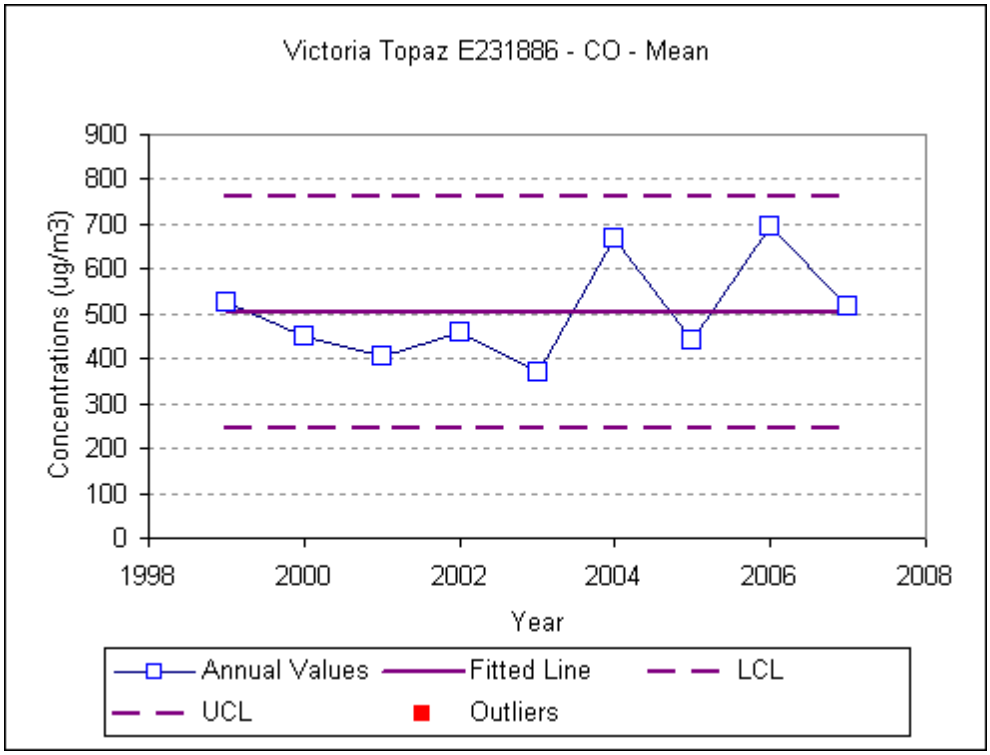
Note: "-" denotes no data or not enough data for trend analysis.
A minimum of four years of data with >80% data recovery is required to complete a trend analysis.
"No trend" indicates that no statistically significant trend can be detected at the 5% significance level.

No other trends were found for CO, NO_2, O_3, $PM_{2.5}$ or PM_{10} data, although there appears to be the suggestion of a weak downward trend in mean $PM_{2.5}$ concentrations post-2002 at both Topaz and Royal Roads. Figures 5.1 to 5.13 show the annual mean and 98th percentile concentration trends for each air contaminant for the period of record at Victoria Topaz, Royal Roads, Saturna Island, Oak Bay, Braefoot and Keating. There was insufficient data to perform trend analysis for Stellys, Langford and Christopher Point, and SO_2 data at Saturna Island for 2006 and 2007 will not be available from Environment Canada until the end of 2008.

Note that the mean concentration, not including the outliers identified during the regression trend analysis, is calculated as the standard deviation of the concentrations. Upper and lower limits (UCL and LCL) are calculated based on the observed mean, standard deviation and appropriate t-statistic for the selected confidence level. Outliers or unusual values are assessed if the annual value is outside the confidence limits. Further discussion of the methodology used for trend analysis is provided in SENES (2006)[12].

[12] SENES Consultants Limited 2006. Method to Assess Presence of Annual Trend or Unusual Values in Air Quality Data. Prepared for the Capital Regional District, Environmental Services Department, Victoria, BC. http://www.crd.bc.ca/airquality/documents/trend_method.pdf

Figure 5.1
CO Trend at Victoria Topaz



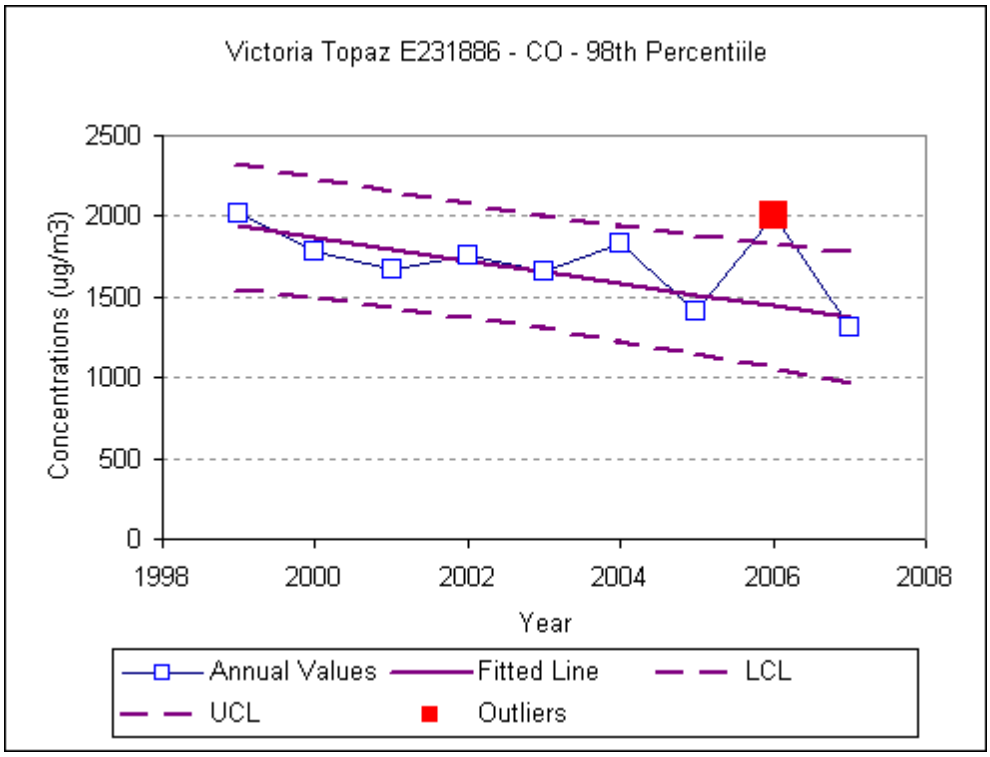
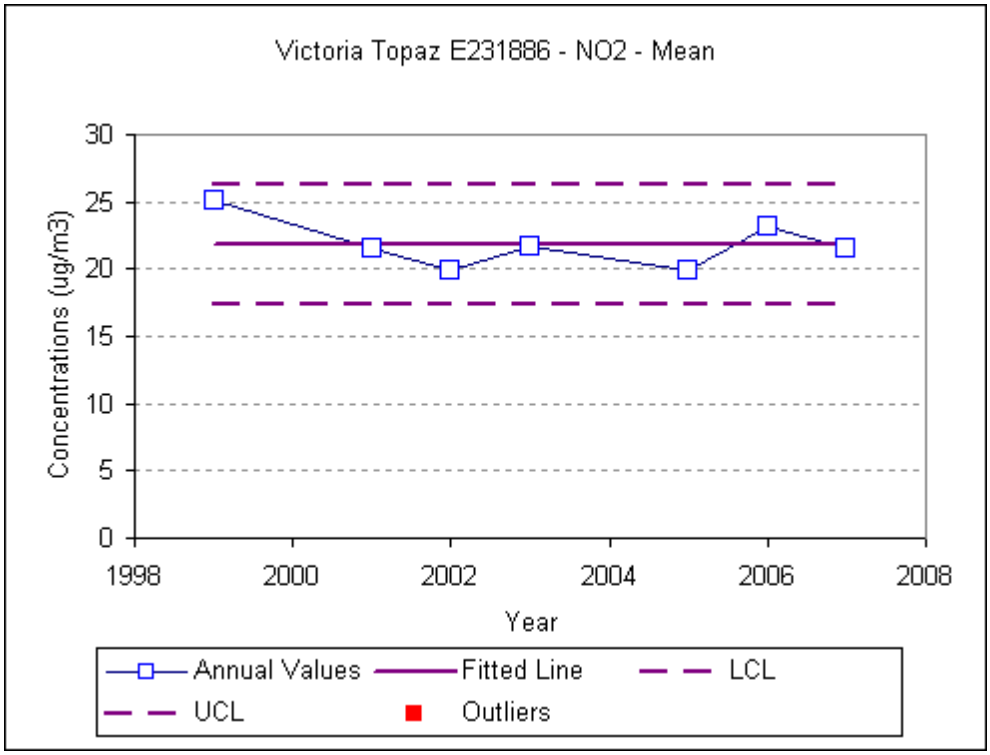


Figure 5.2
NO_2 Trend at Victoria Topaz



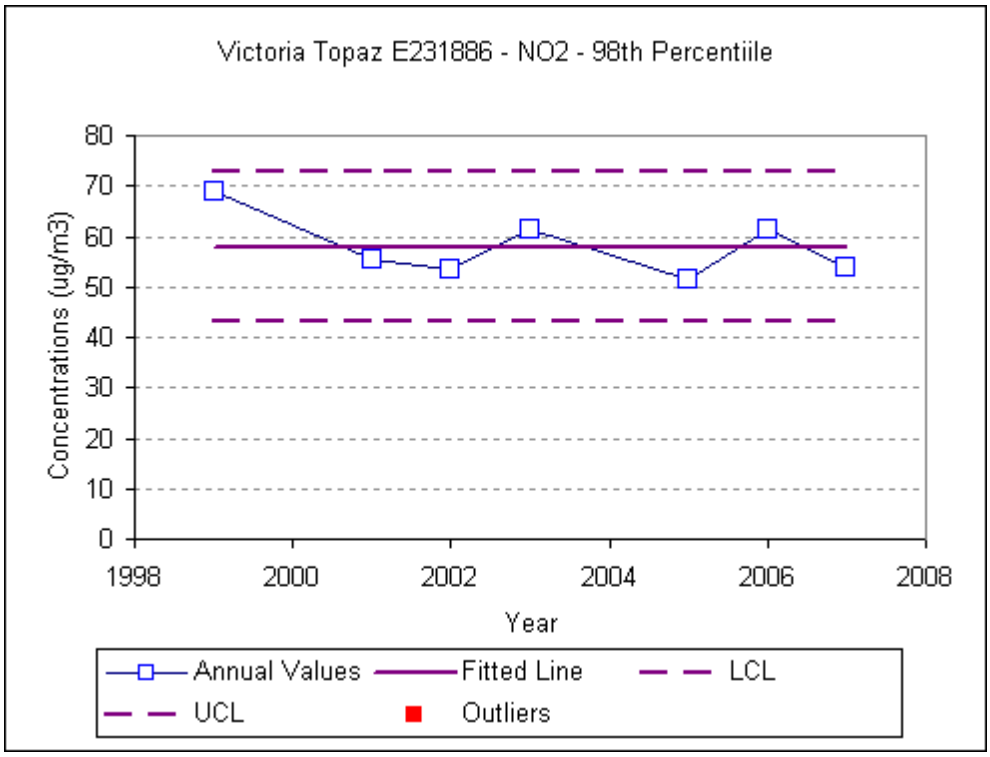
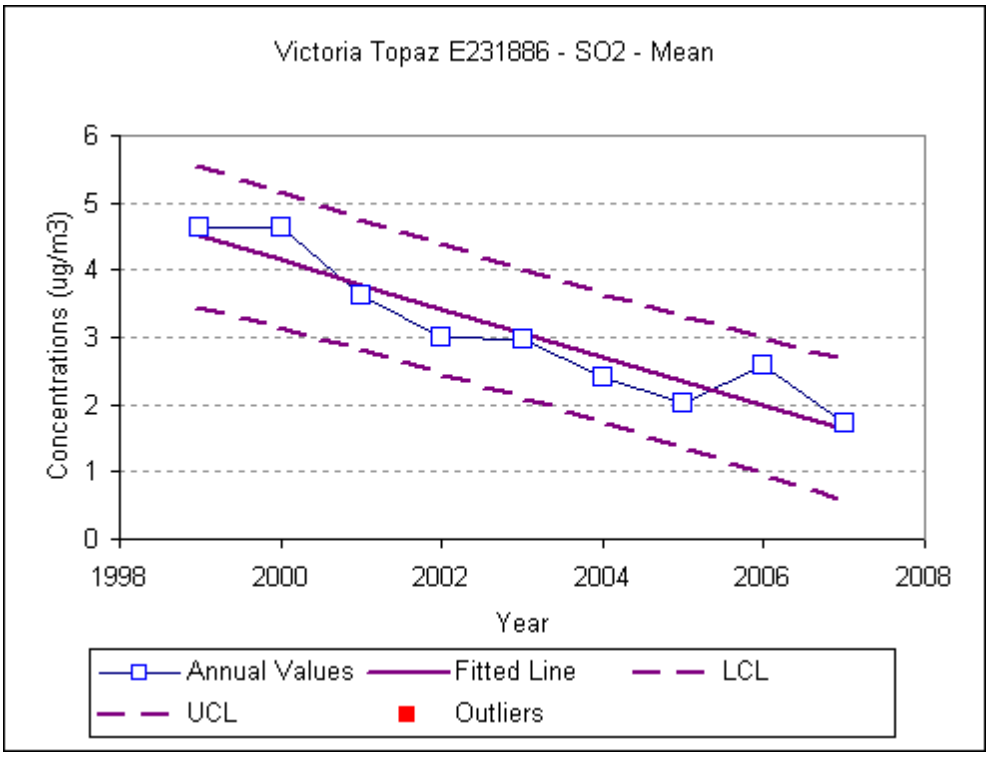


Figure 5.3
SO_2 Trend at Victoria Topaz



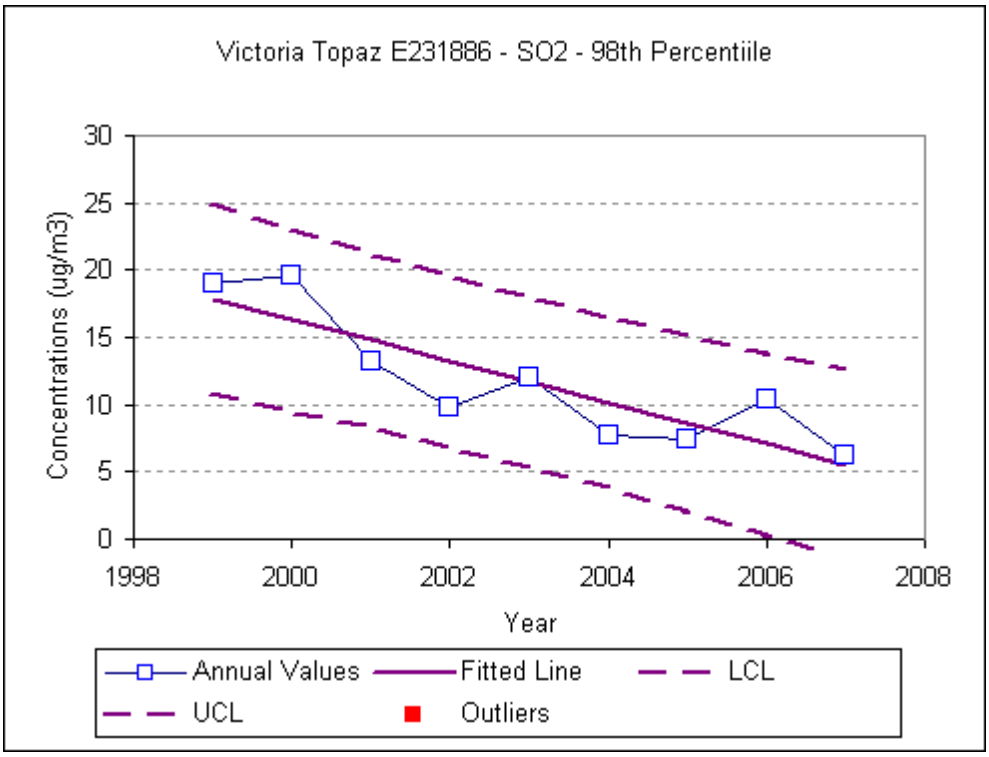
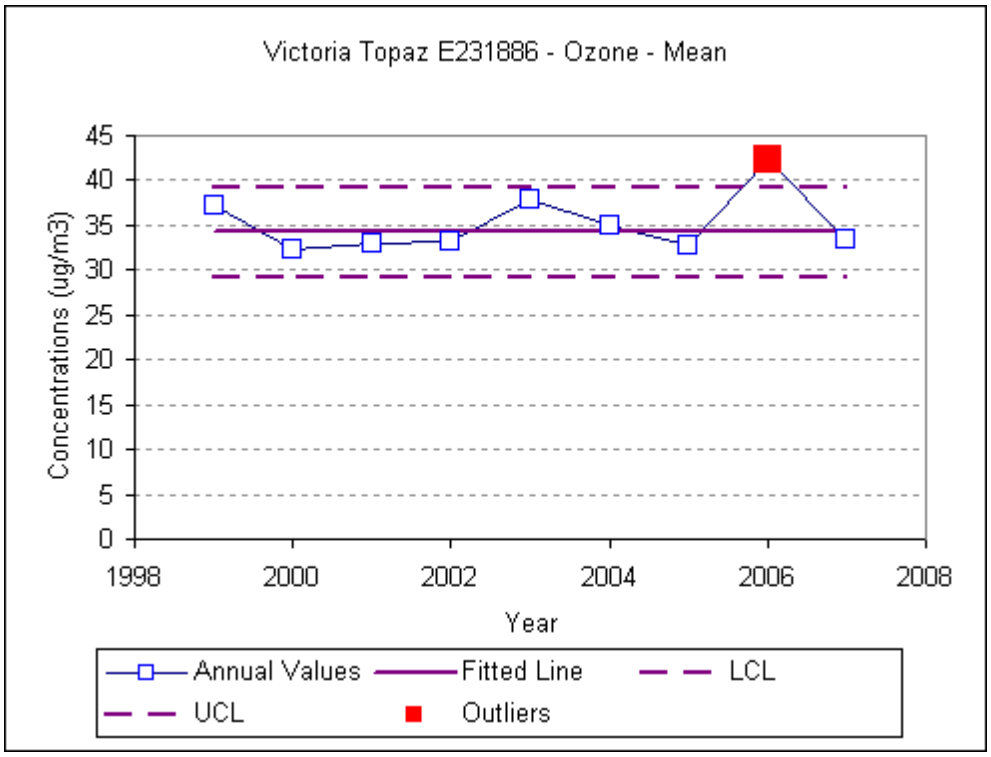


Figure 5.4
O_3 Trend at Victoria Topaz



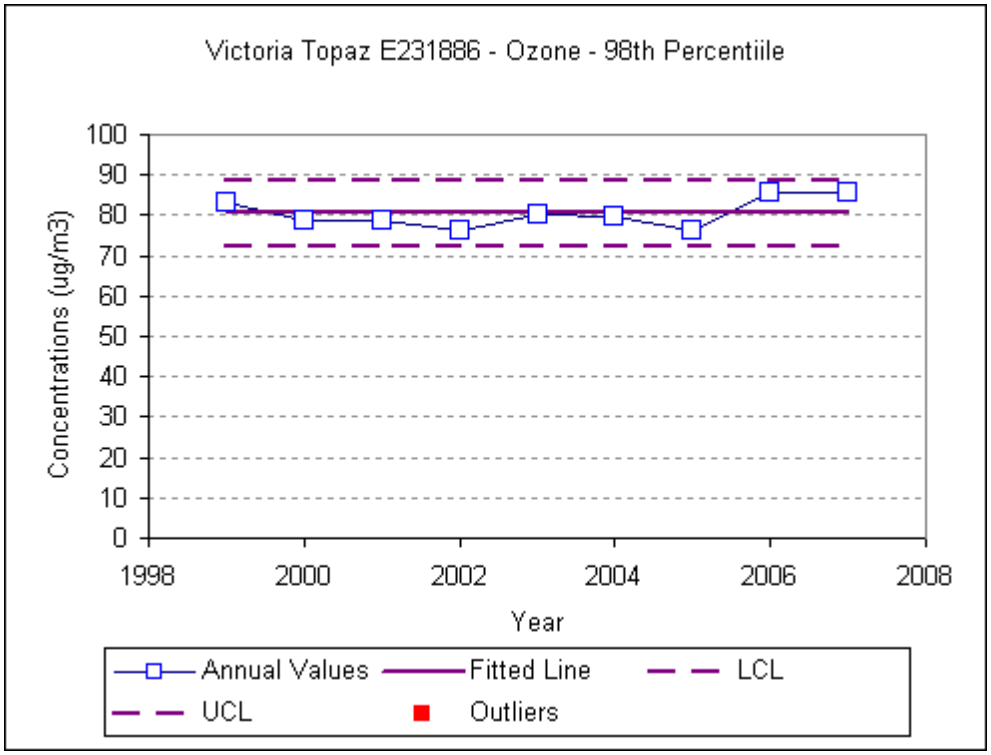
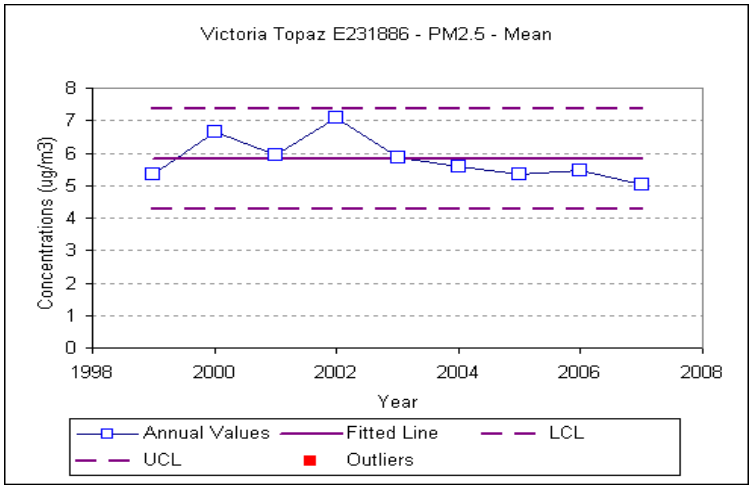
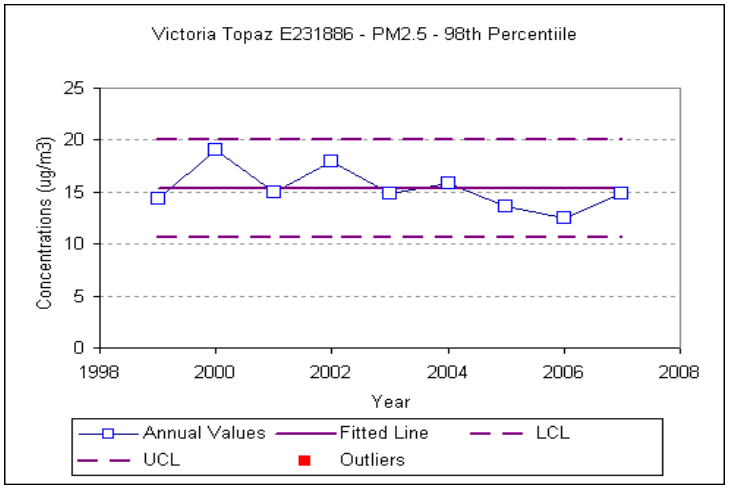


Figure 5.5
$PM_{2.5}$ Trend at Victoria Topaz





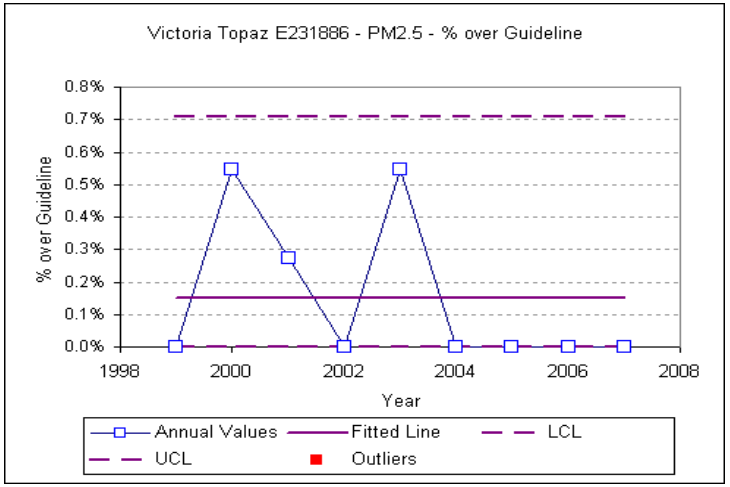
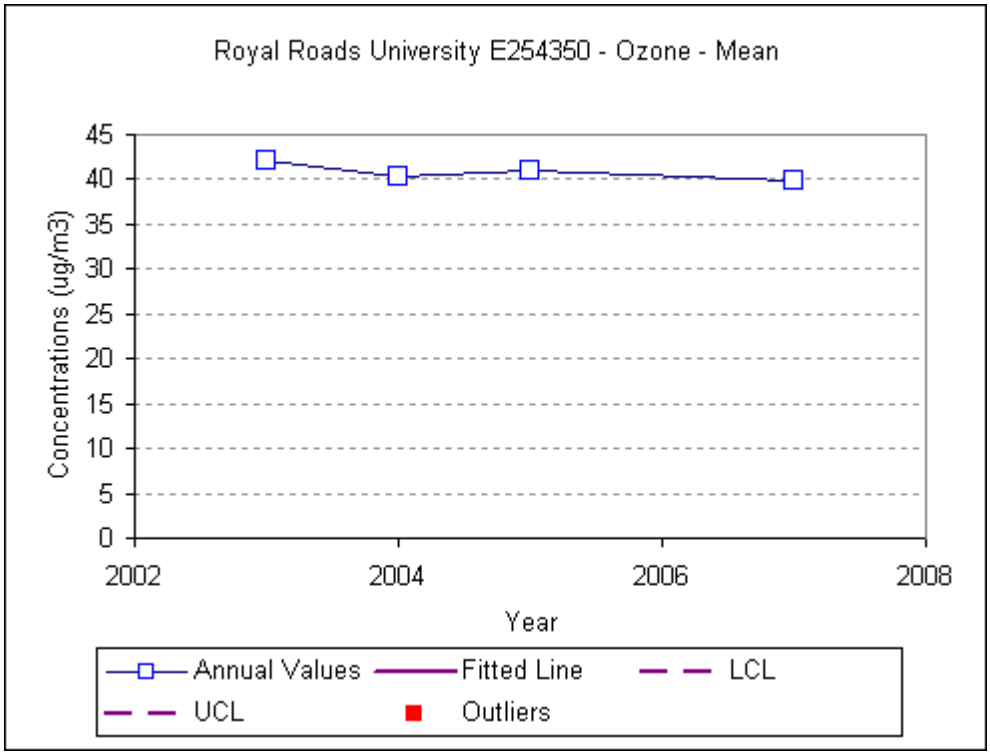


Figure 5.6
O_3 Trend at Royal Roads



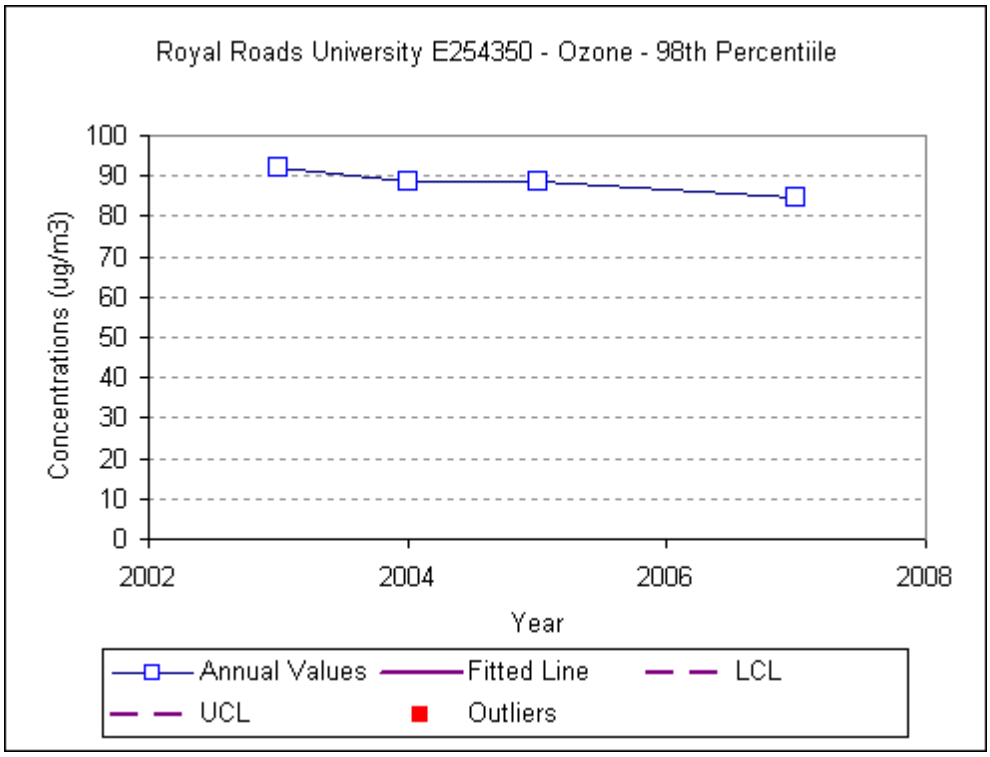
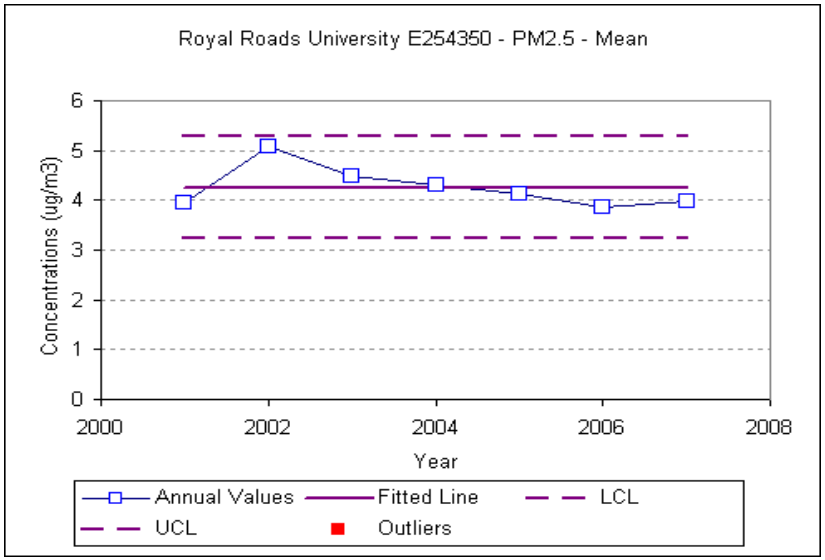
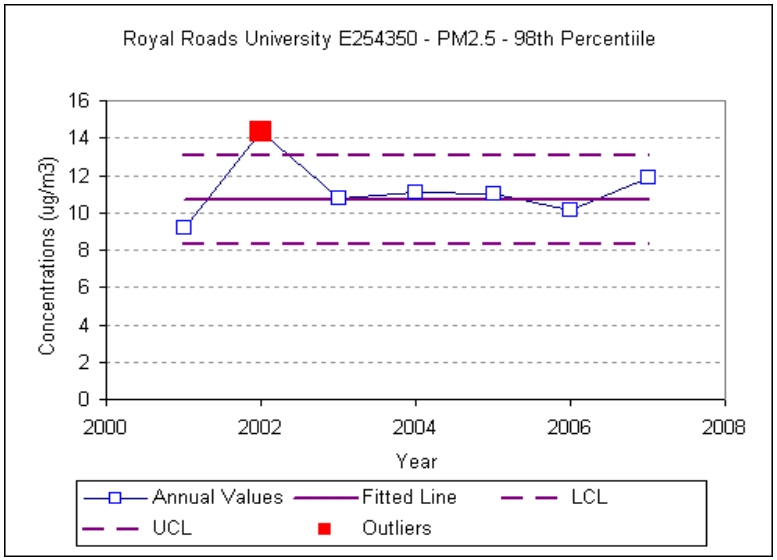


Figure 5.7
$PM_{2.5}$ Trend at Royal Roads





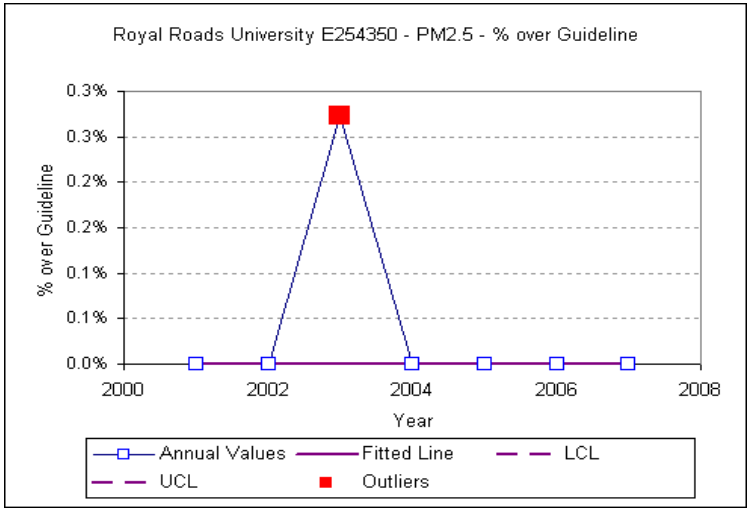
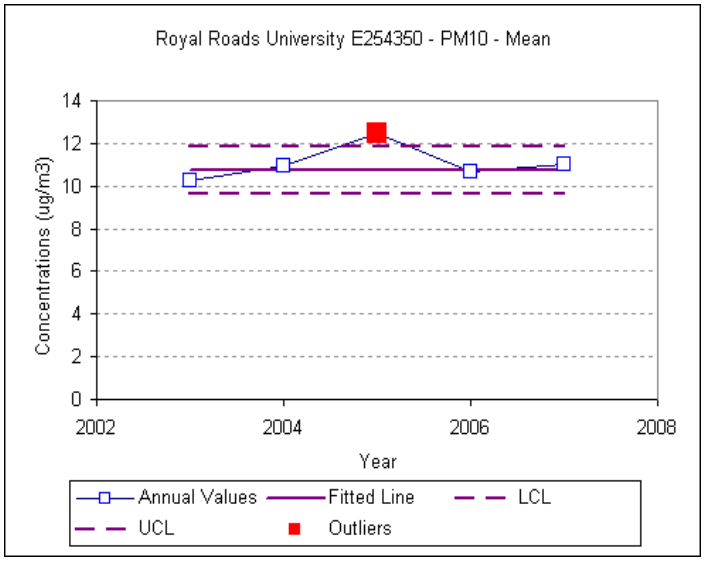
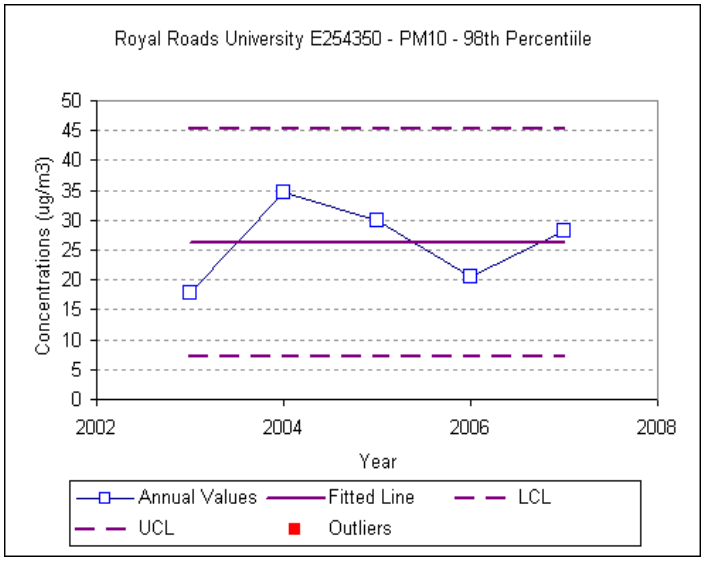


Figure 5.8
PM_{10} Trend at Royal Roads





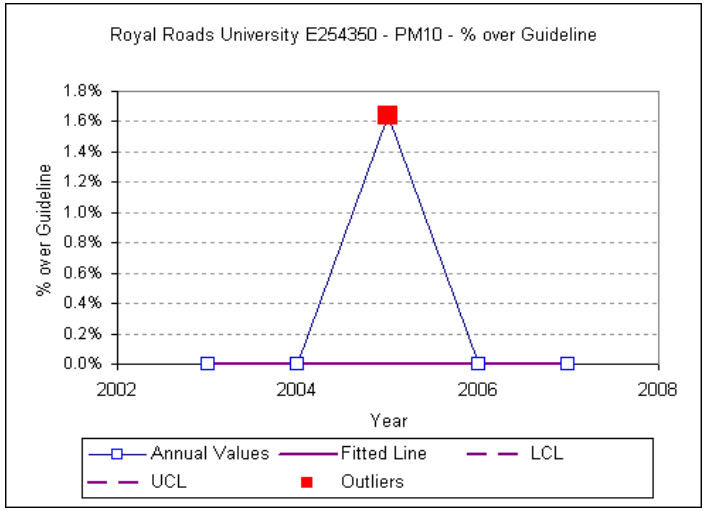
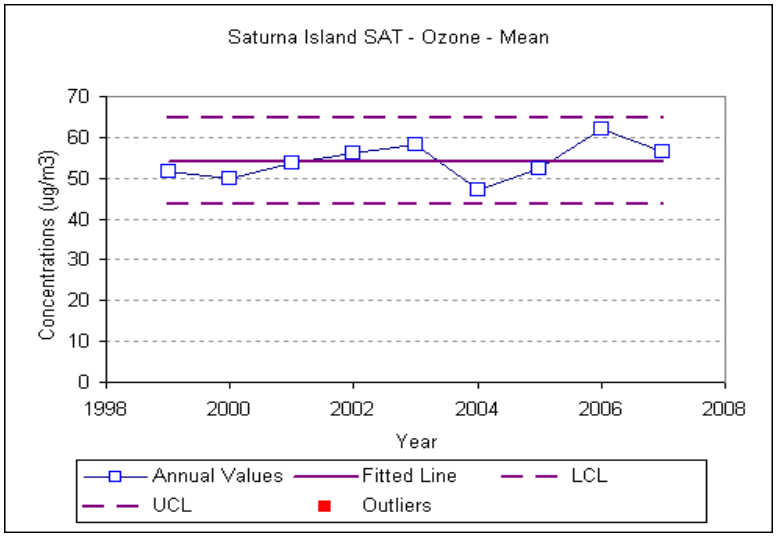
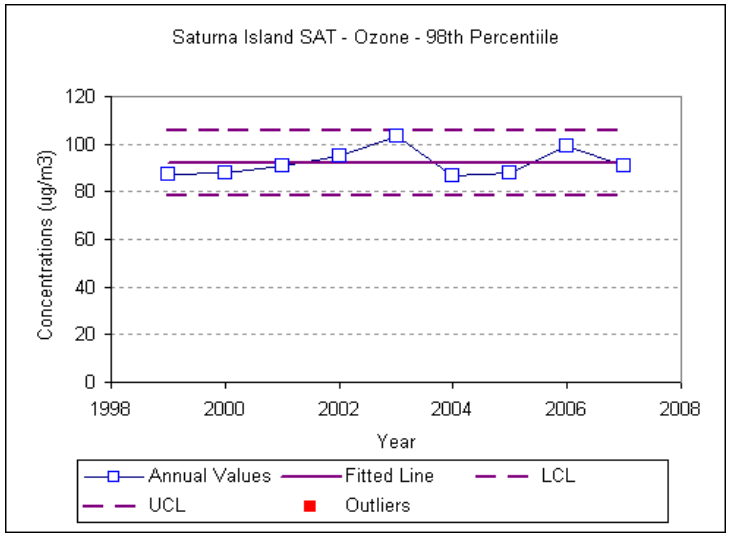


Figure 5.9
O_3 Trend at Saturna Island





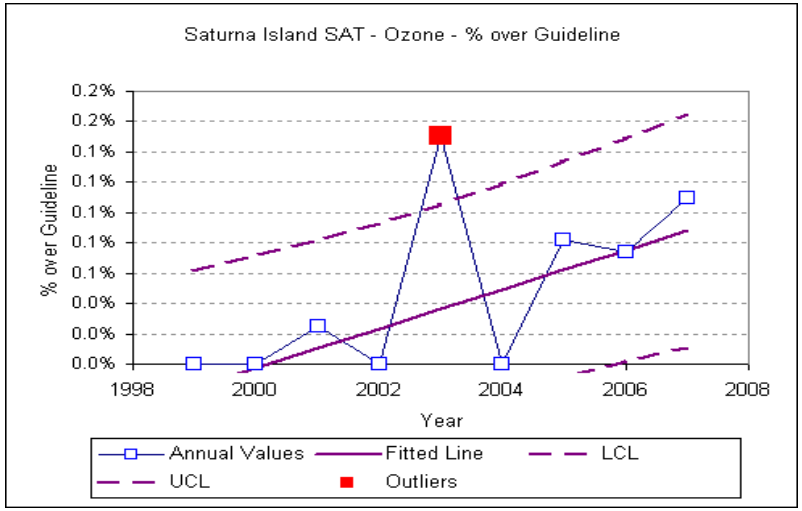
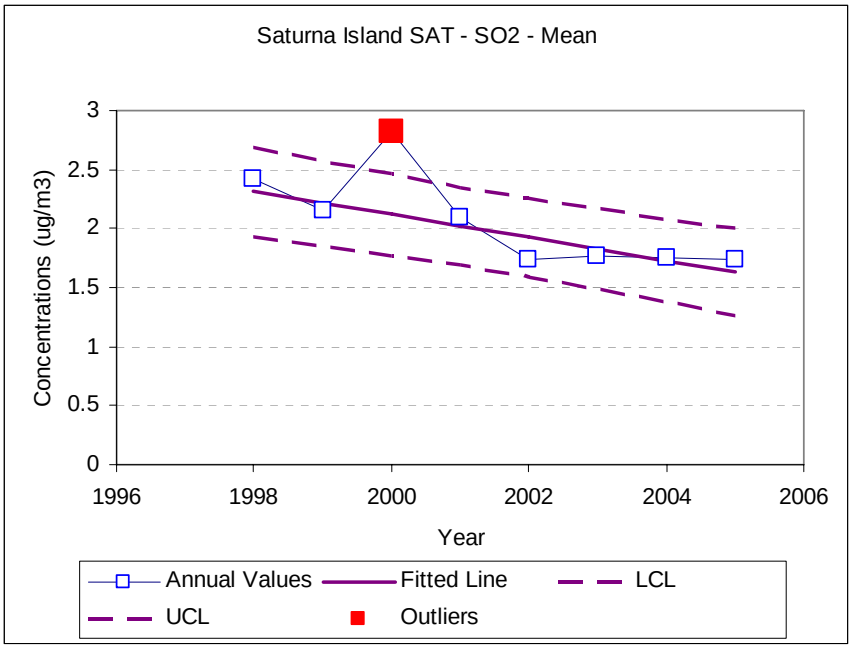


Figure 5.10
SO_2 Trend at Saturna Island



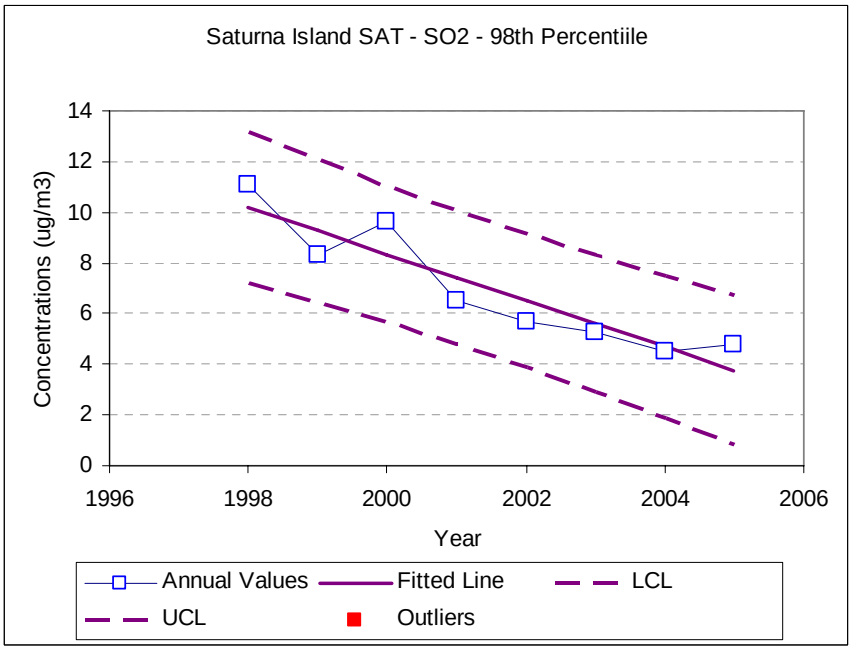
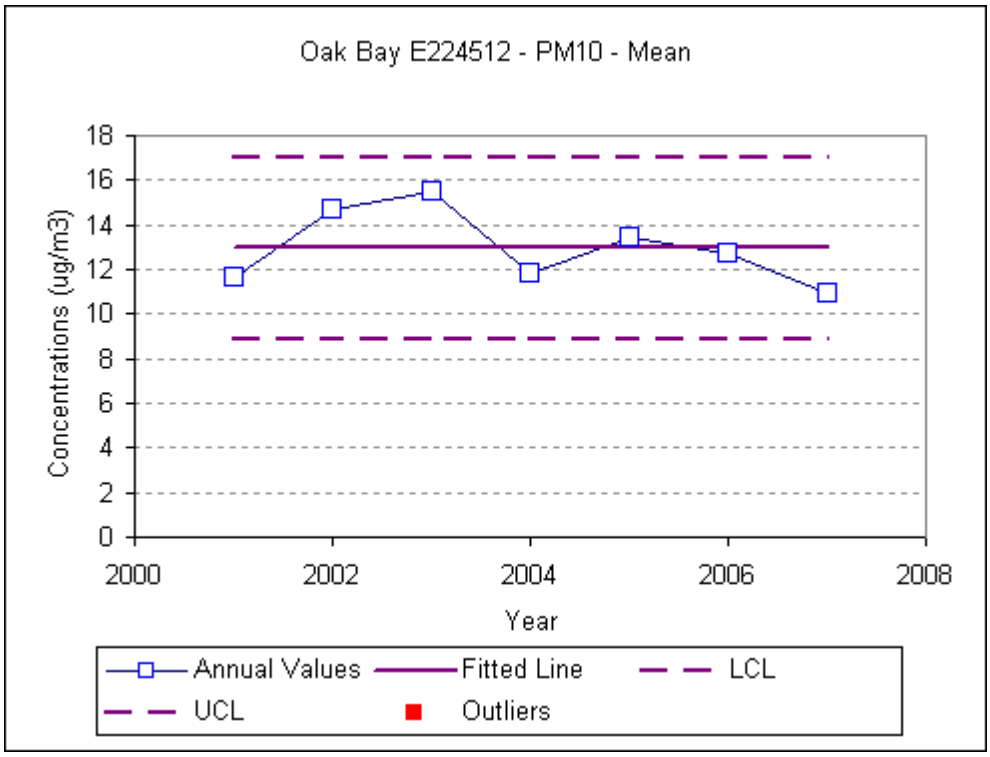


Figure 5.11
PM_{10} Trend at Oak Bay



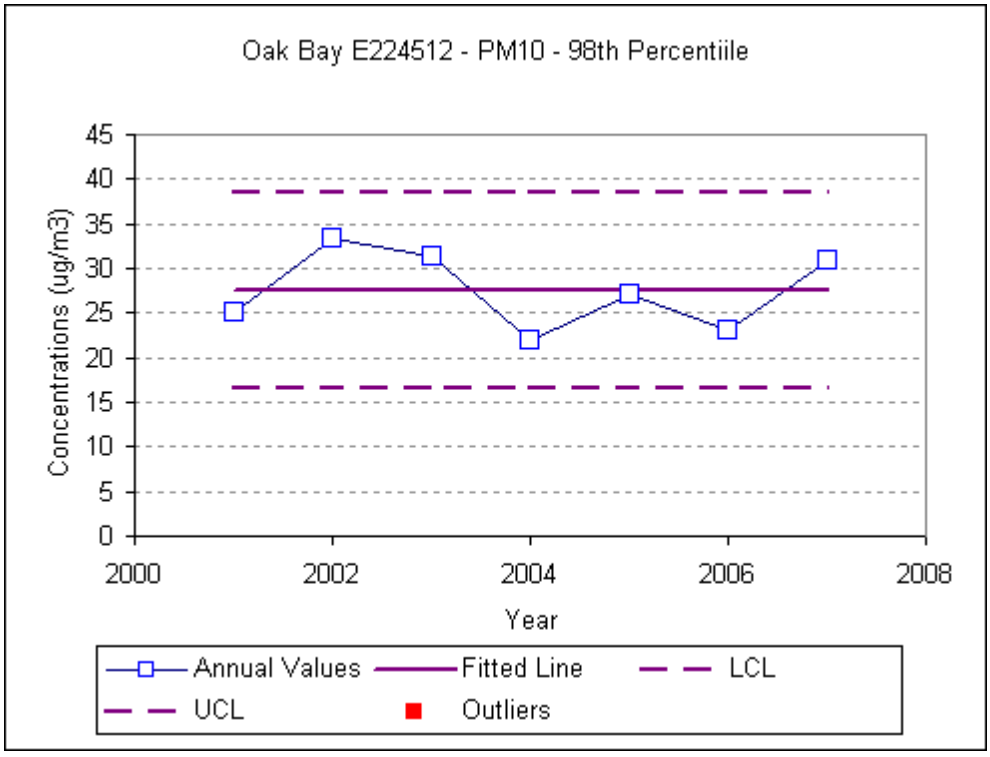
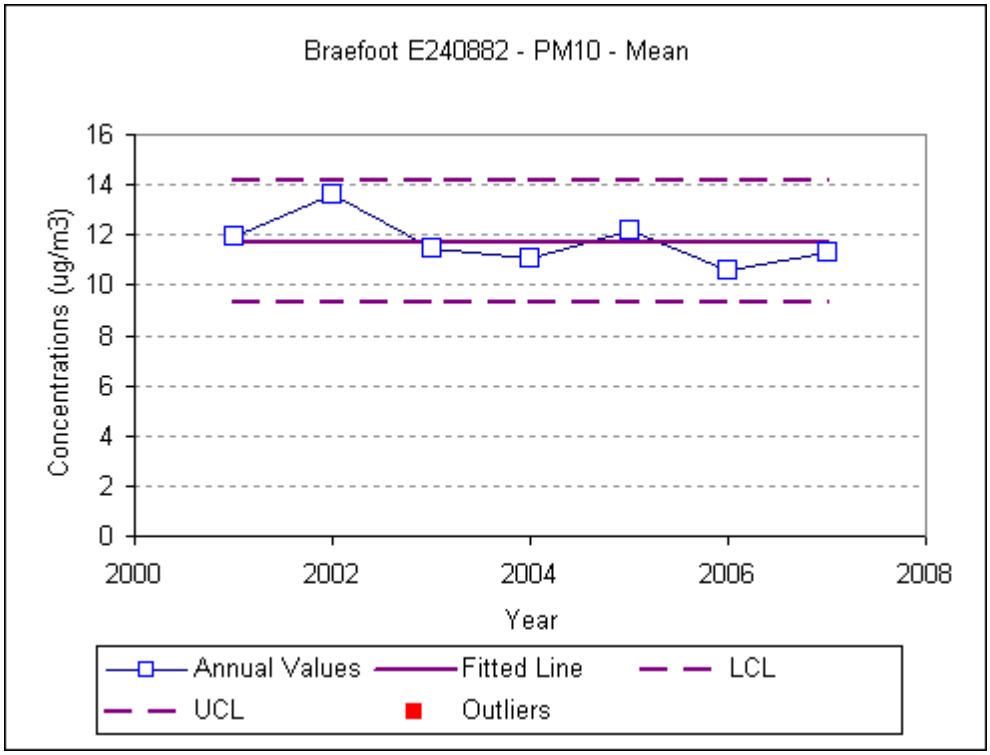


Figure 5.12
PM_{10} Trend at Braefoot



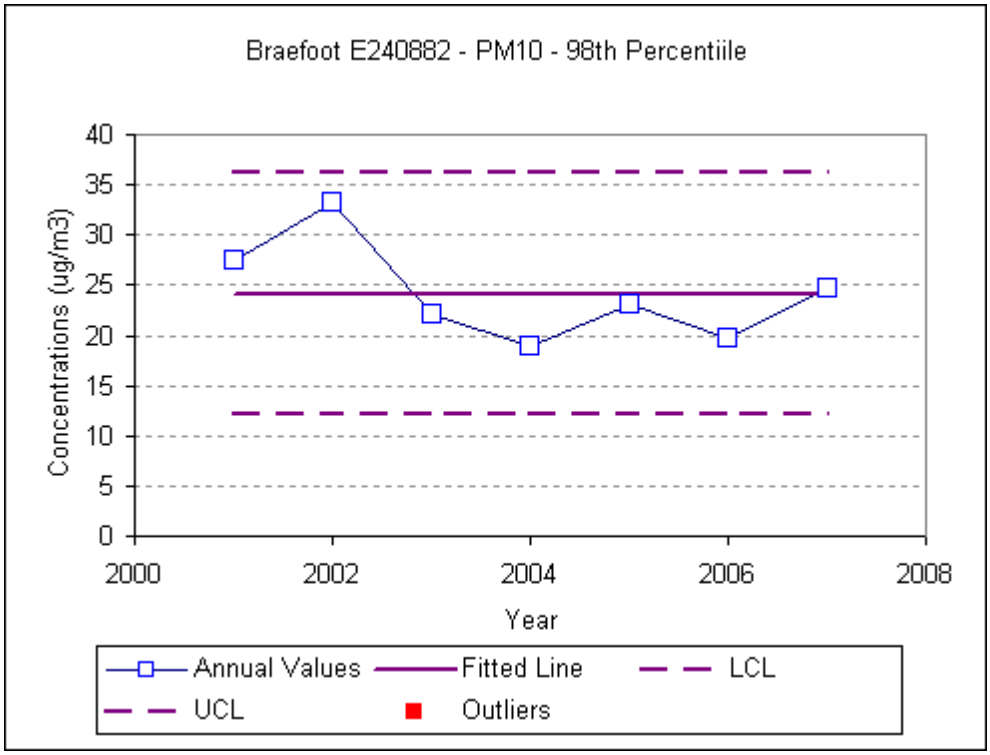
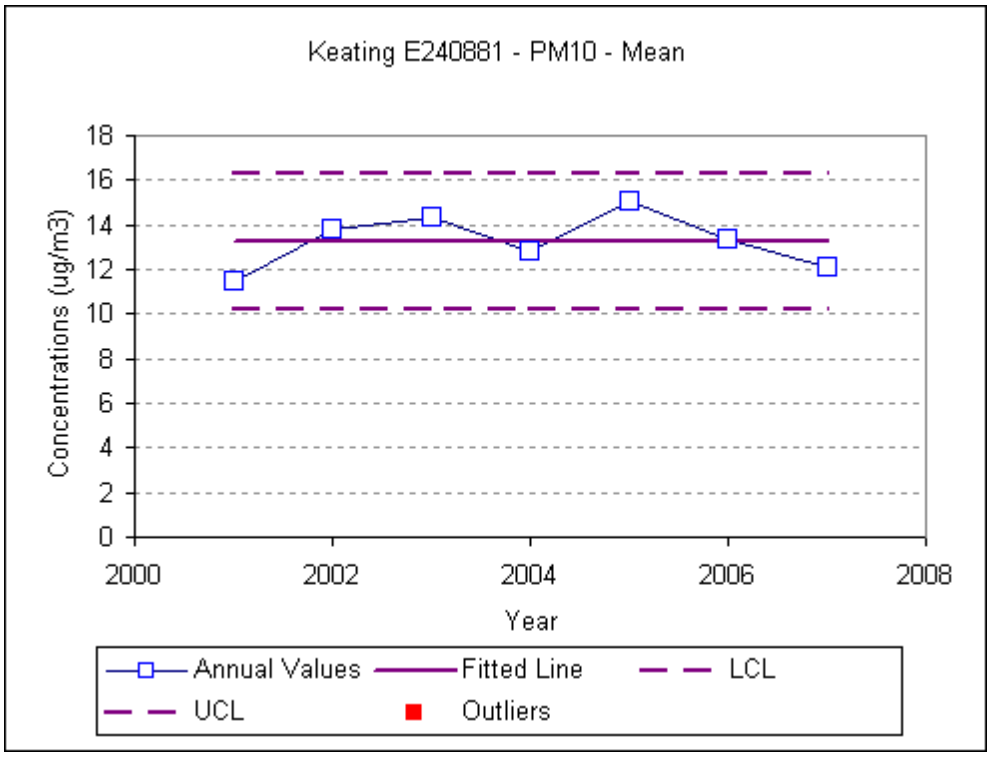
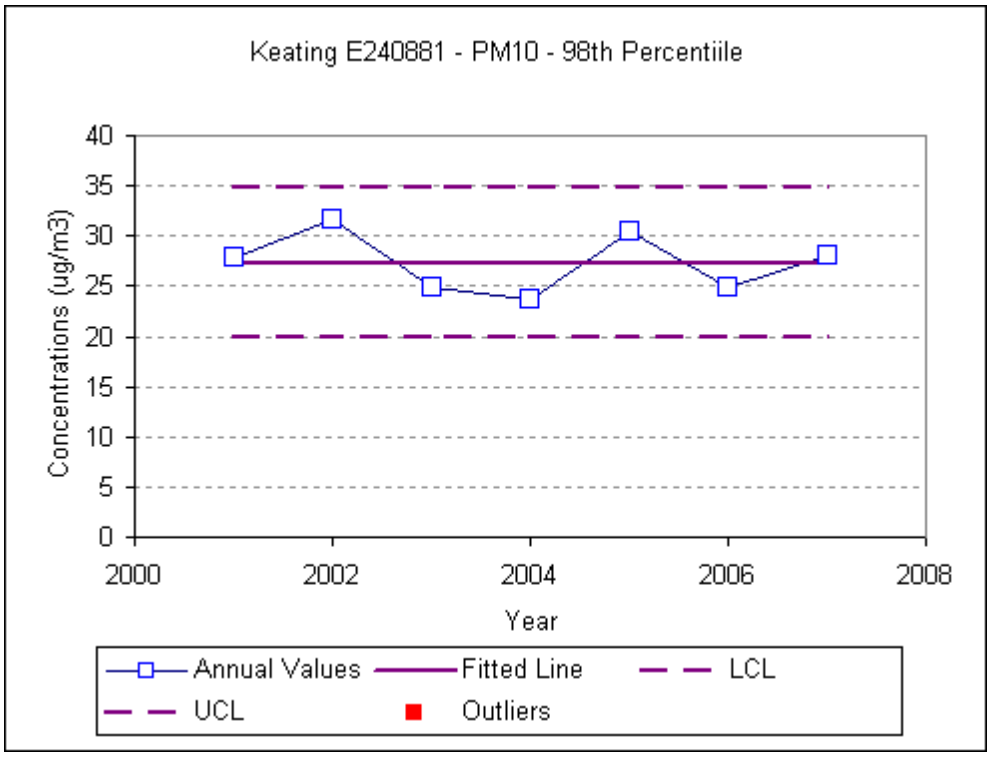


Figure 5.13
PM_{10} Trend at Keating





6.0 CONCLUSION

A summary of comparisons of maximum pollutant concentrations in 2007 to the CRD guidelines and CWS levels are provided in Table 6.1. In general terms, air quality in the CRD was good and far below any applicable guidelines or objectives for most of the time during 2007. There was one exceedence of the CRD guideline for PM_{10}, one slight exceedance for $PM_{2.5}$, and one exceedence of the CRD guideline for ground level ozone. In all cases, the level of exposure to the elevated concentrations was determined to be quite small for the CRD as a whole because the exceedences were localised in the vicinity of a single monitoring location in each case. There were no exceedences of the CRD guidelines for other common air contaminants, and no exceedences of any provincial/federal objectives or standards for any air contaminant over the year. At this time, there is no indication that the Canada Wide Standards (CWS) for ground level ozone and respirable particulate matter ($PM_{2.5}$) will be exceeded at the implementation date (2010).

Table 6.1
Summary of Maximum Pollutant Concentrations (µg/m³) in the CRD for 2007

		Air Quality Criteria		**Monitoring Station**								
Contaminant	Averaging Period	CWS	CRD Guideline	Victoria Topaz	Stellys	Royal Roads	Christopher Point	Langford	Oak Bay	Braefoot	Keating	Saturna Island
CO	8-hour*		5500	2062.5	1000		1325	937.5				
NO_2	1-hour*		200	79.2	54.5	52.4		65.8				
SO_2	24-hour*		125	23.3			8.6	14.5				N/A
O_3	8-hour**		120	109	115	103	120	109.2				**133.8**
PM_{10}	24-hour*		50	38 (Dichot)	23 (Partisol)	41 (HiVol)		23 (HiVol)	32 (HiVol)	**69** (HiVol)	33 (HiVol)	
$PM_{2.5}$	24-hour*		25	21.5 (TEOM)	**25.4** (TEOM)	18 (TEOM)	13.5 (TEOM)	13.1 (TEOM)				
Canada Wide Standards												
Ozone	8-hour**	127.6[1]		95.3	101.3 [3]	98.0 [3]						115.9
$PM_{2.5}$	24-hour*	30[2]		14.3		11.3						

Notes:
* Sequential averaging periods used.
** Rolling average periods used.
[1] Achievement by 2010, based on the annual 4th highest daily measurement, averaged over 3 consecutive years.
[2] Achievement by 2010, based on the 98th percentile ambient measurement annually, averaged over 3 consecutive years.
[3] Compliance determined using data from Stellys and Royal Roads University.
N/A – not yet available

Data collection rates were reasonably good for the year, with some exceptions. The level of missing data was generally higher than in 2006. Approximately 40% of the CO and SO_2 data were missing for the Stellys station and Langford station, respectively. More than 60% of the NO_x data were missing for the Royal Roads station, and almost 40% of the ozone monitoring data were missing from the Langford and Christopher Point stations record because sampling at these two stations did not begin until May. Almost 70% of the $PM_{2.5}$ monitoring data and 50% of the PM_{10} data were missing for the Stellys site due to electrical supply problems at the site. As well, more than 40% of the PM_{10} and $PM_{2.5}$ data from the dichotomous sampler at the Victoria Topaz were not available, and 56% of the PM_{10} data at Langford were missing. There also appear to have been reliability problems with CO data at Christopher Point and TEOM $PM_{2.5}$ data during the first half of the year at both Topaz and Langford. The latter will require more investigation by the MoE to determine the cause of large discrepancies between simultaneous $PM_{2.5}$ samples collected using either dichotomous or Hi-Vol samplers versus TEOMs.

There was one exceedence of the CRD guideline for ground level ozone on May 30th at Saturna Island with a maximum recorded 8-hour average concentration of 133.8 µg/m^3. The exceedence occurred during the spring, when ozone concentrations are typically at the highest levels of the year in the CRD. Although the monitoring data showed simultaneous increases in ozone concentrations at other monitoring sites in the CRD at the start of the episode, elevated levels persisted well into the evening hours at Saturna Island while concentrations at the other CRD monitoring sites declined during the afternoon hours.

The exceedence of the PM_{10} guideline of 50 µg/m^3 occurred at the Braefoot monitoring station on April 12th of the year, with a 24-hour average concentration of 69 µg/m^3. Concentrations recorded at each of the other PM_{10} monitoring stations in the CRD on that date were much lower, indicating that the higher PM_{10} concentration at Braefoot was not experienced throughout a large portion of the CRD.

An exceedence of the CRD guideline for $PM_{2.5}$ occurred at the Stellys monitoring site on February 3rd, with a 24-hour average concentration of 25.4 µg/m^3, slightly over the guideline value by 0.8%. Concentrations recorded at each of the other $PM_{2.5}$ monitoring stations in the CRD on that date were much lower, indicating that the high $PM_{2.5}$ concentration was limited to the Stellys site.

The level of community exposure to the exceedence of the CRD ozone guideline level is uncertain, since the Victoria Topaz, Stellys and Royal Roads stations recorded lower ozone concentrations than that measured at Christopher Point and Saturna Island during the same periods. As such, the related health effects to the ozone exceedences cannot be determined within a suitable degree of confidence.

The PM_{10} and $PM_{2.5}$ exceedences appear to have been representative of localized dust in the air near the Braefoot and Stellys stations. Because of the limited nature of these events, the related health effects to the exceedence cannot be determined within a suitable degree of confidence.

With respect to long-term trends in air quality in the CRD, SO_2 concentrations at the Victoria Topaz site are low and have been declining at a rate of about 12-13% per year over the period 1998-2007 in terms of both the mean and peak (98^{th} percentile) concentrations. A similar decline in SO_2 concentrations at the 98^{th} percentile level has also occurred at Saturna Island, although the decline in the mean annual concentration has been lower at 5% per year. CO concentrations at Victoria Topaz have also been declining at a rate of about 4% per year. On the other hand, the frequency with which O_3 levels exceed the CRD 8-hour average guideline value of 120 $\mu g/m^3$ appear to be increasing at a rate of about 26% per year, although there is no trend towards increasing concentrations at either the mean of the 98^{th} percentile levels. The rate at which the CRD guideline value is exceeded at Saturna Island is low (approximately one 8-hour event per year). At the rate of increase suggested by the trend analysis, the frequency of exceeding the CRD guideline value could rise to two events per year in a few years.

No other statistically significant trends were identified for any of the other pollutants in the monitoring network, although in most cases the period of record is insufficient to determine such trends. There appears to be a suggestion of a very weak downward trend in $PM_{2.5}$ concentrations at both the Victoria Topaz and Royal Roads University monitoring locations, but these are not statistically significant trends to date.

Meteorological data were available from five monitoring stations in the CRD. These stations are co-located with the air quality monitoring stations, with the exception of the Victoria Airport station. Data from the Environment Canada station at Saturna Island could not be obtained in timely fashion. Wind speed and direction data were summarised for each station as wind rose diagrams. In addition, a climate comparison was completed using data from the Environment Canada station at the Victoria Airport.

Appendix A: Meteorological Data

Table A.1 2007 Monthly Climate Data for Victoria International Airport[d,e]

Month	Mean Max Temp	Mean Temp	Mean Min Temp	Extr Max Temp	Extr Min Temp	Total Rain	Total Snow	Total Precip
	Cº	Cº	Cº	Cº	Cº	mm	cm	mm
Jan	6.9	3.4	-0.2	12.4	-9.0	189.1	17.9	203.8
Feb	9.0	5.8	2.6	14.1	-3.7	62.0	0.0	62.0
Mar	10.8	7.3	3.7	14.9	-3.3	124.8	0	124.8
Apr	13.1	8.7	4.3	20.7	-2.1	38.6	0.0	38.6
May	17.3	12.0	6.7	25.1	2.0	19.8	0.0	19.8
Jun	19.0	14.4	9.8	25.8	6.1	36.1	0.0	36.1
Jul	23.3	18.1	12.8	36.3	9.5	31.8	0.0	31.8
Aug	22.1	16.9	11.5	27.4	9.6	36.8	0.0	36.8
Sep	18.3	13.4	8.5	26.3	4.4	36.4	0.0	36.4
Oct								
Nov	9.4	5.8	2.0	15.1	-2.8	90.8	6.0	99.6
Dec	6.9	3.7	0.4	14.9	-3.0	205.2	14.1	219.1
Sum						**908.8**	**32.1**	**940.9**

[d] data missing for the month of October

Table A.2 Climate Normals (1971-2000) for Victoria International Airport[d]

	Mean Max Temp	Mean Temp	Mean Min Temp	Extr Max Temp	Extr Min Temp	Total Rain	Total Snow	Total Precip
	°C	°C	°C	°C	°C	mm	cm	mm
Jan	6.9	3.8	0.7	15.4	-15.6	121.8	15.2	137.0
Feb	8.4	4.9	1.4	18.3	-15.0	98.8	9.0	107.8
Mar	10.5	6.4	2.3	21.4	-10.0	75.8	0.0	75.8
Apr	13.4	8.8	4.1	26.3	-3.9	44.5	0.0	44.5
May	16.6	11.8	6.9	31.5	-1.1	36.5	0.0	36.5
Jun	19.3	14.4	9.3	33.3	2.1	32.0	0.0	32.0
Jul	21.9	16.4	10.8	36.1	4.1	19.5	0.0	19.5
Aug	22.0	16.4	10.8	34.4	4.4	23.9	0.0	23.9
Sep	19.4	14.0	8.4	31.1	-1.1	30.4	0.0	30.4
Oct	14.2	9.8	5.3	27.6	-4.4	75.6	0.2	75.8
Nov	9.5	6.1	2.7	18.3	-13.3	144.4	3.3	147.7
Dec	6.9	4.0	1.0	16.1	-14.4	138.3	13.8	152.1
Sum						**841.5**	**41.5**	**883.0**

[d] Sourced from Environment Canada, http://www.climate.weatheroffice.ec.gc.ca/climateData/

Figure A.1
2007 Wind Rose Diagram for Victoria International Airport

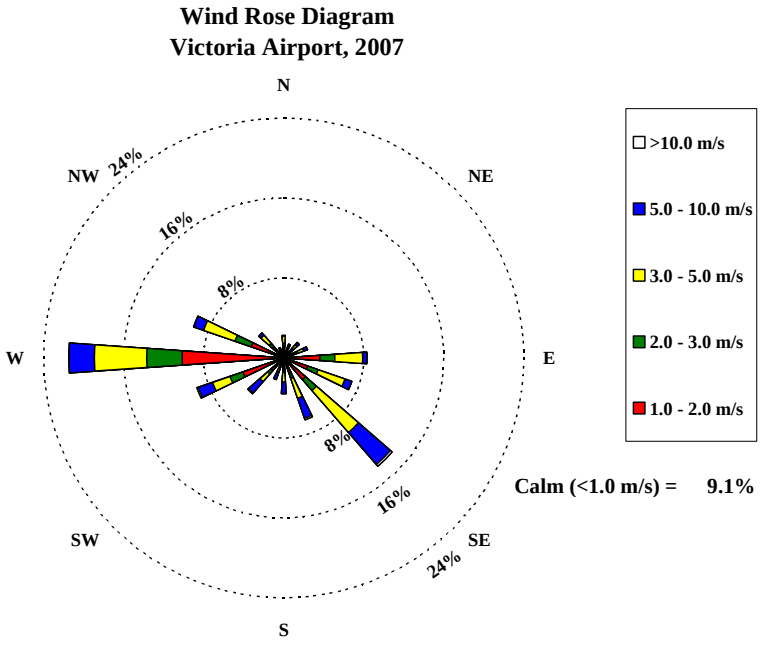


Figure A.2
2007 Wind Rose Diagram for Victoria Topaz

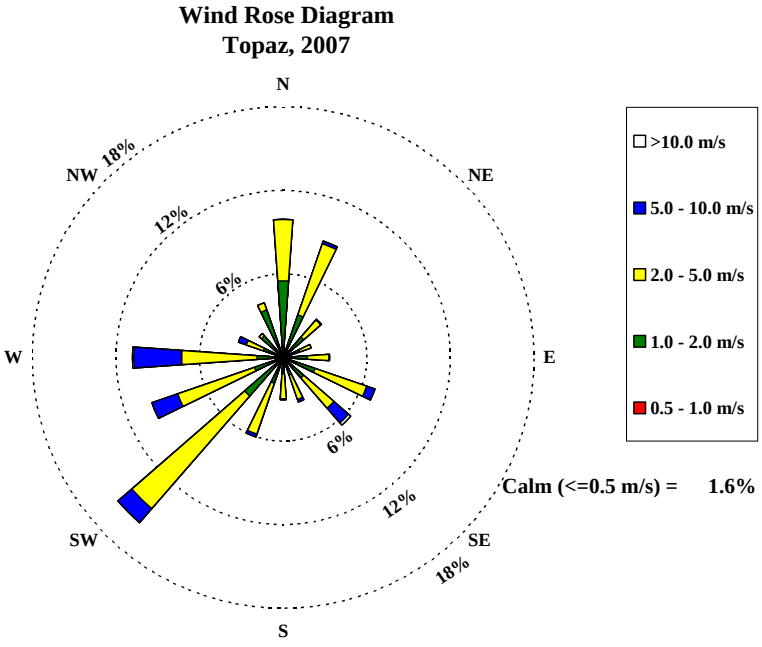


Figure A.3
2007 Wind Rose Diagram for Stellys

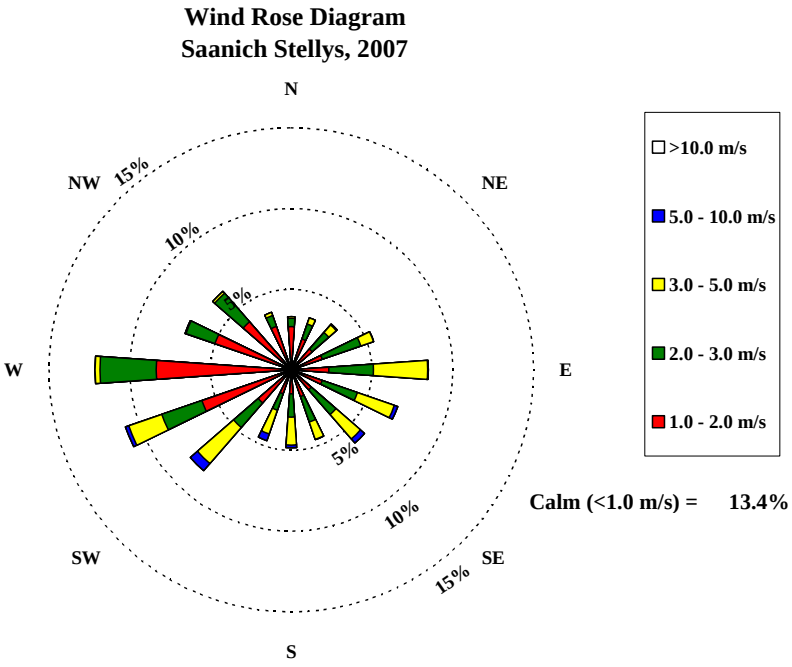


Figure A.4
2007 Wind Rose Diagram for Royal Roads University

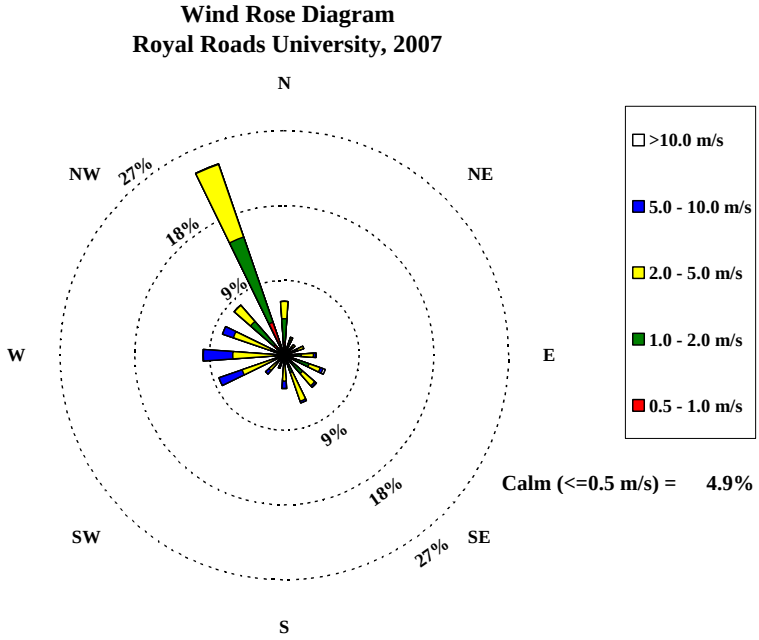
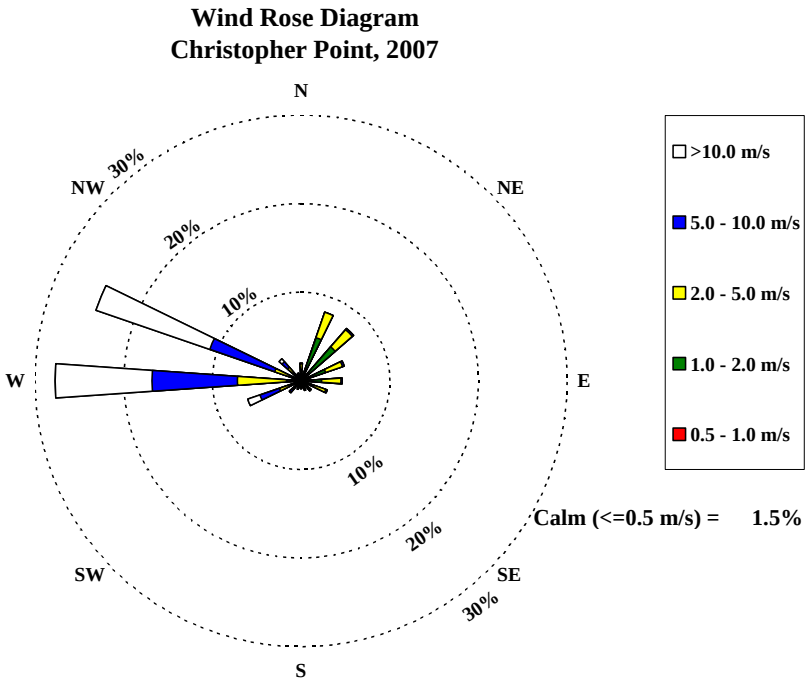


Figure A.5
2007 Wind Rose Diagram for Christopher Point[f]



[f] **Dataset 82.7% complete for the year.**

Appendix B: Federal/Provincial Air Quality Objectives

The Canadian National Ambient Air Quality Objectives (NAAQO) is a three-tiered system. Each level has a specific concentration for an individual air contaminant, with one or more averaging periods used. The three levels are:

- The **Maximum Tolerable Level**, representing a time-averaged concentration, above which immediate action is necessary to protect the health of the general population.

- The **Maximum Acceptable Level**, representing a time-averaged concentration suitable to protect human health, animals, soils, water, vegetation, materials and visibility against the effects of air pollution.

- The **Maximum Desirable Level**, representing a time-averaged concentration that is a long term goal for air quality and also provides a benchmark for preserving air quality in the least polluted parts of the country.

Some of the effects of air contaminants above or below the three Federal objective levels are summarised in Table B.1.

British Columbia also has air quality criteria for ambient air concentrations defined at three levels. However, there are no consistent or official definitions for these objectives. For example, in the case of the Bulkley Valley, the levels have been interpreted in the same manner as the Federal objectives, but use simplified descriptions[13]. These levels are:

- **Level A;** below this level, air quality is 'good'. It represents the maximum desirable concentration.

- **Level B;** below this level (but above Level A), air quality is 'fair'. It represents the maximum acceptable concentration.

- **Level C;** below this level (but above Level B), air quality is 'poor'. Above this level, air quality is 'very poor'. It represents the maximum tolerable concentration.

All federal and provincial air quality criteria are presented in Table B.2. Ambient air quality levels in the CRD in 2006 are compared with federal and provincial objectives in Table B.3.

[13] Johnson, D., *Bulkley Valley Air Quality Management Plan*. February 1999. http://wlapwww.gov.bc.ca/ske/skeair/reports/BVAQMP1999.pdf

Table B.1:
National Ambient Air Quality Objectives
and Their Relationship to Some Health and Environmental Effects
(Source: Environment Canada 1991)[14]

POLLUTANT	GOOD RANGE (0-MAX. DESIRABLE)	FAIR RANGE (MAX. DESIRABLE-MAX. ACCEPTABLE)	POOR RANGE (MAX. ACCEPTABLE - MAX. TOLERABLE)	VERY POOR RANGE* (OVER THE MAX. TOLERABLE)
Sulphur Dioxide (SO_2)	no effects	increasing injury to species of vegetation	odorous; increasing vegetation damage and sensitivity	increasing sensitivity of patients with asthma and bronchitis
Total Suspended Particulate (TSP)	no effects	decreasing visibility	decreased visibility; evident soiling	increasing sensitivity of patients with asthma and bronchitis
Ground-Level Ozone (O_3)	no effects	increasing injury to some species of vegetation	decreasing performance by some athletes exercising heavily	light exercise produces effect in some patients with chronic pulmonary disease
Carbon Monoxide (CO)	no effects	no detectable impairment but blood chemistry changing	increasing cardiovascular symptoms in smokers with heart disease	increasing cardiovascular symptoms in non-smokers with heart disease; some visual impairment
Nitrogen Dioxide (NO_2)	no effects	odorous	odour and atmospheric discoloration; increasing bronchial reactivity in asthmatics	increasing sensitivity of patients with asthma and bronchitis

***The upper limit of the very poor range is not defined. At extremely high levels of any of these pollutants, symptoms would be worse than those listed.**

[14] Environment Canada 1991. *The State of Canada's Environment.* Government of Canada, Ministry of Supply and Services, Ottawa.

Table B.2 Federal and Provincial Air Quality Objectives

For Contaminants Monitored in the CRD

Contaminant	Averaging Period	Canada Maximum Desirable	Canada Maximum Acceptable	BC Level A	BC Level B	BC Level C
Carbon Monoxide	1-hour	15000	35000	14300	28000	35000
	8-hour	6000	15000	5500	11000	14300
Nitrogen Dioxide	1-hour		400			
	24-hour		200			
	Annual Arithmetic Mean	60	100			
Sulphur Dioxide	1-hour	450	900	450	900	900 -1300
	24-hour	150	300	160	260	360
	Annual Arithmetic Mean	30	60	25	50	80
Ozone	1-hour	100	160			
	24-hour	30	50			
	Annual Arithmetic Mean		30			
Ambient Air Quality Objectives Established in 1995						
PM_{10}	24- hour			50		

Notes:
[1] All units in $\mu g/m^3$

Table B.3
Comparison of Maximum Observed Pollutant Concentrations (µg/m^3) in the CRD for 2007 with Provincial and Federal Objectives

Contaminant	Averaging Period*	B.C. or Federal Maximum Acceptable Level	Victoria Topaz	Royal Roads	Stellys	Christopher Point	Langford	Oak Bay	Braefoot	Keating	Saturna Island
Carbon Monoxide	1-hour	28000	3400		1500	1500	2100				
	8-hour	11000	2062.5		1000	1325	938				
Nitrogen Dioxide	1-hour	400	79.2	52.4	54.5		65.8				
	24-hour	200	43.5	23.3	35.6		26.6				
	Annual	100	21.6	11.5	12.2		12.3				
Sulphur Dioxide	1-hour	900	88			42	89				
	24-hour	300	23.3			8.6	14.5				N/A
	Annual	60	1.8			2.3	3.3				
Ozone	1-hour	160	117.7	111.7	129.7	135.7	127.7				140
	24-hour	50	89.5	85.6	86.9	105.4	82.1				101.8
	Annual	50	33.5	40	40.1	54.5	36.6				56.6
PM_{10}	24-hour	50	38 (Dichot)	41 (Hi-Vol)	23 (Partisol)		23 (Hi-Vol)	32 (HiVol)	69 (Hi-Vol)	33 (HiVol)	