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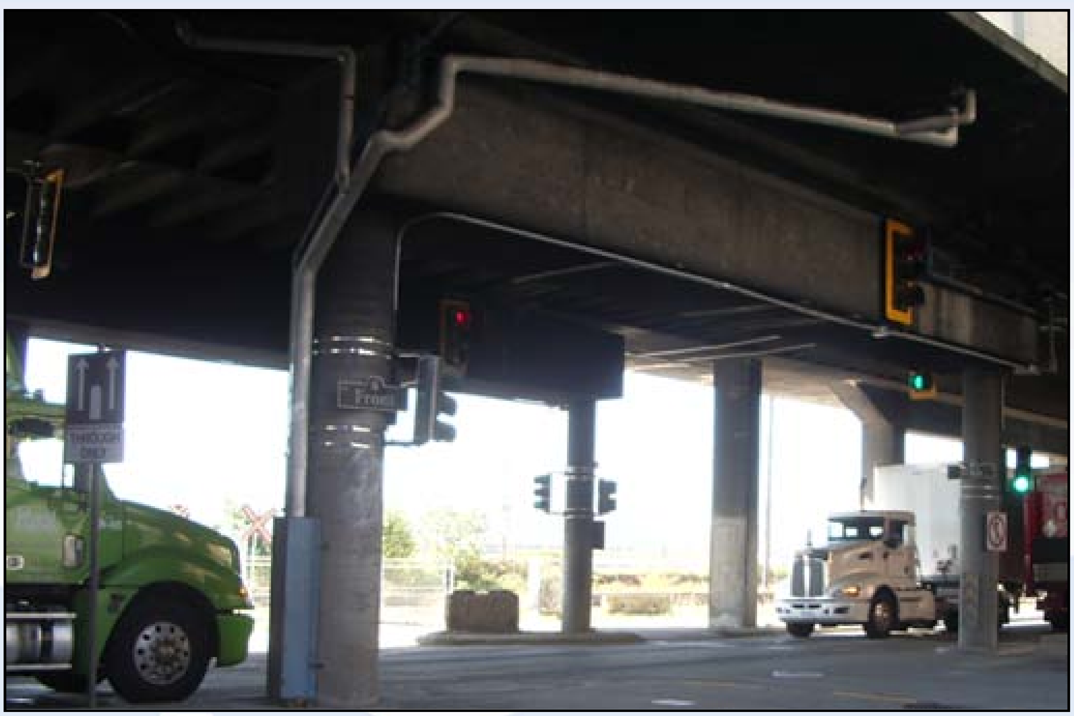
2009-10 New Westminster Air Quality Monitoring Study

November 2011



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SUMMARY FOR POLICYMAKERS

Study Background

To fulfill a City of New Westminster request, in 2008 Metro Vancouver began planning a two-year local air quality monitoring study in the municipality. The 2009-10 New Westminster Air Quality Monitoring Study builds upon the findings of a previous study conducted on Front Street in New Westminster in 2004. The 2004 study indicated that motor vehicle emissions were a major contributing source of elevated air contaminant concentrations in an area of Front Street near the multi-story above-ground parkade. The 2009-10 study was carried out to get a better understanding of the magnitude, extent and impacts of traffic-related sources of emissions in the Front Street area of New Westminster and to assess air quality conditions more widely throughout New Westminster. A notable enhancement in the present study was the addition of air quality monitoring in a community location to provide baseline conditions more typical of those experienced throughout New Westminster.

Five key objectives were defined for the 2009-10 New Westminster Air Quality Monitoring Study:

1. To follow up and expand on the findings of the 2004 New Westminster Air Quality Monitoring Study to gain a better understanding of the magnitude and spatial extent of air pollutant concentrations in the vicinity of Front Street.
2. To gather baseline air quality data in advance of local development and transportation projects near Front Street in New Westminster.
3. To gain a better understanding of the impact of heavy duty motor vehicle emissions and other traffic-related emissions on the local air quality.
4. To compare the air quality conditions measured in the vicinity of Front Street and elsewhere in New Westminster with measurements from other communities in the Lower Fraser Valley.

5. To explore the possibility and need for conducting air quality modelling to help identify and understand any neighbourhood-scale variability of pollutants.

The 2009-10 monitoring study was carried out in New Westminster by Metro Vancouver in partnership with the City of New Westminster between January 2009 and December 2010. The analysis of the results and recommendations arising from the study, which are summarized in this 'Summary for Policymakers', are described in detail in the technical report.

Four sites were selected as air quality monitoring sites in New Westminster: next to the multi-story above-ground parkade on Front Street; in Sapperton Park; at City Hall close to Royal Avenue; and behind the UFCW Local 1518 building on Front Street. Monitoring at the sites was conducted using a variety of instruments as well as the Mobile Air Monitoring Unit (MAMU). Contaminants monitored included nitrogen dioxide (NO_2), nitric oxide (NO), carbon monoxide (CO), fine particulate matter ($PM_{2.5}$), sulphur dioxide (SO_2), ozone (O_3) and black carbon particulate (BC). The periods in which monitoring was carried out at each site and the contaminants monitored are shown in Table S-1.

Table S-1. Summary of dates of operation of study monitoring sites.

Monitoring Location	Dates of Operation	Contaminants Monitored
Parkade site	April 7, 2009 – December 8, 2010	NO_2, NO, $PM_{2.5}$, BC
Sapperton site	January 12, 2009 – December 8, 2010	NO_2, NO, $PM_{2.5}$, CO, O_3
City Hall (MAMU) site	November 12, 2009 – December 9, 2009	NO_2, NO, $PM_{2.5}$, BC, CO, O_3, SO_2
	July 13, 2010 – August 17, 2010	
UFCW (MAMU) site	November 19, 2010 – December 7, 2010	NO_2, NO, $PM_{2.5}$, BC, CO, O_3, SO_2

Measurements made in New Westminster during the 2009-10 New Westminster Air Quality Monitoring Study were also compared to other air quality monitoring network stations within Metro Vancouver. Metro Vancouver operates a network of 26 air quality monitoring stations within Metro Vancouver and the Fraser Valley Regional District.

The air quality monitoring network stations that are nearest to New Westminster are in south Burnaby (Burnaby South Secondary School) and north Delta (116 St. and 86 Ave.). No location in New Westminster is located more than 9 kilometres from one or both of these stations. The station in Burnaby is also one of five regional “supersites”, continuously measuring concentrations of a wide range of air contaminants including nitrogen oxides, ground-level ozone, carbon monoxide, sulphur dioxide, fine particulate matter and inhalable particulate matter as well as the constituents of the particulate matter (referred to as “speciation” – to determine individual species within fine particulate), black carbon particulate and UV absorbing component measurements, volatile organic compounds, and meteorological data.

Air Quality on Front Street

Ambient air quality objectives are intended to define the upper limit of acceptable air contaminant concentrations, and they take into consideration the health impacts associated with a specific air contaminant. As a result air quality objectives provide important benchmarks against which air quality is measured – exceeding an air quality objective can indicate when air pollution is occurring, or when the public is being exposed to air contaminant concentrations that can contribute to adverse health effects.

Measured air contaminant concentrations at the Parkade site were much higher on occasion than Metro Vancouver’s short-term ambient air quality objectives for both fine particulate ($PM_{2.5}$) and nitrogen dioxide (NO_2). Short-term air quality objectives were exceeded for a total of 464 hours and 74 hours for $PM_{2.5}$ and nitrogen dioxide respectively during the study. In addition the study period averages were considerably higher than the annual objectives for both these pollutants. The maximum and average concentrations of these air contaminants measured at this site are shown in Table S-2. Black carbon particulate, which is useful as an indicator of diesel emissions, was also measured at the Parkade site, but air quality objectives have not been established for this contaminant.

Table S-2. Summary of air quality monitoring data from the Parkade site on Front Street.

	$PM_{2.5}$ (µg/m^3)		NO_2 (ppb)	
		Objective		*Objective*
Study period average	12	*8* [a]	38	*22* [a]
Study period maximum [b]	50	*25*	226	*107*

[a] Average objective concentrations shown are values for the annual average
[b] $PM_{2.5}$ concentrations are based on a rolling 24 hour average. NO_2 concentrations are based on an hourly average.

The results of the 2009-10 New Westminster Air Quality Monitoring Study indicated that air contaminant concentrations measured around the parkade area were elevated compared to concentrations measured in other parts of New Westminster as well as those typically measured at air quality monitoring network stations elsewhere in Metro Vancouver (Figure S-1).

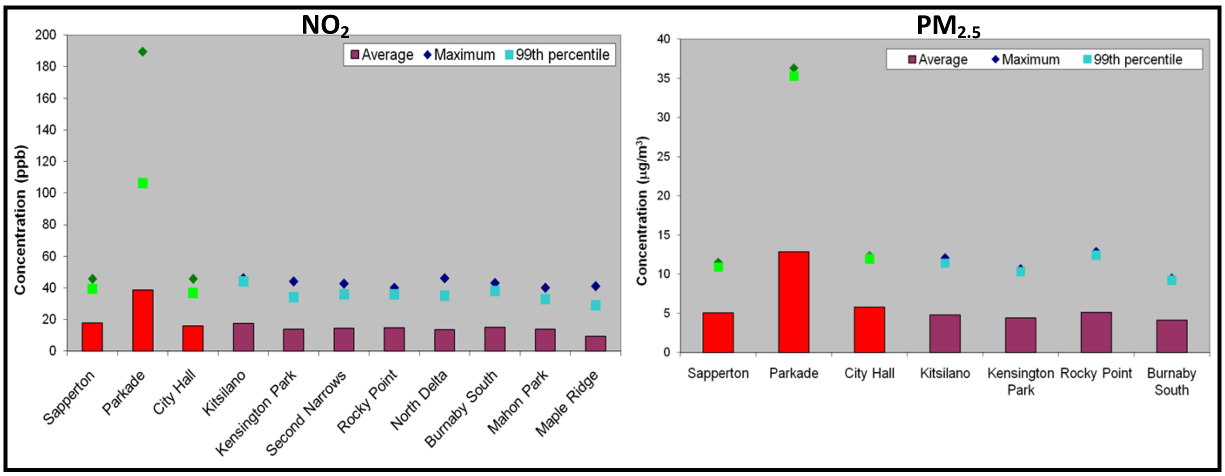


Figure S-1. Average, maximum and 99th percentile concentrations of hourly NO2 and 24 hour rolling average $PM_{2.5}$ measured at the Parkade site between November 12, 2009 and July 31, 2010 (during City Hall periods of operation only) compared with other stations in Metro Vancouver.

There was a large difference in average air contaminant concentrations between weekdays and weekends; the highest concentrations occurred during the day on weekdays (Figure S-2). The weekday air contaminant concentrations showed a similar shaped profile to traffic volume data from traffic surveys carried out on Front Street. However, the difference between the traffic volume profile and air contaminant concentration profiles on weekends suggested that air quality in the area around the parkade on Front Street is most strongly influenced by commercial traffic such as diesel trucks.

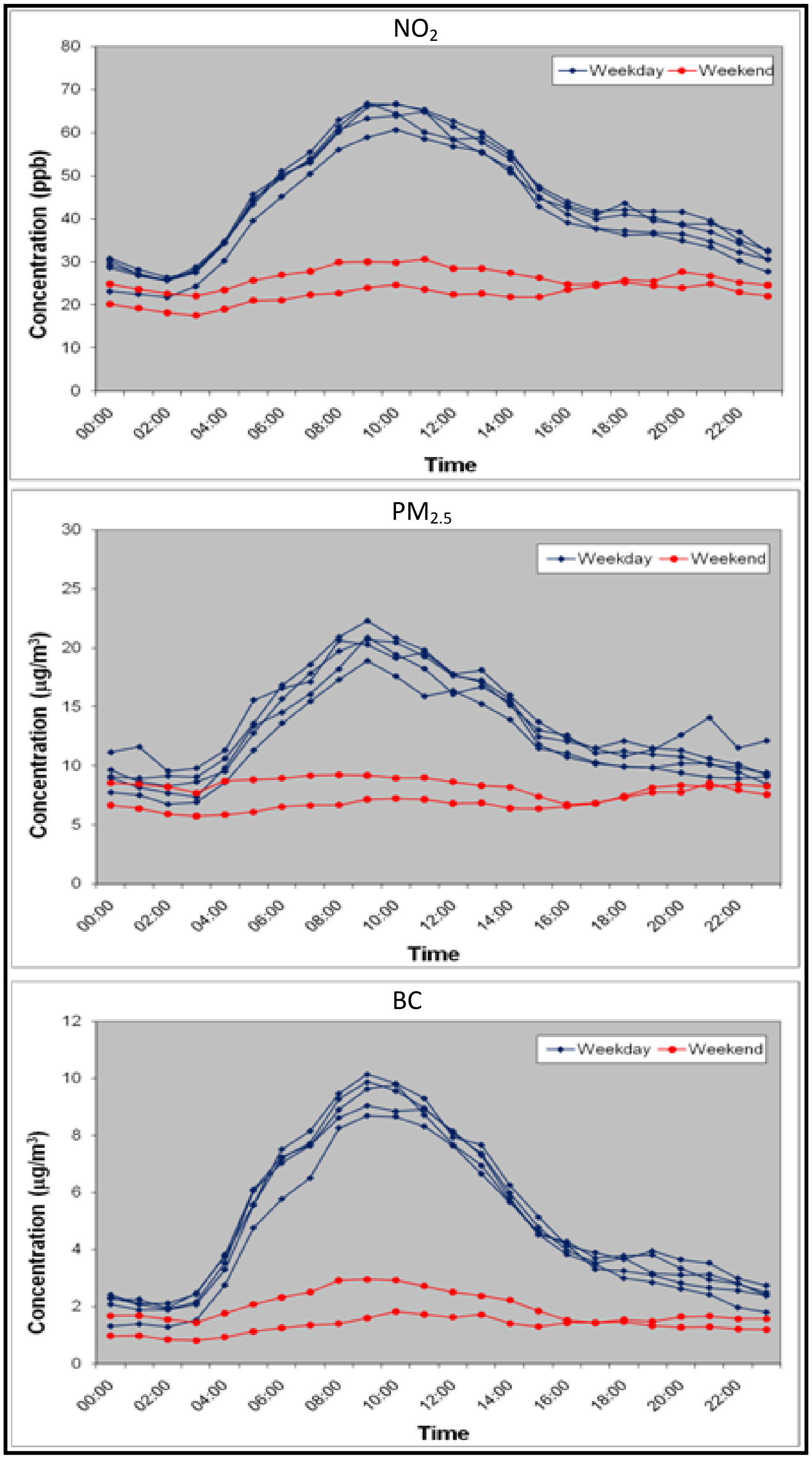


Figure S-2. Daily patterns of air contaminant concentrations from the Parkade site. Concentrations shown are the averages for the study period.

The reduction of diesel particulate matter emissions is a priority within Metro Vancouver's air quality management program, as studies have shown that diesel PM is the most important pollutant in the airshed from a human health perspective, accounting for an estimated 67% of the lifetime cancer risk from exposure to air pollution. In February 2011, Metro Vancouver's Board adopted a Non-Road Diesel Engine Emission Regulation Bylaw that promotes the reduction of these harmful emissions from industrial and construction machines such as excavators, forklifts, cranes, and generators. The initiative to reduce emissions from diesel-powered trucks, bulldozers and other off-road vehicles will help protect human health and reduce emissions of a pollutant that also contributes to climate change.

From measurements made at the UFCW site, it is unlikely that the elevated concentrations measured near the parkade impair air quality in the surrounding area to a large degree. Within a very short distance (approximately 20 metres), concentrations decreased considerably (Figure S-3).

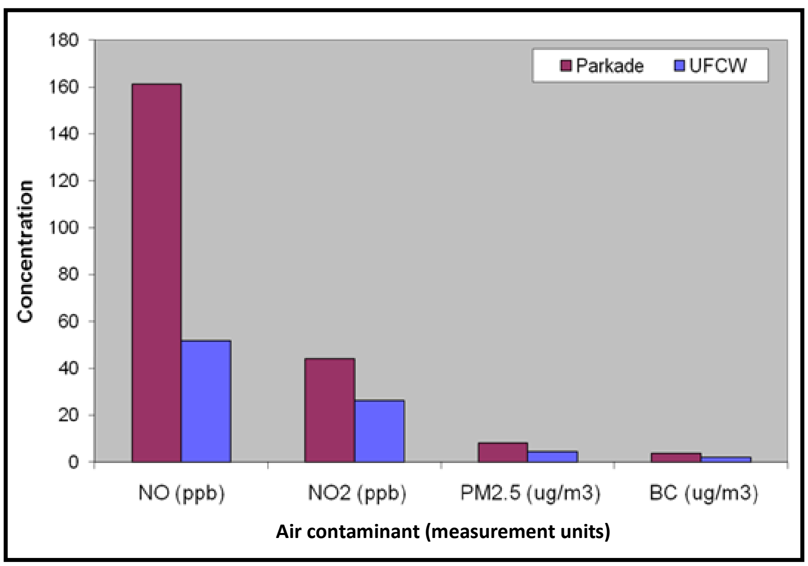


Figure S-3. Average air contaminant concentrations measured during simultaneous monitoring at the Parkade site and the UFCW site.

The results from this study have resulted in a clearer understanding of the seasonal and spatial characteristics of air contaminant concentrations on Front Street compared to the 2004 study. Air quality objectives were exceeded on numerous occasions in all seasons indicating that there are periods of unacceptable air quality in this area at any time of year. The highest concentrations of air contaminants occurred during the day on weekdays, most likely due to a combination of traffic congestion on Front Street and the parkade structure allowing some build-up of air contaminants by restricting dispersion of the local emissions. In particular, diesel vehicles were found to have a significant impact on air quality in this location. Away from the parkade and the road, air contaminant concentrations decreased significantly and therefore degraded air quality in this location is considered to be a localized issue.

Air Quality in Sapperton and near City Hall

Comparison of air contaminant concentrations at the Sapperton site with Metro Vancouver's short-term ambient air quality objectives indicated that air quality in the Sapperton area was generally better than air quality objectives. Air quality objectives were exceeded only during times when air quality was degraded throughout the entire region due to wildfire smoke from the interior of British Columbia, which caused elevated concentrations of $PM_{2.5}$. The maximum and average concentrations of these air contaminants measured at this site are shown in Table S-3.

Table S-3. Summary of air quality data from the Sapperton site.

	$PM_{2.5}$ ($\mu g/m^3$)	**NO_2** (ppb)	**CO** [c] (ppm)	**O_3** [d] (ppb)
Study period average	5	18	0.35	11
Study period maximum [b]	31	59	2.89	56
Objectives				
Average	*8*	*22*	*-na-*	*30*
Maximum [b]	*25*	*107*	*26.5*	*82*

-na- No applicable objective available
[b] $PM_{2.5}$ concentrations are based on a rolling 24 hour average. NO_2, CO and O_3 concentrations are based on an hourly average.
[c] CO data was collected between January 12, 2009 and June 28, 2010.
[d] O_3 data was collected only between June 28, 2010 and December 8, 2010.

Examination of the daily patterns of nitrogen dioxide and $PM_{2.5}$ concentrations at the Sapperton site indicated that there was a small difference in average air contaminant concentrations on weekdays and weekends with the highest concentrations generally occurring on weekdays. In contrast to the profiles observed at the Parkade site which had a single daytime maximum (Figure S-2), there were two maxima on weekdays for both air contaminants. In addition, the daily Sapperton air contaminant patterns were not fully consistent with traffic volume profiles from East Columbia Street. Weekday peak concentrations occurred between 7 am and 9 am, coinciding with morning commuter traffic, but the second peak occurred late in the evening at around 10 pm, which may be caused by meteorological conditions. However, analysis of nitric oxide (an air contaminant associated with local sources of fuel combustion) data suggested that traffic emissions played a significant role in air quality conditions in the area.

Compared to other stations in the air quality monitoring network, in general the measurements from New Westminster for air contaminants associated with combustion sources (nitrogen oxides and carbon monoxide) were slightly higher than generally seen in the region (Figure S-4). Ozone and $PM_{2.5}$ concentrations were generally the same or lower.

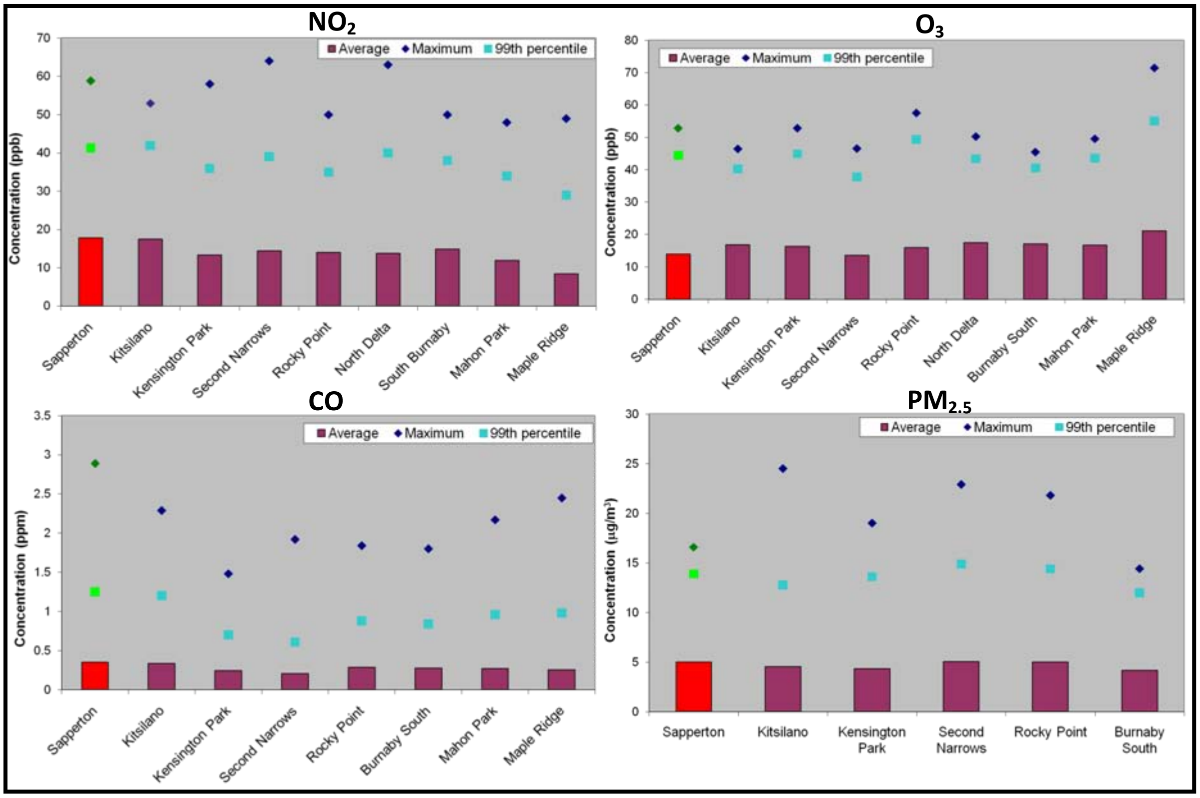


Figure S-4. Average, maximum and 99th percentile concentrations of hourly NO_2, O_3 and CO, and 24 hour rolling average $PM_{2.5}$ measured at the Sapperton site between January 2009 and July 31, 2010 compared with other stations in Metro Vancouver.

Statistical analysis indicated that although air quality in New Westminster is usually better than air quality objectives, concentrations measured at nearby stations are not always representative of air contaminant concentrations in New Westminster on an hourly basis. This suggested that one or more local emissions sources may affect the daily air quality pattern in the Sapperton area which is not entirely reflected by the two nearest air quality monitoring stations. However, these local emissions sources did not cause air quality objectives to be exceeded, and their impact was considered to be similar to those seen in similar areas within the Metro Vancouver region.

Analysis of the results from Sapperton and City Hall indicated that there were small differences in air quality between the two sites (Table S-4). Detailed statistical analysis was carried out to compare the data collected from these two sites hour by hour. This analysis indicated that the measurements from both sites were in good general agreement with each other and in particular there was better agreement between the City Hall and Sapperton sites than with stations in other parts of Metro Vancouver.

Table S-4. Summary of air quality monitoring data from the Sapperton and the City Hall sites. Maximum and average concentrations for Sapperton are for the period shown during which measurements from City Hall were available.

	$PM_{2.5}$ ($\mu g/m^3$)	**NO_2** (ppb)	**CO** (ppm)	**O_3** (ppb)	**Black carbon** ($\mu g/m^3$)	**SO_2** (ppb)
November – December 2009						
Sapperton average	4	19	0.36	-na-	-na-	-na-
City Hall average	4	18	0.30	10	1	0.4
Sapperton maximum [a]	12	46	1.67	-na-	-na-	-na-
City Hall maximum [a]	12	46	1.28	35	3	4
July – August 2010						
Sapperton average	8	16	-na-	13	-na-	-na-
City Hall average	9	14	0.20	14	1	1
Sapperton maximum [a]	31	46	-na-	56	-na-	-na-
City Hall maximum [a]	30	44	0.55	53	3	11

-na- Not measured

[a] $PM_{2.5}$ and black carbon concentrations are based on a rolling 24 hour average. NO_2, CO, O_3 and SO_2 concentrations are based on an hourly average.

Local sources affect air quality in Sapperton and may also impact air quality in the area around City Hall. Local sources of air contaminants in Sapperton are likely to include traffic as well as sources commonly found throughout the area such as residential heating. Other possible sources in the area include nearby commercial and industrial facilities. Near City Hall, local sources of air contaminant emissions include traffic and heating of residential and commercial buildings.

Based on the results from Sapperton and City Hall, it is likely that air quality in much of New Westminster, beyond the immediate vicinity of the parkade on Front Street, is acceptable most of the time. Within New Westminster, the air quality to which the population is exposed most of the time may be better represented by monitoring air contaminants at a single site in the area than at present by the nearby air quality monitoring stations in Burnaby and Delta. However, air contaminant concentrations are not currently at a level to cause more concern than air quality in other parts of the region. In particular, ozone and $PM_{2.5}$, the air contaminants that are of most concern with respect to health impacts, are similar or lower than concentrations measured in other parts of the region.

Conclusions and Recommendations

During the approximate two-year period of air quality monitoring undertaken in Sapperton as part of this study, air quality was found to be very similar to the air quality measured during two shorter periods at the New Westminster City Hall. Based on the comparison of these two sites and an understanding of the factors affecting air quality in New Westminster, it is thought that the Sapperton monitoring results are broadly indicative of the air quality experienced throughout many parts of New Westminster most of the time. All concentrations measured throughout the study at Sapperton (and City Hall) were below Metro Vancouver's health-based air quality objectives, with the exception of two summertime periods when air quality was degraded throughout the entire region due to wildfire smoke from the interior of British Columbia. Compared to other nearby stations in the air quality monitoring network:

- Sapperton data showed slightly higher concentrations of nitrogen dioxide (NO_2) and carbon monoxide (CO), two air contaminants most closely associated with emissions from vehicles.
- Sapperton data showed similar or lower concentrations of particulate matter ($PM_{2.5}$) and ozone (O_3).

The comparison to other nearby stations in the air quality monitoring network also suggested that New Westminster may not be well-represented by the two closest stations (South Burnaby and North Delta). While the air quality levels appear to be quite similar in terms of long-term averages and short-term peak concentrations, there are likely local influences in the Sapperton area (and possibly throughout New Westminster) that causes the daily air quality patterns to differ from nearby stations. Findings of this study indicate that commuter and commercial traffic probably has a significant influence on New Westminster's air quality.

Measured air contaminant concentrations near the parkade on Front Street are elevated on occasion. As an outcome of the 2009-10 New Westminster Air Quality Monitoring Study, the following recommendations should be considered:

1. Actions should be taken to reduce exposure of people to the air quality conditions present under the parkade on Front Street.
    a. Use of land use planning guidelines and best practices for development around the Front Street parkade may mitigate the effects of local emissions and help minimize exposure to air pollution in the area.
    b. Involvement in the cross-agency partnership developing urban design guidelines may be a useful means to explore further options for reducing exposure to traffic.
    c. Options to improve dispersion of air contaminants around the parkade may be evaluated. It is likely that this would involve major changes to the structure and therefore a modelling study may be a useful way of determining the effectiveness of different alternatives under this course of action.
2. Based on the study results and in recognition of New Westminster's high population density and the expectation for continued community growth, especially around Sapperton and the waterfront, Metro Vancouver should consider options for ongoing monitoring in New Westminster. This may be achieved through one or more initiatives, including:
    a. Periodic deployment of air quality monitoring equipment in New Westminster to compare conditions to the baseline established by this study. Metro Vancouver is increasing capacity for undertaking localized studies with portable or mobile monitoring equipment. These studies can allow for greater spatial coverage and more flexibility than a single fixed station.
    b. Establishing a fixed station as part of the longer-term planning for the coverage offered by the Lower Fraser Valley air quality monitoring network.

c. Being part of a federal government pilot program (under Environment Canada's National Air Pollution Surveillance Program) to develop a strategy for air quality monitoring near roadways and to better understand the population's exposure to emissions from traffic. As Metro Vancouver has just initiated discussions with the federal government on this program, the details are not yet clear.

New Westminster Air Quality Monitoring Study (2009 – 2010)

1 Introduction

Metro Vancouver operates an extensive network of air quality monitoring stations across the Lower Fraser Valley from Horseshoe Bay to Hope. This network is designed to provide sufficient information to assess the condition of the ambient air to which most of the population is exposed most of the time. To supplement data from the fixed monitoring station network, specialized air quality monitoring studies are carried out to investigate local air quality conditions, address needs arising from specific incidents, and verify that locations in the region are still adequately represented by existing monitoring.

In 2009 the City of New Westminster requested that Metro Vancouver carry out an air quality monitoring study to characterize current air quality in the municipality. Although studies have been carried out in Queensborough and on Front street within the last ten years, improvements in instrumentation offer opportunities to develop more detailed knowledge about air contaminants and their sources. For the 2009-10 New Westminster study there was a desire to augment the findings of the study carried out by Metro Vancouver in 2004 in the Front Street area as well as to assess the adequacy of existing air quality monitoring coverage for New Westminster.

The air quality monitoring study described in this report was carried out in New Westminster by Metro Vancouver in partnership with the City of New Westminster between January 2009 and December 2010. This 2009-10 study offered an opportunity to revisit Front Street to get a more detailed understanding of the magnitude, extent and impacts of traffic-related sources of emissions in that area as well as to investigate the air quality conditions experienced by residents and visitors in other parts of New Westminster. The details of the monitoring, analysis of the results and recommendations arising from the analysis are described in the following sections.

2 Study Rationale

Air quality monitoring equipment is used to determine whether air quality is acceptable as compared against criteria defined by established ambient air quality objectives. If air quality does not meet these criteria, it can be considered degraded.

The causes of degraded air quality can be investigated using air quality monitoring data in tandem with expertise about air contaminant sources. Knowledge of possible sources from which air contaminants can be emitted as well as dispersion and dilution of the emitted air contaminants is used to assess air quality. Air contaminant transformation is also considered; direct emissions may tell only part of the story as atmospheric chemical reactions involving the emitted air contaminants can introduce new species, known as secondary contaminants, into the air.

2.1 Study background

In 2004 an air quality monitoring study was carried out at the intersection of Front Street and 6th Street in New Westminster. The results of this 2004 study indicated that motor vehicle emissions were a major contributing source of air contaminants in the area. The conclusions of the 2004 study suggested not only that air quality on Front Street was adversely affected by these traffic emissions, but also that the presence of a parking garage inhibited dispersion of emitted pollutants thus exacerbating the issue. Due to projections of increased traffic on Front Street, updated monitoring data was sought by the City of New Westminster to enhance their understanding of the factors affecting air quality in this area and provide a baseline for future reference.

New Westminster is a relatively densely populated municipality on the north bank of the Fraser River. The area is bounded by Highway 1 and Coquitlam to the north, the Fraser River to the south and east and Burnaby to the west. Land use within the municipality is mixed and includes high density and medium density residential, industrial, and commercial areas. In addition, several all day and limited hours designated truck routes run through New Westminster. The roads designated as truck routes include Royal Avenue, Columbia Street, Brunette Avenue, Braid Street and Front Street.

Some areas of New Westminster, including some residential areas, are expected to undergo significant changes in the near future including increased population densification through the development of high-rise residential units and increased traffic movement influenced by transportation plans in the region. In order to assess the potential for adverse air quality impacts to residents, air quality data collected in 2009-10 was intended to establish the baseline for air quality conditions to support effective land use and densification planning and against which future measurements may be compared.

2.2 Study Objectives

The primary purpose of this study was to characterize existing air quality conditions in areas of New Westminster expected to undergo significant development. Study objectives were developed by Metro Vancouver staff in discussion with staff from the City of New Westminster. The objectives defined in the scope of work for the project were:

1. Follow up and expand on the findings of the 2004 study to gain a better understanding of the magnitude and spatial extent of air pollutant concentrations in the vicinity of Front Street.
2. Gather baseline air quality data in advance of local development and transportation projects near Front Street in New Westminster.
3. Gain a better understanding of the impact of heavy duty motor vehicle emissions and other traffic-related emissions on the local air quality.
4. Compare the air quality conditions measured in the vicinity of Front Street and elsewhere in New Westminster with measurements from other communities in the Lower Fraser Valley.
5. Explore the possibility and need for conducting air quality modelling to help identify and understand any neighbourhood-scale variability of pollutants.

3 Assessing Air Quality

Air quality describes the state of the air, i.e. how much the air is contaminated by species known to cause air pollution. Air contaminants make up a very small proportion of ambient air compared to the concentrations of the major components of air such as nitrogen and oxygen. However, even at low concentrations air contaminants can have a significant effect on health and the environment. The air contaminant concentrations present at any given time depend on the amounts of various substances emitted into the air from local and long-range sources, reactions the contaminants undergo in the environment, weather conditions and the nature of the area (e.g. surface influences such as land use and topography). Air quality is assessed using specialist tools and an understanding of these factors. Assessing the state of the air forms an important part of air quality management.

The analysis of the effect of emissions on ambient air quality involves considering either the emission sources, the contaminant type, or both. For example, fossil fuel combustion is the underlying process behind emissions from many different types of sources ranging from mobile sources (such as vehicles), to point sources (such as industrial facilities), to area sources (such as home heating), and gives rise to the emission of several air contaminants including carbon monoxide, nitrogen oxides and particulate matter as well as greenhouse gases.

When describing the air quality in an area in which there is a single source or source type, a modelled evaluation of the emissions source can be an effective way of determining the types and concentrations of air contaminants that may be present in the area. However, when an investigation is focussed on concerns about specific air contaminants in an area in which a wide variety of different sources may be present it is helpful to use monitoring to determine ambient air quality then assess possible sources for each contaminant.

3.1 Monitoring air quality

Direct measurement of contaminants in the ambient (outdoor) air is one of the tools that is applied to air quality evaluation. In Metro Vancouver, measurements are made continuously at air monitoring stations forming part of the Lower Fraser Valley ambient air quality monitoring network (Figure 1, note network stations in the FVRD not shown). Stations are located at sites that are considered to be representative of the typical conditions experienced in different parts of the region. To supplement the information available from the network, monitoring is also carried out at other locations (e.g. special air quality monitoring sites) for fixed periods of time to assess local air quality conditions and identify any specific air quality issues or concerns.

Air quality monitoring data from the existing Lower Fraser Valley air quality monitoring network provide residents of and visitors to New Westminster with access to ambient air quality information. New Westminster's nearest monitoring network stations are located in Burnaby (Burnaby South) and Delta (North Delta). At least one of these stations is within 9 km of any location in New Westminster.

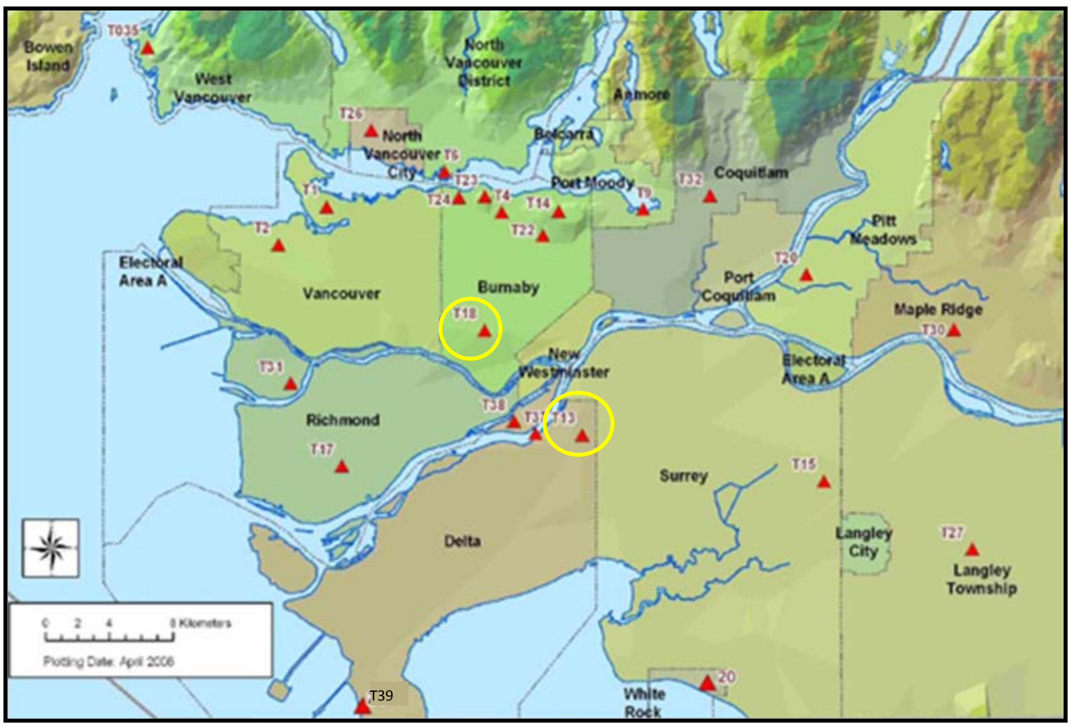


Figure 1. Air quality monitoring network stations in Metro Vancouver. New Westminster's nearest monitoring stations (indicated in the yellow circles) are located in Burnaby (T18: Burnaby South) and Delta (T13: North Delta). T37 and T38 provide meteorological data only.

The Burnaby South station is a "super site" in the Lower Fraser Valley air quality monitoring network. At these super sites the most comprehensive suite of air quality measurements is made. Air quality data collected at the Burnaby South station include concentrations of nitrogen oxides, ground-level ozone, carbon monoxide, sulphur dioxide, fine particulate matter and inhalable particulate matter as well as the constituents of the particulate matter from speciation, black carbon and UV absorbing component measurements, volatile organic compounds, and meteorological data. At the North Delta station nitrogen oxides, ground-level ozone, and fine particulate matter data are collected as well as meteorological data.

3.2 Common air contaminants

Understanding the composition of the air we breathe and which materials are air contaminants that cause air quality degradation are critical to air quality assessment. Commonly occurring air contaminants include nitrogen oxides (NO_x), particulate matter (PM), ground-level ozone (O_3), sulphur dioxide (SO_2), carbon monoxide (CO) volatile organic compounds (VOC) and ammonia. Fine particulate matter ($PM_{2.5}$) and ground-level ozone have been identified by health experts as being associated with serious health effects and are considered priorities for air quality policy makers and public health experts.

3.2.1 Nitrogen oxides (NO_x)

NO_x is the term used to refer to a combination of nitrogen dioxide (NO_2) and nitric oxide (NO). These contaminants are important because of their association with health impacts and with the formation of secondary pollutants. NO_x are involved in the reactions from which ground-level ozone is formed. They can also react in the air with ammonia to produce airborne fine particulate matter.

The 2005 emissions inventory for the region (section 3.4) indicates that in Metro Vancouver vehicles (35%), non-road engines (17%) and heating (over 10%) are significant sources of NO_x. In general NO is associated with the presence of a nearby combustion source whereas NO_2 is formed fairly quickly in the atmosphere by the oxidation of NO and is indicative of the regional picture.

High concentrations of NO_2 can be seen as a brownish haze and therefore also affect visual air quality in the region.

3.2.2 Particulate matter (PM)

PM comprises microscopic liquid droplets and solid particles that remain suspended in the air. It can be categorized by size:

- Fine particulate matter ($PM_{2.5}$) consists of particles less than 2.5 micrometres (millionths of a metre) in diameter;
- Inhalable particulate matter (PM_{10}) consists of particles less than 10 micrometres in diameter.

Fine particulate matter is a significant cause of degraded visual air quality in the Lower Fraser Valley, often seen as a white haze in the summer.

$PM_{2.5}$ emissions in Metro Vancouver predominantly come from heating (20%), burning (15%) and non-road engines (approximately 12%).[2] This proportion does not include the $PM_{2.5}$ arising from road dust and secondary particulate matter which is not directly emitted into the air. Neither are included in Metro Vancouver's emissions inventory.

3.2.3 Black carbon and UV absorbing particulate matter

Particulate matter may contain black carbon (BC), or soot, particles and particulate matter that absorbs ultraviolet light (UVPM). These particles come from different processes and can help identify the sources of airborne particulate matter. BC is associated with emissions from incomplete combustion processes such as diesel engine emissions. UVPM indicates the presence of particulate matter that contains organic chemicals.

The size of BC particles generally falls within the $PM_{2.5}$ fraction of particulate matter.

3.2.4 Ground-level ozone

Ozone is a highly oxidizing form of oxygen containing three oxygen atoms. Although found naturally in the upper parts of the atmosphere, the ozone in the lower part of the atmosphere, referred to as ground-level ozone, is mostly formed from reactions of NO_x and VOC in the presence of sunlight. It is a secondary contaminant, meaning that it is not directly emitted into the air. As warm, sunny conditions are favourable for the formation of ground-level ozone the highest concentrations are often found during the summer.

In the following sections of this report the term ozone (or O_3) will be used to refer to ground-level ozone specifically.

3.2.5 Sulphur dioxide (SO_2)

Sulphur dioxide (SO_2) is a water soluble acidic gas that is most commonly known because of the environmental damage caused by acid rain. However, SO_2 also contributes to the formation of airborne particulate matter (secondary particulate matter) through reactions involving ammonia.

The largest source of SO_2 in the region is marine vessels. Other significant contributors of SO_2 emissions are some of the region's industrial facilities such as those in the petroleum refining and primary metals sectors.

3.2.6 Carbon monoxide (CO)

Carbon monoxide (CO) is a colourless, odourless gas that is a product of the incomplete combustion of carbon-containing fuels. It is well known as an indoor air contaminant as well as an outdoor air contaminant.

The vast majority of CO emissions in the region come from vehicles and non-road engines (over 90%).

3.2.7 Volatile organic compounds (VOC)

VOC refers not to a single material but to a class of chemicals. As such, the term refers to a large number of different chemical compounds with many different properties and sources. They all have in common the characteristic that in the air they are found as contaminant gases. However, VOC may also become associated with the airborne particles forming particulate matter.

VOC are important to air quality because they are involved in the reactions that form ozone, along with NO_x. However, due to the number and complexity of VOC, measurements are highly specialized and generally are made at only a few locations. VOC were not measured for this study.

3.2.8 Ammonia

Ammonia is a gaseous air contaminant that is involved in the formation of secondary particulate matter through reactions in the air with other air contaminants such as NO_x and SO_2. Ammonia was not measured for this study.

3.3 Ambient air quality objectives

When present at sufficiently high concentrations, air contaminants may have impacts on health, the environment and the economy. A number of metrics can be applied to air quality measurements to determine whether impacts may occur. Health-based ambient air quality standards, or objectives, are particularly relevant to air quality concerns in populated areas as they provide benchmarks against which effects and ambient air quality conditions can be compared. These benchmarks define the upper bounds of acceptable concentrations of air contaminants over both long- and short-term averaging periods according to health or environmental criteria.

In this region Metro Vancouver, the provincial government and the federal government have set objectives for commonly found air pollutants (see Table 1).

Table 1. Ambient air quality objectives observed in Metro Vancouver

	Short-term objective		**Long-term objective**	
	Concentration	***Averaging period***	**Concentration**	***Averaging period***
$PM_{2.5}$	25 $\mu g/m^3$	*24 hours*	8 $\mu g/m^3$	*1 year*
O_3	82 ppb	*1 hour*	30 ppb	*1 year*
	65 ppb	*8 hours*		
NO_2	107 ppb	*1 hour*	22 ppb	*1 year*
SO_2	174 ppb	*1 hour*	12 ppb	*1 year*
	48 ppb	*24 hours*		
CO	26.5 ppm	*1 hour*		
	8.8 ppm	*8 hours*		

3.3.1 Air quality in Metro Vancouver

Most of the time, based on evaluation against ambient air quality objectives, ambient air quality is good in Metro Vancouver.[1] Exceedances of short-term ambient air quality objectives occasionally occur which may result in air quality advisories being issued to the public. Episodes of elevated ozone and $PM_{2.5}$ concentrations are the usual causes of advisories in the region and tend to occur in the summer.

Ozone formation is particularly favoured by summer weather when it is hot and sunny. In the summer, dry conditions can increase the incidence of forest fires in British Columbia and western parts of the United States. Advisories due to elevated $PM_{2.5}$ concentrations have occurred in recent years largely driven by the influence on regional air quality of smoke transported from such forest fires, however local sources also contribute to $PM_{2.5}$ levels in the region.

3.4 Sources of air contaminants

A wide variety of human and natural sources release contaminants into the air. Each source may emit one or more different air contaminants. The number and types of sources in an area are two of the factors that influence air quality in that area.

Every five years, Metro Vancouver carries out an inventory of the emissions sources in the Lower Fraser Valley for a specified year. The last inventory was carried out for the year 2005.[2] The 2005 emissions inventory, which includes backcasts and forecasts covering a 40 year period from 1990 to 2030, provided an assessment of total emissions of eight air contaminants as well as several greenhouse gases for each municipality in the Canadian portion of the Lower Fraser Valley including New Westminster[3].

New Westminster, like many urban areas in Metro Vancouver, contains a wide variety of emissions sources within the municipality. However, the emissions inventory indicates that a relatively small proportion (less than 5% for each air contaminant) of total emissions in the Lower Fraser Valley originate in New Westminster.

4 Study methodology

4.1 Monitoring sites

Monitoring was carried out at four locations in New Westminster (Figure 2, Table 2); two on Front Street, one in Sapperton Park and one at the City Hall close to Royal Avenue. Air contaminants measured included NO_x, ozone, CO, $PM_{2.5}$ and black carbon and UV absorbing fractions of particulate matter.

Figure 2. Locations of temporary air quality monitoring sites in New Westminster during the 2009-2010 study. *Map modified from the City of New Westminster Interactive City Map View tool.*

Table 2. Summary of dates of operation for study monitoring sites

Monitoring Location	Dates of Operation
Parkade site	April 7, 2009 – December 8, 2010
UFCW (MAMU) site	November 19, 2010 – December 7, 2010
Sapperton site	January 12, 2009 – December 8, 2010
City Hall (MAMU) site	November 12, 2009 – December 9, 2009
	July 13, 2010 – August 17, 2010

4.1.1 Front Street sites

Front Street is a designated truck route[4] through New Westminster and vehicle traffic is expected to be a significant source of air contaminants in this location. A railway line runs alongside Front Street and the road also runs parallel to the Fraser River therefore additional potential sources of air contaminants include rail locomotives and marine vessels. The area around Front Street is mainly zoned commercial with some agricultural zoning next to the river and some industrial zoning along the river to the northeast.[5]

Two monitoring locations on Front Street were used during this study.

> **Parkade site**: Air sampling inlets were attached to the parking garage over Front Street close to the intersection of Sixth Street and Front Street (Figure 3). The monitoring equipment was housed in an air conditioned storage room inside the parking garage. Data were collected measuring concentrations of NO, NO_2, and black carbon and UV absorbing particulate matter from April 7, 2009 until December 7, 2010. $PM_{2.5}$ concentrations were measured from July 10, 2009 until December 8, 2010.

Figure 3. Parkade site at Front Street. *Sampling inlets are indicated by the yellow arrow.*

UFCW site: Metro Vancouver's Mobile Air Monitoring Unit (MAMU) was deployed at a second location close to Front Street in a parking lot behind the UFCW Local 1518 building (Figure 4). In this location the railway line was between the sampling site and Front Street. Concentrations of NO, NO_2, SO_2, CO, ozone, $PM_{2.5}$, black carbon and UV absorbing particulate matter as well as wind speed and direction were measured at this location from November 19, 2010 until December 7, 2010.

Figure 4. MAMU at the UFCW site close to Front Street.

4.1.2 Sapperton and City Hall sites

The sites located in Sapperton Park (close to Columbia Street East) and at City Hall (close to Royal Avenue) were considered to be generally representative of the conditions that are typically experienced by residents in New Westminster. These measurements provide a basis for comparison not only with Front Street but also with similar locations in other communities in Metro Vancouver.

In the vicinity of Sapperton Park there is commercial, low rise apartment, single detached home and institutional zoning with some mixed, townhouse, industrial and unzoned areas also close by. The area around City Hall comprises commercial, apartment (low rise and high rise) and single detached home zoning. In addition, both Columbia Street East and Royal Avenue are limited hours (7 am – 9 pm only) designated truck routes[4], therefore some traffic emissions are expected to influence air contaminant concentrations in these areas. However, given the mixture of land use in both of these areas, many potential emissions sources may affect air contaminant concentrations in the area.

Sapperton site: Air was sampled through inlets located on the roof of the change rooms building in Sapperton Park (Figure 5). The monitoring instruments were located inside the building. Measurements of NO, NO_2, $PM_{2.5}$, CO and ozone were made at this site. NO, NO_2 and $PM_{2.5}$ data were collected in this location from January 12, 2009 until the end of the study. Due to constraints of the site, only one additional instrument at a time could be installed at this location; CO concentrations were measured from January 2009 until June 28, 2010 and ozone concentrations were measured from June 28, 2010 until the end of the study.

Figure 5. Sapperton site in Sapperton Park. *Sampling inlets are indicated by the yellow arrow.*

City Hall site: MAMU was deployed in front of New Westminster City Hall on the Royal Avenue side of the building for two periods from November 12, 2009 until December 9, 2009 and between July 13, 2010 and August 17, 2010. Measurements of NO, NO_2, CO, SO_2, ozone, $PM_{2.5}$ and black carbon and UV absorbing particulate matter as well as wind speed, wind direction and temperature were made at this site.

4.2 Monitoring equipment

Gas phase measurements (NO, NO_2, ozone, SO_2 and CO) were made using Thermo Scientific or Teledyne-API gas phase analyzers. These analyzers are routinely employed in the Lower Fraser Valley air quality monitoring network. Calibrations of the gas analyzers at Sapperton and the Parkade were performed every third or fourth day using the automatic 'zero/span' check capabilities of the analyzers. Calibrations of instruments housed in the MAMU were performed on a weekly basis.

Measurements of $PM_{2.5}$ at the Sapperton, City Hall and UFCW sites were made using a TEOM (Thermo Scientific), based on direct mass measurements. Measurements of $PM_{2.5}$ at the Parkade and UFCW were made using an E-sampler (Met One Instruments) which uses a light scattering based measurement method. Measurements of BC and UV absorbing particulate matter were made using an aethalometer (Magee Scientific). TEOMs and aethalometers are instruments currently deployed in the Lower Fraser Valley air quality monitoring network.

Data from the analyzers located at study sites were collected at one minute intervals by onsite dataloggers. Data from Sapperton and the Parkade sites were transmitted to a central computer at Metro Vancouver's head office in Burnaby every 15 minutes. Data from the MAMU instruments were retrieved once per day. A one hour average, calculated from the minute data, was archived after verification and quality assurance of the data had been completed. One hour averages were used for reporting and to calculate longer term averages (e.g. rolling 24 hour averages). For data to be considered valid, at least 75% of the data for the period had to be available.

4.3 Data analysis

Valid data from the Sapperton and Parkade study sites was available up to midnight of December 7, 2010. These data and subsets of these data were used in the air quality assessment provided in the following sections of this report. When comparing these sites with the New Westminster MAMU sites (City Hall and UFCW) for which only periodic data were available, the analysis was carried out using data from the Parkade and Sapperton sites that matched to the relevant data collection periods from MAMU.

Comparisons with Lower Fraser Valley air quality monitoring network station data were carried out using valid data collected during the study period up to July 31, 2010, the date for which network station data was available at the time of the preparation of this report.

4.4 Demographics and emissions analysis

Information on demographic projections, land use, traffic counts and proposed development (proposed at the time of report compilation) was either provided by email by City of New Westminster staff or obtained through the municipality's website. This information was supplemented as necessary with data from Metro Vancouver publications.

Information relating to emissions in New Westminster was drawn from the 2005 Lower Fraser Valley Air Emissions Inventory & Forecast and Backcast documents available on Metro Vancouver's website.[6]

5 Monitoring results

Monitoring results are presented in this section. The interpretation and discussion of these results can be found in Section 6.

5.1 Air contaminant monitoring on Front Street

5.1.1 Comparison with the ambient air quality objectives

$PM_{2.5}$ and NO_2 data from the Front Street Parkade site for the study period April 2009 – December 2010 are summarized in Table 3. Average and maximum $PM_{2.5}$ and NO_2 concentrations for two 12 month periods are also shown in Table 3. The 12 month periods, from May 2009 – April 2010 (period 1) and from December 2009 – November 2010 (period 2), were chosen to represent the greatest temporal difference between 12 month periods within the data collection period.

Table 3. Summary of air quality monitoring data from the Parkade site on Front Street.

	$PM_{2.5}$ (µg/m^3)		NO_2 (ppb)	
Study period (Apr 2009 – Dec 2010)		*Objective*		*Objective*
Average	12	*-na-*	38	*-na-*
Maximum [a]	50	*25*	226	*107*
Period 1 (May 2009 – Apr 2010)				
Average	12 [b]	*8* [c]	39	*22*
Maximum [a]	36 [b]	*25*	226	*107*
Period 2 (Dec 2009 – Nov 2010)				
Average	11	*8* [c]	38	*22*
Maximum [a]	50	*25*	226	*107*

-na- no objective available for periods averaged over more than 12 months
[a] $PM_{2.5}$ maximum concentrations are based on a rolling 24 hour average concentration.
[b] Measurements started in July 2009
[c] Based on the average of mean midnight to midnight averages for each quarter (Jan.-Mar., Apr.-Jun., Jul.-Sep., Oct.-Dec.) as outlined in the provincial guidance document Guidance on Application of Provincial Air Quality Criteria for $PM_{2.5}$

Values from the two 12 month periods provide a way to compare NO_2 concentrations measured at this site with Metro Vancouver's long-term ambient air quality objective (Table 1). Average and maximum concentrations of NO_2 at this site for all periods shown in the table exceeded the long-term (annual) and short-term (1 hour) objectives for the region.

The average $PM_{2.5}$ concentrations for these two periods cannot be compared with the current annual ambient air quality objective for $PM_{2.5}$. The calculation to compare concentrations with the new provincial annual objective is based on daily (midnight to midnight) and quarterly averages. Due to the start and finish dates of the study, the data completeness criteria were not met for either 2009 or 2010 and therefore an annual average concentration using this metric could not be applied. Average concentrations at the Parkade site, calculated based on the provincial calculation methodology for two 12 month periods during the study, were 12 µg/m^3 and 11 µg/m^3 for the periods July 2009 – June 2010 and October 2009 – September 2010 respectively. These concentrations exceeded the annual provincial ambient air quality objective and were consistent with the values shown in Table 3.

The instrument used to measure $PM_{2.5}$ at this site (E-sampler) was not an instrument typically deployed in the network as standard. Due to physical constraints at this site, it was not possible to install a standard instrument. The E-sampler has been used by Metro Vancouver in several short-term air quality studies. Based on an instrument comparison using data collected by the instrument type used at this site and the standard type of instrument deployed in the network, it was found that the instrument at the Parkade site may slightly underestimate concentrations by up to a few percent compared to concentrations measured at air quality monitoring network stations.

5.1.2 Analysis of $PM_{2.5}$ exceedances at the Parkade site

The $PM_{2.5}$ rolling 24 hour average exceeded the short-term ambient air quality objective 4% (464 hours out of 12184 hours available data) of the time at the Parkade site during this 1½ year study. The monthly distribution and frequency of these exceedances of this objective is shown in Figure 6.

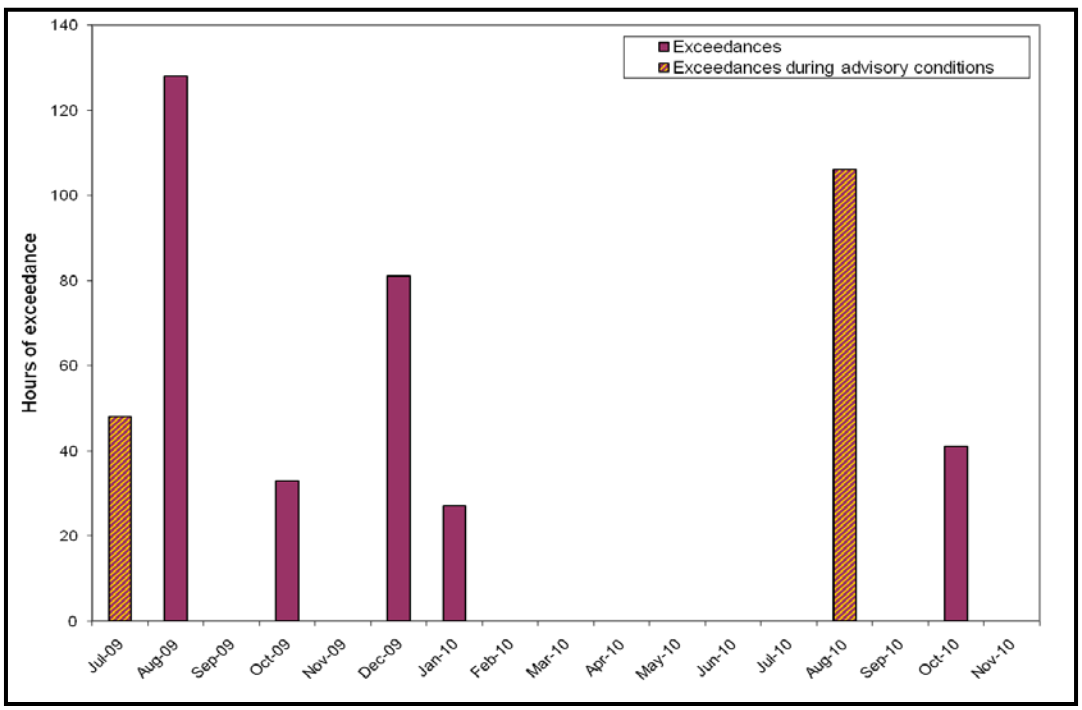


Figure 6. Exceedances of the rolling 24 hour average ambient air quality objective for $PM_{2.5}$ at the Parkade site during the study period.

Approximately 154 hours of the $PM_{2.5}$ exceedances, representing one third of the total hours of exceedance, occurred during periods of degraded air quality in the region when an air quality advisory was in effect. However, it should be noted that 48 of the 154 hours occurred at times in which an advisory had been issued due to elevated ozone concentrations in the region, not $PM_{2.5}$.

Analysis of the monthly distribution of exceedances indicates that elevated 24-hour levels were most common in the winter and summer during the study period. During the entire study, exceedances occurred in January, July, August, October and December. A combination of factors is responsible for these episodes. Qualitative examination of the data for the October periods in 2009 and 2010 indicated that while in general the air quality patterns at air quality monitoring network stations in Metro Vancouver and the Parkade site were similar, concentrations were much higher at the Parkade site, probably because of a combination of the localized issue of substantial emissions in the area from traffic sources and the build up of air contaminants due to the parkade structure restricting dispersion of the emissions. Further discussion of the effects of the local emissions sources and the resulting high $PM_{2.5}$ concentrations at the Parkade site compared to monitoring network stations can be found in section 6.

5.1.3 Black carbon and UV absorbing PM measurements

Measured concentrations of black carbon at the Parkade site are shown with $PM_{2.5}$ concentrations in Table 4. Black carbon may be considered indicative of the presence of the types of particulate matter associated with diesel engine emissions. The UV absorbing fraction can be used as an indicator for woodsmoke[7] however measurements cannot generally be used quantitatively.

Table 4. Summary of $PM_{2.5}$ and black carbon concentrations, based on rolling 24 hour average values, measured at the Parkade site during the study.

	$PM_{2.5}$ ($\mu g/m^3$)	**Black carbon** ($\mu g/m^3$)
Study period (Apr 2009 – Dec 2010)		
Average	12	4
Maximum	50	13
12 month period 2 (Dec 2009 – Nov 2010)		
Average	11	4
Maximum	50	13

The maximum $PM_{2.5}$ concentration shown in Table 4 was recorded on August 5, 2010 and the maximum black carbon concentration was recorded on February 15, 2010, therefore using a ratio of maximum concentrations to determine the proportion of $PM_{2.5}$ that can be attributed to black carbon is not appropriate from these data.

The average data indicated that approximately one third of $PM_{2.5}$ by mass concentrations comprised black carbon over the periods analyzed, however, from the ratio of black carbon to $PM_{2.5}$ for hourly data the proportion of black carbon particles in $PM_{2.5}$ was found to vary widely. By illustration, the hourly black carbon to $PM_{2.5}$ ratios for each month in which the $PM_{2.5}$ objective was exceeded during the study are shown in Figure 7. The black carbon to $PM_{2.5}$ ratio for the months in which the $PM_{2.5}$ objective was exceeded indicated that variation in the proportion of black carbon in $PM_{2.5}$ indicated by the ratio was generally in the range 0.1 to 0.6 (or 10% to 60%). During exceedances, measured concentrations of black carbon were generally similar in magnitude to periods in which the objective was not exceeded.

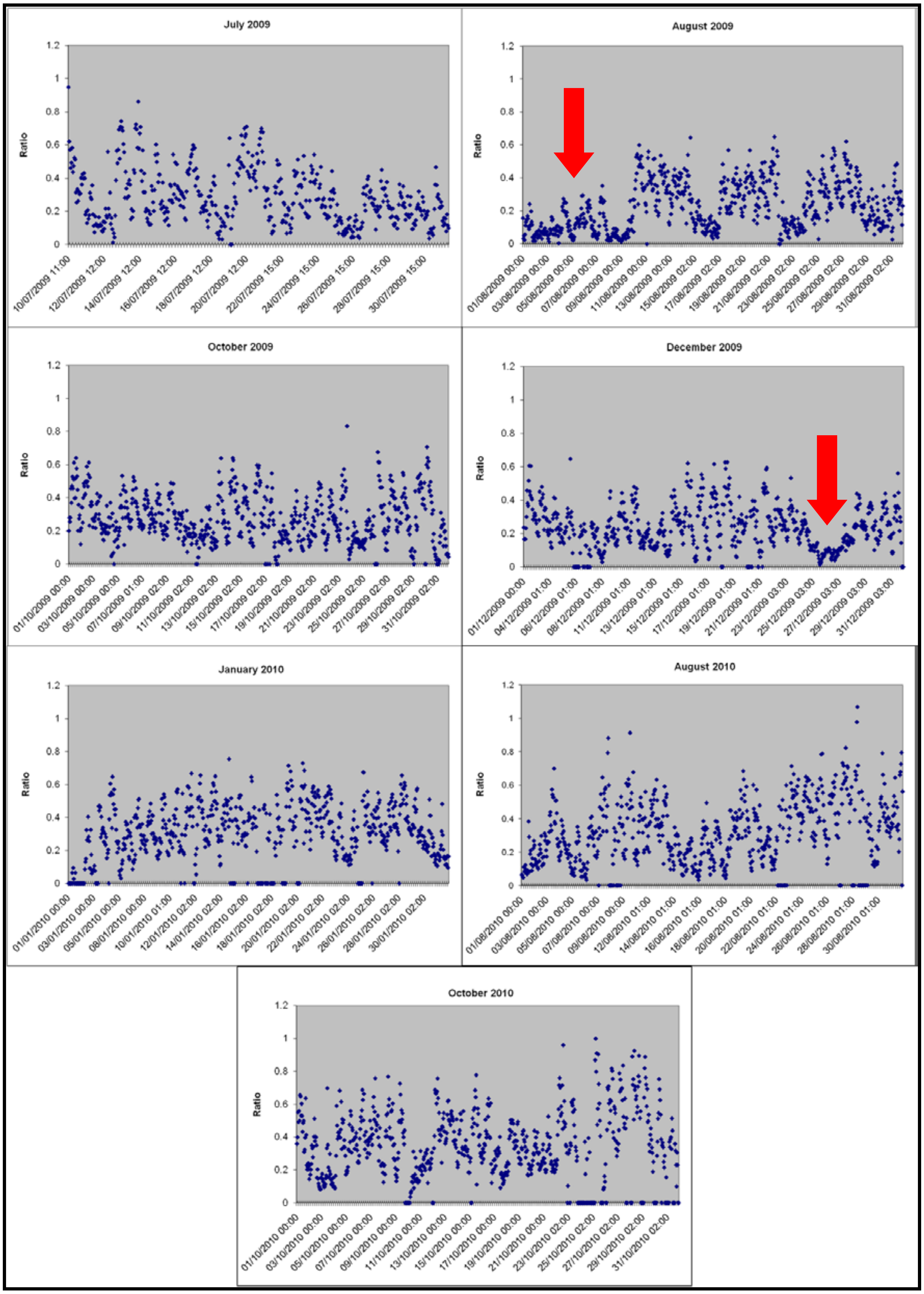


Figure 7. Black carbon:$PM_{2.5}$ ratios during months in which the $PM_{2.5}$ 24 hour rolling average objective was exceeded at the Parkade site. Only data from time points in which the $PM_{2.5}$ concentration exceeded 3 $\mu g/m^3$ are shown. The red arrows indicate the periods in which exceptions to the typical profile were observed.

In spite of the wide variation in values, ratio analysis can be used to identify periods in which a significant deviation from typical patterns for a specific location occur. More detailed data analysis can then be performed for these periods.

Two exceptions to the typical black carbon:$PM_{2.5}$ ratio were noted at the beginning of August 2009 and near the end of December 2009 (indicated by red arrows in Figure 7). In both cases the ratio was notably lower and persisted at values between approximately 0.05 and 0.1. The ratio profiles for $PM_{2.5}$ and the black carbon and UV absorbing particulate matter for August 2009 and December 2009 are shown in Figure 8.

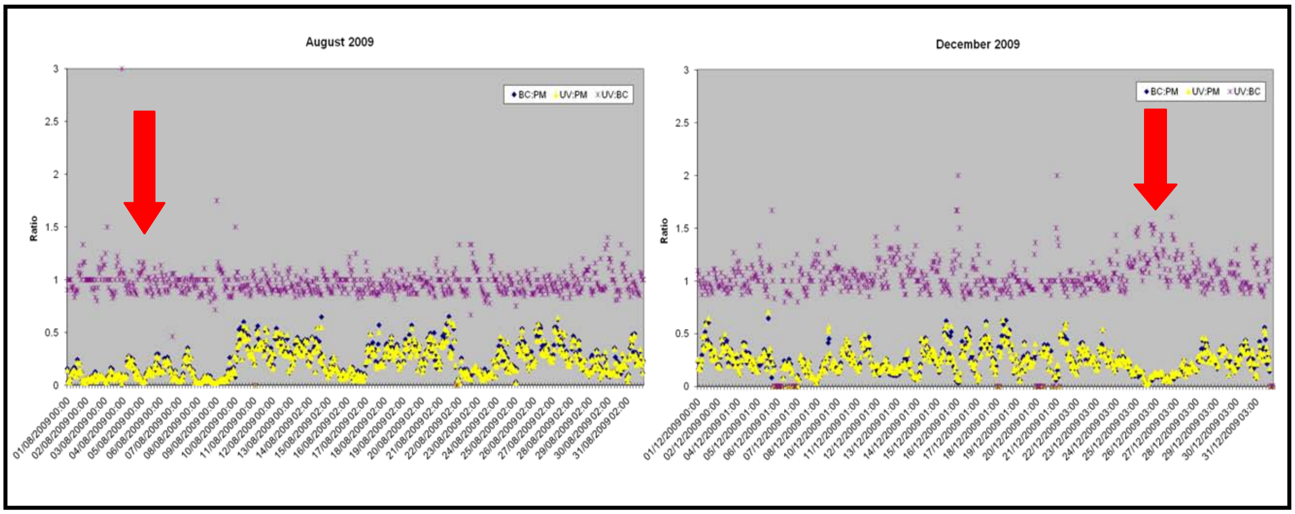


Figure 8. Ratios of black carbon: $PM_{2.5}$ (BC:PM), UV absorbing particulate matter: $PM_{2.5}$ (UV:PM) and UV absorbing particulate matter:black carbon (UV:BC) for July 2009 and December 2009 from the Parkade site. Only data from time points at which the $PM_{2.5}$ concentration exceeded 3 $\mu g/m^3$ are shown. The red arrows indicate the periods in which exceptions to the typical profile (as also indicated in **Figure 7**) were observed.

For the August 1 to 9, 2009 period, several hours in which the black carbon to $PM_{2.5}$ ratio was particularly low were observed. The beginning of this period coincided with the BC Day long weekend in which black carbon concentrations over the three day period were typical of lower concentrations measured on weekends (section 5.1.5). In the second half of this period, $PM_{2.5}$ concentrations were significantly raised by smoke from forest fires in the interior of BC reaching the Lower Fraser Valley. Hourly $PM_{2.5}$ concentrations increased from values close to the average to concentrations of between approximately 20-45 $\mu g/m^3$. The 24 hour rolling average concentration exceeded the ambient air quality objective for 119 hours between August 4 and 9, 2009. No corresponding increase in black carbon concentrations was observed.

The second occurrence of an atypical black carbon to $PM_{2.5}$ ratio profile was observed during the period December 25 – 27, 2009. Over the weekend of December 26 – 27, 2009, particulate matter was elevated at the Front Street site and black carbon concentrations were low (Figure 9). In addition, measurements of the UV absorbing particulate matter were slightly higher than generally observed at this site resulting in an increase in the UV to black carbon ratio. Discussion of these observations can be found in section 6.1.

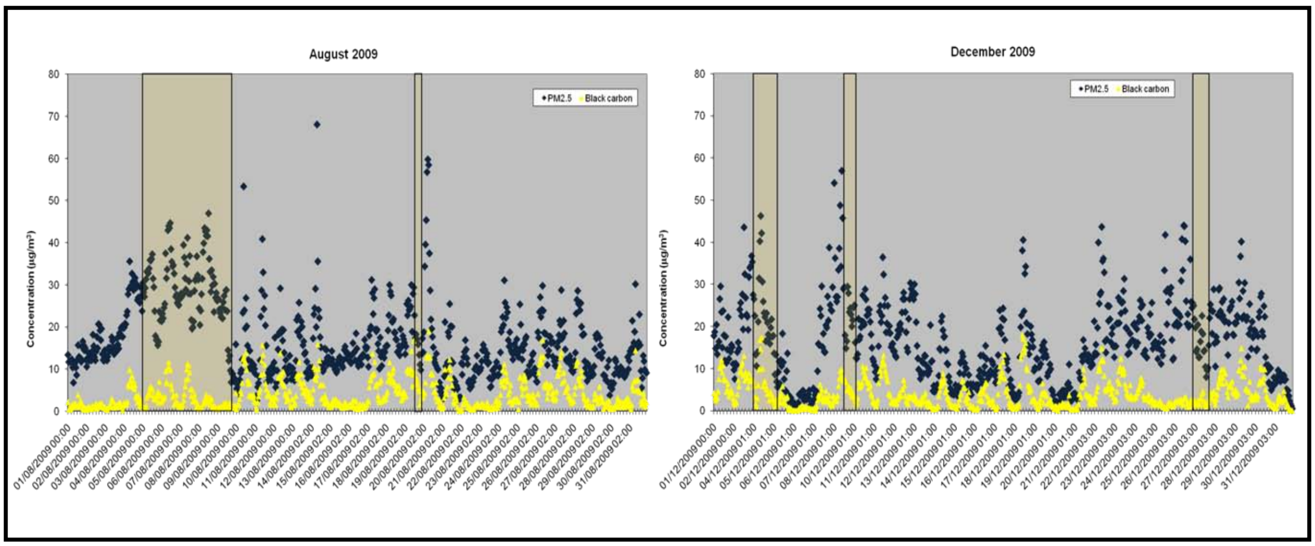


Figure 9. $PM_{2.5}$ (in blue) and black carbon (in yellow) hourly concentrations measured at the Parkade site in August 2009 and December 2009. Orange shaded areas indicate periods in which the $PM_{2.5}$ rolling 24 hour average (data not shown) objective was exceeded.

5.1.4 Nitrogen dioxide monitoring at the Parkade site

Elevated concentrations of NO_2 at the Front Street site occurred throughout the year, generally for short periods of up to three hours. Hourly NO_2 concentrations exceeded the short term ambient air quality objective for less than 1% (74 hours out of 14410 hours available data) of the time at the Parkade site during this study. Examples of the distribution of exceedances of the nitrogen dioxide objective by month for two 12 month periods at the Front Street site are shown in Figure 10.

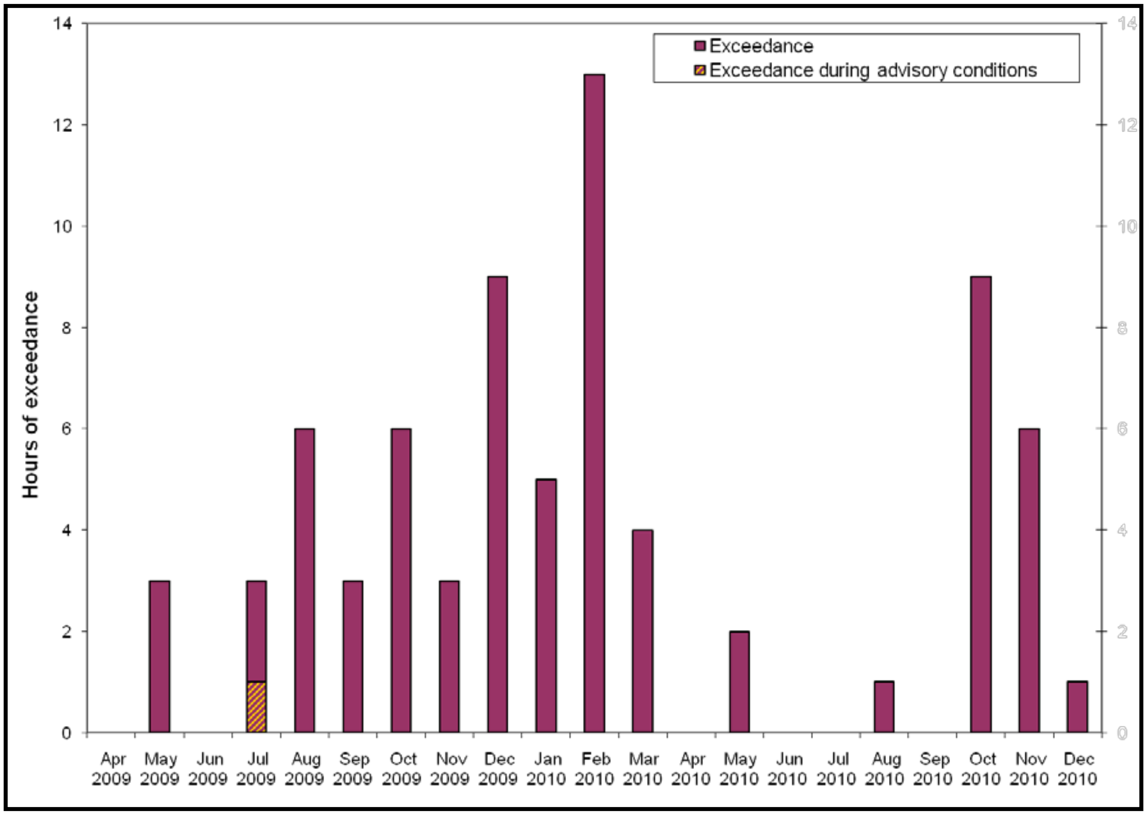


Figure 10. Exceedances of the one hour ambient air quality objective for NO_2 at the Parkade site during the study period.

Although the greatest number of hours of exceedance occurred in December and February, there was no distinct pattern in the monthly distribution. During the entire study period, the only months in which no exceedances ever occurred were April and June.

Exceedances of the hourly NO_2 objective were generally shorter than episodes in which the $PM_{2.5}$ objective was exceeded. However in one event in February 2010 elevated concentrations persisted for nine hours, during which measurements exceeded the objective for eight hours. Although NO_2 is considered to be indicative of regional air quality conditions, similar exceedances were not recorded at air monitoring network stations in the region.

5.1.5 Daily air contaminant profiles at the Parkade site

Average air contaminant concentrations at different times of day on each day of the week are illustrated in Figure 11.

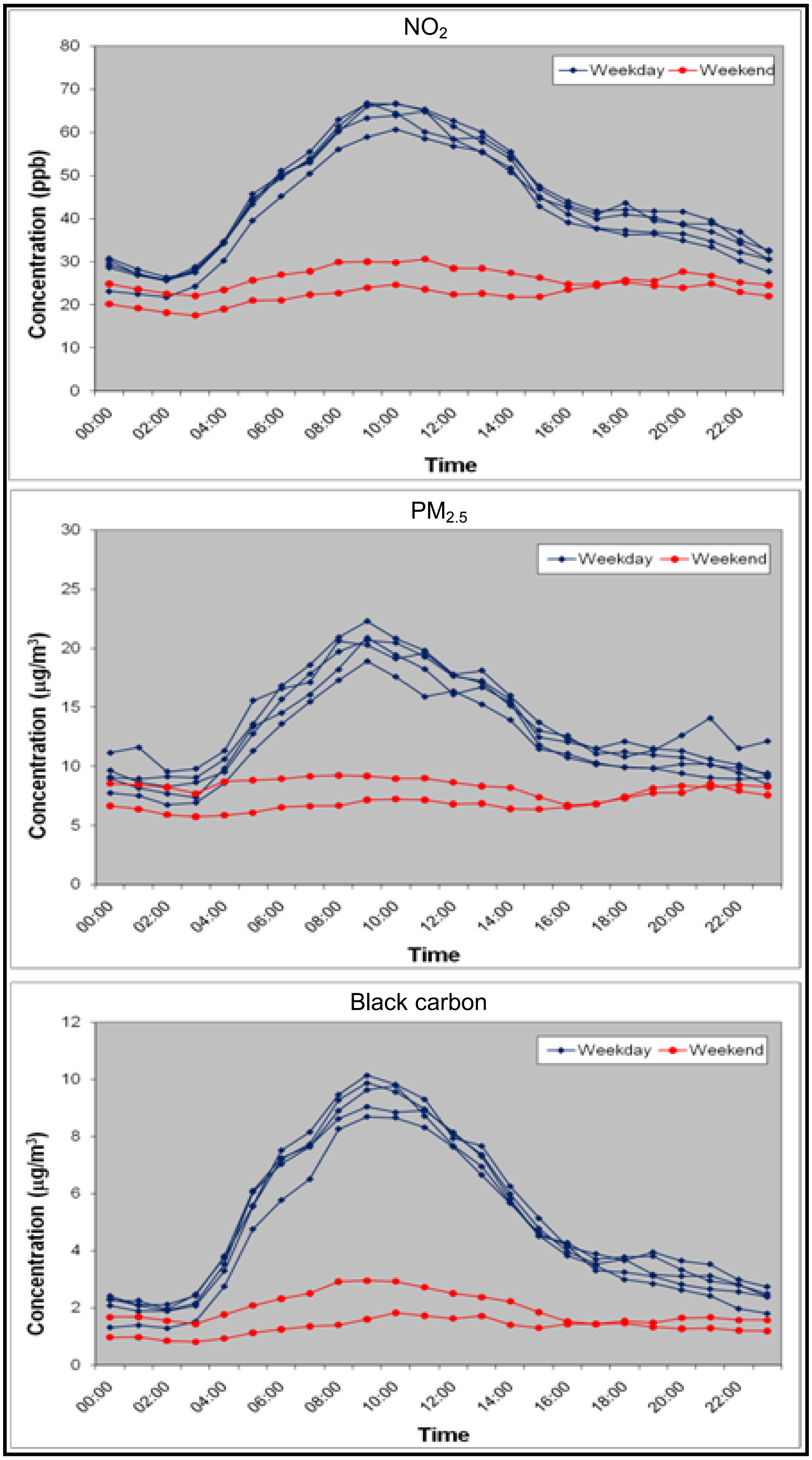


Figure 11. Diurnal profiles of NO_2, $PM_{2.5}$ and black carbon concentrations from the Parkade site. Concentrations shown are averages for the study period.

The daily concentration (diurnal) analysis showed that a clear difference was measured between average weekday and weekend concentrations for each contaminant. On weekdays, concentrations peaked at around 9 am (local standard time). On weekends, concentrations were lower than on weekdays and the variation in measured concentration throughout the day was much lower with a morning peak barely discernible on Saturdays and generally not present on Sundays.

Comparing traffic volume profiles to diurnal air contaminant profiles can help to identify whether vehicles are a key source. Traffic survey data was obtained from City of New Westminster staff. Data are shown for the survey carried out in 2009 in Figure 12.

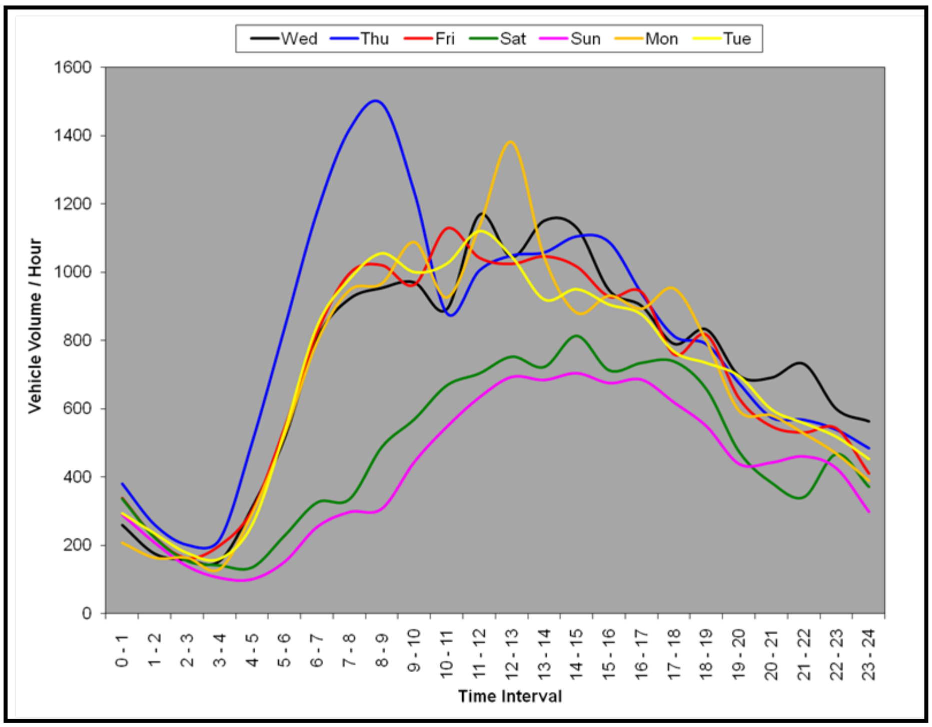


Figure 12. Traffic volumes on Front Street in 2009. Charts show data supplied by the City of New Westminster[8]. Traffic counts were carried out on Front Street east of Elliot Street.

Clear differences in traffic volumes between weekdays and weekends were recorded in the surveys. On weekdays peak traffic volumes occurred between 7 am and 12 noon before traffic volume decreased through the evening to a minimum in the early hours of the morning, a pattern very similar to the air contaminant data patterns illustrated in Figure 11. The weekend peak traffic volume occurred in the afternoon and peak volume was also lower than on weekdays. Analysis of these profiles is discussed in section 6.1.2.

5.1.6 Comparison of air contaminant concentrations between sites on Front Street

$PM_{2.5}$, black carbon (BC), UV absorbing particulate matter, NO and NO_2 concentrations were measured simultaneously at two different locations on Front Street, the UFCW site and the Parkade site, for a short period from November 19, 2010 to December 7, 2010, near the end of the study. Comparing the measurements from these two sites over this period provided insight into the spatial extent of the elevated air contaminant concentrations found at the Parkade site throughout the study. The results from both stations are summarized in Figure 13 and Figure 14.

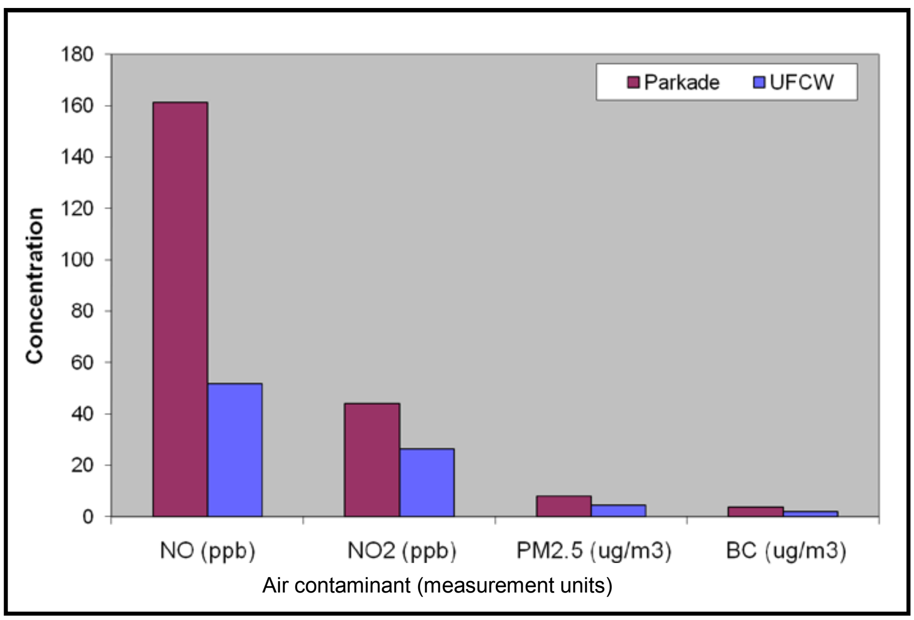


Figure 13. Average air contaminant concentrations measured during simultaneous monitoring at the Parkade site and the UFCW site.

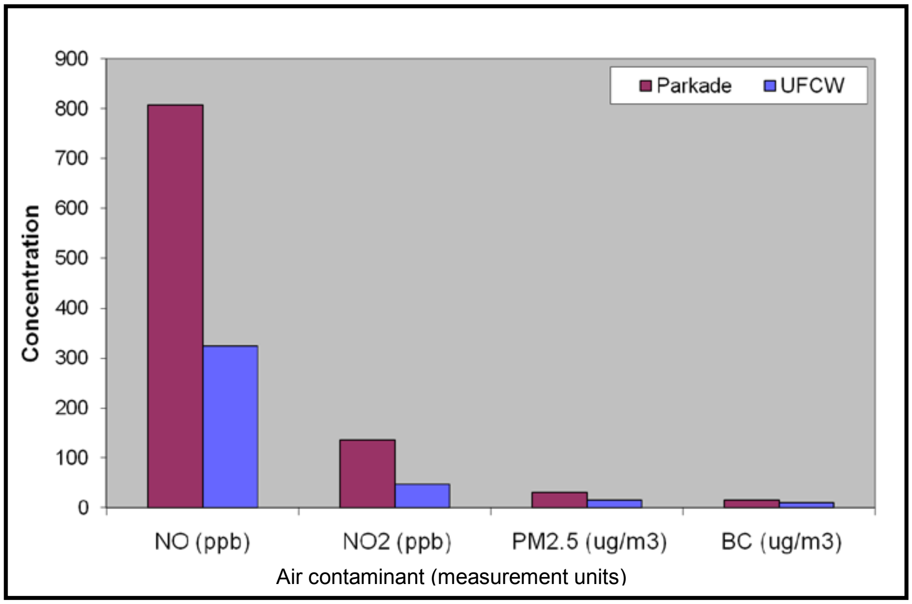


Figure 14. Maximum air contaminant concentrations during simultaneous monitoring at the Parkade site and the UFCW site.

Average concentrations for every measured air contaminant were higher at the Parkade site than at the UFCW site. The average NO concentration was approximately three times higher at the Parkade site than at UFCW. $PM_{2.5}$, black carbon and average NO_2 concentrations were almost twice as high at the Parkade site as at the UFCW site.

Maximum hourly concentrations for each air contaminant were also higher at the Parkade site than at the UFCW site. For NO and NO_2, the maximum concentrations measured at the Parkade site were approximately 2.5 to 3 times higher than those at the UFCW site during the same period. Measured particulate matter maximum concentrations ($PM_{2.5}$ and black carbon) were approximately 1.5 to 2 times higher at the Parkade site than at the UFCW site. Maximum values for each contaminant did not occur on the same day at each site. The NO monitoring data clearly indicates that localized emissions had a greater adverse impact on air quality at the parkade site than at the UFCW site.

5.2 Air quality conditions in Sapperton and near City Hall

Data from the Sapperton site for the study period January 2009 – December 2010 are summarized in Table 5. In order to evaluate concentrations in these locations against annual objective values, averages were calculated for two 12 month periods during the study and are also shown in Table 5. The 12 month periods selected, from February 2009 – January 2010 (period 1) and from December 2009 – November 2010 (period 2), provided the greatest temporal separation between available 12 month periods within the total data collection period at this station.

Table 5. Summary of air quality data from the Sapperton site.

	$PM_{2.5}$ (µg/m³)	NO_2 (ppb)	CO (ppm)[c]	O_3 (ppb)[d]
Study period (Jan 2009 – Dec 2010)				
Average	5	18	0.35	11
Maximum [b]	31	59	2.89	56
12 month period 1 (Feb 2009 – Jan 2010)				
Average	5 [a]	18	0.33	-na-
Maximum [b]	17	58	2.89	-na-
12 month period 2 (Dec 2009 – Nov 2010)				
Average	5 [a]	18	-na-	-na-
Maximum [b]	31	58	-na-	-na-
Objectives				
Average	*8*	*22*	*-na-*	*30*
Maximum	*25*	*107*	*26.5*	*82*

-na- data was not collected for the full 12 month period
[a] Calculation of these values is based on provincial annual objective. Quarterly completeness criteria were applied to 3-month periods starting from the first month of the period as indicated.
[b] $PM_{2.5}$ maximum concentrations are based on a rolling 24 hour average.
[c] CO data was collected between January 12, 2009 and June 28, 2010.
[d] O_3 data was collected only between June 28, 2010 and December 8, 2010.

Long-term ambient air quality objectives, based on annual averages, were not exceeded at this location. Average values over the study period and for the two 12 month periods were almost identical.

In addition to the two 12 month periods shown, the data completeness criteria for calculation of the annual average $PM_{2.5}$ concentration were also met for the calendar year 2009. The $PM_{2.5}$ annual average at Sapperton for 2009 was 6 µg/m³. This was within the annual objective for $PM_{2.5}$ and equal to the more stringent provincial planning goal of 6 µg/m³.

Maximum concentrations can be compared with short-term ambient air quality objective values. With the exception of $PM_{2.5}$, air contaminant concentrations did not exceed ambient air quality objectives during the study period.

The maximum measured $PM_{2.5}$ concentration did exceed the Metro Vancouver 24 hour objective of 25 $\mu g/m^3$ for several hours over two days in August 2010. This occurred during a period of degraded air quality throughout the region in which an air quality advisory was issued for the Metro Vancouver and the FVRD due to elevated levels of $PM_{2.5}$ from wildfire smoke originating outside the Lower Fraser Valley.

5.2.1 Neighbourhood scale variability in air quality

Monitoring carried out at the City Hall site during two different periods provided additional information on air quality conditions experienced by residents and visitors of New Westminster and to compare to other locations in Metro Vancouver.

A summary of the results from Sapperton and City Hall during the City Hall monitoring periods November 12, 2009 to December 9, 2009 and July 13, 2010 to August 17, 2010 is shown in Table 6. Maximum and average concentrations at the Sapperton and City Hall sites were very similar.

The average concentrations were broadly similar to those recorded at Sapperton over the whole study period at that site, except for the average $PM_{2.5}$ concentration for the July-August period. In August 2010 two regional air quality advisories due to elevated $PM_{2.5}$ concentrations were issued. Transported smoke from forest fires in the interior of British Columbia were the major additional source of $PM_{2.5}$ for the region during the advisories. During the July-August period the presence of forest fire smoke is likely to have caused the noticeable increase in the average concentration compared to other periods.

The highest concentrations of $PM_{2.5}$ measured at both Sapperton and at City Hall also occurred during the period August 5 – 6, 2010 in which the ambient air quality objective was exceeded for a total of 24 hours at each site. This period coincided with one of the air quality advisories issued for the region. There were no other exceedances of short-term ambient air quality objectives for any pollutant at either site.

Table 6. Summary of simultaneous air quality monitoring data from the Sapperton and the City Hall sites. Maximum and average values for Sapperton are only for the period in which measurements from City Hall were available

	$PM_{2.5}$ ($\mu g/m^3$)	**NO_2** (ppb)	**CO** (ppm)	**O_3** (ppb)	**Black carbon** ($\mu g/m^3$)	**SO_2** (ppb)
November – December 2009						
Sapperton average	4	19	0.36	-na-	-na-	-na-
City Hall average	4	18	0.30	10	1	0.4
Sapperton maximum [a]	12	46	1.67	-na-	-na-	-na-
City Hall maximum [a]	12	46	1.28	35	3	4
July – August 2010						
Sapperton average	8	16	-na-	13	-na-	-na-
City Hall average	9	14	0.20	14	1	1
Sapperton maximum [a]	31	46	-na-	56	-na-	-na-
City Hall maximum [a]	30	44	0.55	53	3	11

-na- not measured

[a] $PM_{2.5}$ and black carbon maximum concentrations are based on a rolling 24 hour average. NO_2, CO, O_3 and SO_2 concentrations are based on an hourly average.

Statistical analysis of the data was also carried out (Appendix A). The results of this indicated that a strong correlation between the Sapperton and City Hall sites for each air contaminant generally applied during the monitoring periods.

In addition to the contaminants measured at the Sapperton site, sulphur dioxide and black carbon and UV absorbing particulate matter were also monitored at City Hall. Summary data for these air contaminants are also shown in Table 6.

The maximum concentrations of sulphur dioxide for both monitoring periods were below the short term ambient air quality objectives of 174 ppb (one hour average) and 48 ppb (24 hour average - data not shown). Insufficient data were collected to compare with the annual objective for sulphur dioxide.

During the November-December monitoring period 517 hours of 24 hour rolling average values were available. During the July August monitoring period approximately 50% more hours of data (771 hours of 24 hour rolling average values) were available. In the November-December period, black carbon accounted for approximately 25% of the mass concentration of $PM_{2.5}$. In contrast, during the summer the data indicated that black carbon accounted for 9% of the $PM_{2.5}$, based on average values (Table 6). More secondary $PM_{2.5}$ is generally expected to be present in the summer than the winter. This factor is likely to contribute to the relative differences in the proportion of $PM_{2.5}$ comprising black carbon between the two monitoring periods.

5.2.1.1 Comparison of City Hall and the Front Street Parkade

Summary data from the Parkade site and City Hall over the same periods are shown in Table 7.

Table 7. Summary of $PM_{2.5}$ and black carbon particulate matter monitoring data from the City Hall and Parkade sites. Maximum and average values for the Parkade are only shown for the period in which concurrent measurements from City Hall were available.

	$PM_{2.5}$ ($\mu g/m^3$)	**Black carbon** ($\mu g/m^3$)
November – December 2009		
Parkade average	12	3
City Hall average	4	1
Parkade maximum [a]	36	8
City Hall maximum [a]	12	3
July – August 2010		
Parkade average	15	4
City Hall average	9	1
Parkade maximum [a]	50	8
City Hall maximum [a]	30	3

[a] $PM_{2.5}$ and black carbon maximum concentrations are based on a rolling 24 hour average.

Concentrations of both $PM_{2.5}$ and black carbon were much higher at the Parkade site than at City Hall. In the November-December period, concentrations of $PM_{2.5}$ and black carbon were approximately three times higher at the Parkade than at City Hall. In the summer period, both $PM_{2.5}$ and black carbon were also much higher at the Parkade site but the magnitude of the difference in $PM_{2.5}$ concentrations between the two sites was slightly lower. The influence of meteorology on air quality is discussed in section 6.1. Maximum and average $PM_{2.5}$ concentrations at the Parkade were nearly double the concentrations recorded at City Hall, suggesting that degraded air quality on Front Street probably does not have a major effect on air quality near City Hall.

5.2.2 Daily air contaminant profiles

Average air contaminant concentrations at different times of the day and on different days of the week for the Sapperton site are shown in Figure 15. A clear difference between the concentration profiles for weekdays and weekends was revealed.

NO_2 concentrations were slightly higher on weekdays than on weekends. Two distinct peaks in the NO_2 profiles occurred on weekdays, in the morning between 7 and 8 am and in the late evening at around 10 pm, whereas on weekends one clear maximum occurred in late evening after 9 pm. During the morning on weekends a small increase in average concentrations was observed creating a minor peak in concentration at around 7 am.

$PM_{2.5}$ weekday concentrations were larger than weekend concentrations at the same time of day in the morning and early afternoon. However, from early evening through the night weekday concentration profiles were indistinguishable from weekend concentration profiles. In general $PM_{2.5}$ concentration profiles were less distinctively different between weekdays and weekends than NO_2 concentration profiles. Peak $PM_{2.5}$ concentrations on weekdays occurred in the morning (8 – 9 am) and late evening (10 – 11 pm). On weekends peak concentrations occurred late in the evening at the same time as on weekdays but no distinct morning maximum was observed. The significance of these findings with respect to air quality traffic related emissions sources in Sapperton are discussed in section 6.2.1.

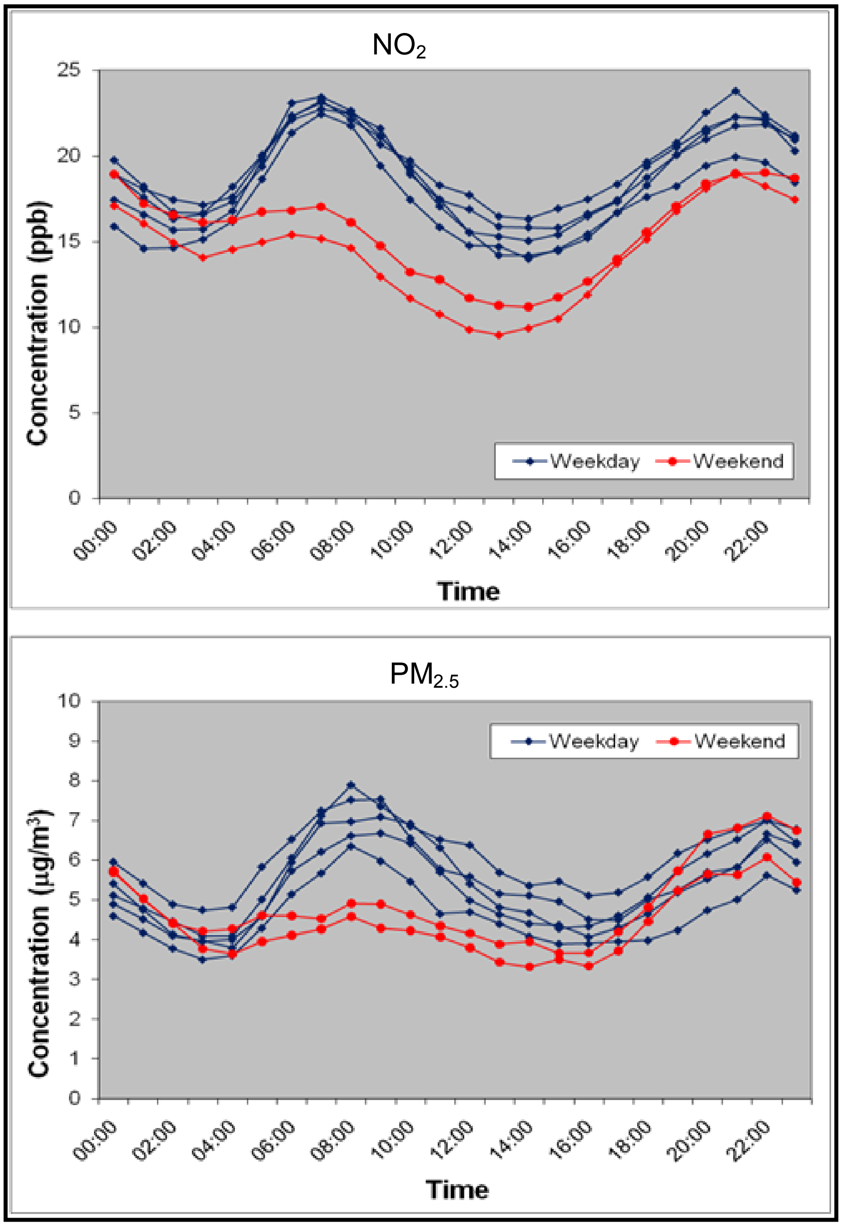


Figure 15. Diurnal profiles of NO_2 and $PM_{2.5}$ concentrations at the Sapperton site. Concentrations shown are averages for the study period.

5.3 Comparison of New Westminster with other parts of Metro Vancouver

To investigate whether there were significant differences in air contaminant concentrations in New Westminster compared to other areas in Metro Vancouver maximum, 99th percentile and average air contaminant concentrations at the

Sapperton, Parkade and City Hall sites were examined in conjunction with data from a selection of ambient air quality monitoring stations in the region (Figure 16). The selection of stations was based on proximity to New Westminster and similarities in surrounding land use with Sapperton.

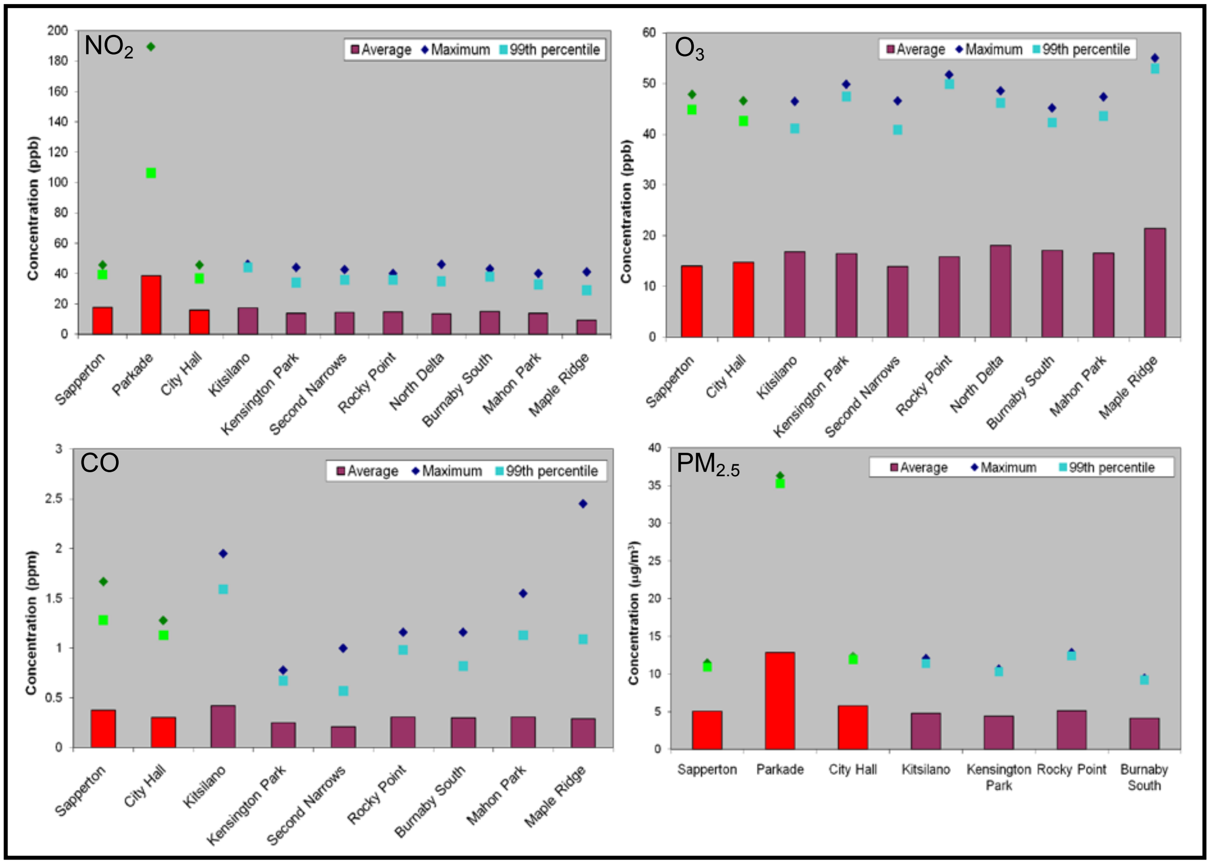


Figure 16. Maximum, average and 99th percentile hourly concentrations for NO_2, O_3, and CO and 24 hour rolling average concentrations for $PM_{2.5}$. Only data for the periods between November 12th, 2009 – December 9th, 2009 and July 13th, 2010 – July 31st 2010 for which data were available for all stations has been included in the calculation of these values. Ambient air quality monitoring network stations in these charts have been identified using abbreviated names. The full station identifier for each network station is provided in Table 8.

Table 8. Ambient air quality monitoring network station identification. The numeric identifiers (Figure 1) and full station names to which the abbreviated names used in Figure 16 and Figure 17 correspond are shown in this table for reference.

Abbreviated name	Monitoring network identifier	
Kitsilano	T2	Vancouver – Kitsilano
Kensington Park	T4	Burnaby – Kensington Park
Second Narrows	T6	North Vancouver – Second Narrows
Rocky Point	T9	Port Moody
North Delta	T13	North Delta
Burnaby South	T18	Burnaby South
Mahon Park	T26	North Vancouver – Mahon Park
Maple Ridge	T30	Maple Ridge

It is clear from Figure 16 that air quality conditions at the Parkade site were much poorer than typical air quality conditions in the region for NO_2 and $PM_{2.5}$. However, it should be emphasized that monitoring network stations are generally located in areas that are representative of "average" conditions for an area and are deliberately located at sites that are not usually affected by very local issues. Sapperton and City Hall were more typical of monitoring network station locations and the data reflect this. In contrast to results from the Parkade, summary data from Sapperton and City Hall were generally within the range of concentrations found in other locations for all four air contaminants.

To provide a comparison over a more extended period, summary data were calculated from measurements collected over a period of approximately 18 months and are shown in Figure 17. Average, maximum and 99th percentile air contaminant concentrations from Sapperton and air quality monitoring network stations are shown. The 99th percentile concentration provides a useful alternative to the maximum concentration; maximum values can be affected by anomalous events occurring for a very short period which are not representative of the general picture of air quality in an area.

Average concentrations in Sapperton were similar to those measured in other parts of Metro Vancouver for most pollutants. Average and maximum concentrations were also better than air quality objectives during this period.

NO_2 concentrations were slightly higher than generally measured elsewhere in the network. Average concentrations were slightly higher in Sapperton and the maximum and 99th percentile NO_2 concentrations in Sapperton were amongst the highest measured compared to the Metro Vancouver air monitoring network stations assessed for this study.

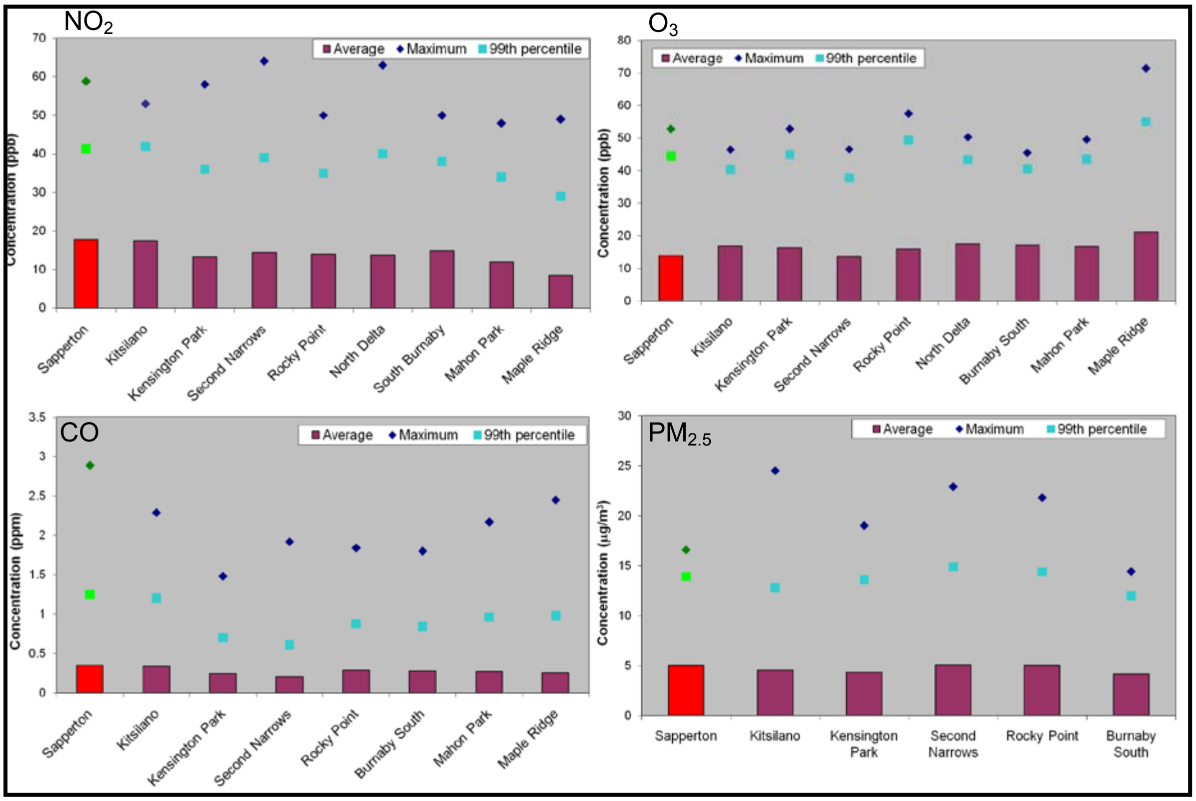


Figure 17. Maximum, average and 99th percentile hourly concentrations for NO_2, O_3, and CO and 24 hour rolling average concentrations for $PM_{2.5}$. Data for the period from January 2009 up to July 31st, 2010 were used to calculate these values. Data from periods in which multiple consecutive hourly values were missing for any one station were excluded from the calculations for all stations. The full station identifier for each network station is provided in Table 8.

A very limited amount of data (approximately one month of measurements) was available to compare ozone concentrations in Sapperton with other parts of Metro Vancouver. These data were available from a summer period when highest ozone concentrations are typically measured in the Lower Fraser Valley. The results show that during the period June to July 2010 the average ozone concentration was lower than at most other locations, with the exception of measurements from the station near the Second Narrows Bridge in North Vancouver. Maximum and 99^{th} percentile ozone concentrations at Sapperton were comparable to concentrations elsewhere in Metro Vancouver. The highest maximum recorded concentration of the stations included in this analysis occurred at Maple Ridge (72 ppb) and was around 20 ppb higher than seen at the other stations, except the station in Port Moody. This was generally consistent with the pattern of peak ozone concentrations observed in the Lower Fraser Valley.[9]

Average, maximum and 99^{th} percentile CO concentrations were slightly higher in Sapperton than at any of the air quality monitoring network stations examined. However, with a maximum recorded 1 hour concentration of 2.89 ppm concentrations were approximately one tenth of the 1 hour objective level of 26.5 ppm. Similarly the maximum recorded 8 hour average concentration of 1.81 ppm was well below the Metro Vancouver 8 hour objective of 8.8 ppm.

The average concentration of $PM_{2.5}$ was about the same as those measured at network stations in Metro Vancouver for the period. With the exception of Sapperton and Kensington Park, maximum $PM_{2.5}$ concentrations generally occurred on different days for each station. The maximum 24 hour rolling average concentration recorded for Sapperton compared favourably with other stations in Metro Vancouver but the 99^{th} percentile concentration was very similar across all of the stations.

Although $PM_{2.5}$ concentrations in Sapperton were slightly higher than at the nearest network monitoring station in south Burnaby, ambient air quality objectives were not exceeded at either station. It should be noted that the results shown in Figure 17 cover the period up to July 31, 2010 and therefore do not include any period in which a regional air quality advisory due to elevated $PM_{2.5}$ was in place.

More robust statistical analysis was applied to hourly data from Sapperton, City Hall and nearby monitoring network stations to determine whether the results shown in Figure 16 and Figure 17 were supported at a finer temporal level, specifically how well concentrations in New Westminster were represented by measurements from nearby monitoring network stations most of the time. Results from these statistical analyses (Appendix A) indicated that there was generally a moderate correlation between Sapperton and the monitoring network stations.

Correlation coefficients were generally weak to moderate between study stations and network stations, the exceptions being for $PM_{2.5}$ at Sapperton compared to Burnaby South during fall 2009 and summer 2010 (strongly correlated), for NO at Sapperton compared to North Delta in winter 2009 (strongly correlated), and for CO at Sapperton compared to Kitsilano (very weakly correlated). City Hall data generally correlated strongly with data from Sapperton, the only exceptions occurring for NO and $PM_{2.5}$ in the summer period, both of which showed moderate correlation. Correlations between City Hall and the Parkade site were moderate, with the exception of NO in the summer which was weakly correlated. Concentrations at City Hall were weak to moderately correlated with Burnaby South (the nearest network station) except for both ozone and $PM_{2.5}$ in the fall-winter period of 2009.

Of the nearest stations, Burnaby South consistently showed better correlation with Sapperton than the other nearby stations except for NO concentrations. The strongest correlation for NO was found between Sapperton and North Delta.

The diurnal profiles of nitrogen oxides and ozone at Sapperton and air quality monitoring network stations in south Burnaby, north Delta and east Surrey (Figure 18) were scrutinized to determine whether the profiles could help explain the differences in correlation.

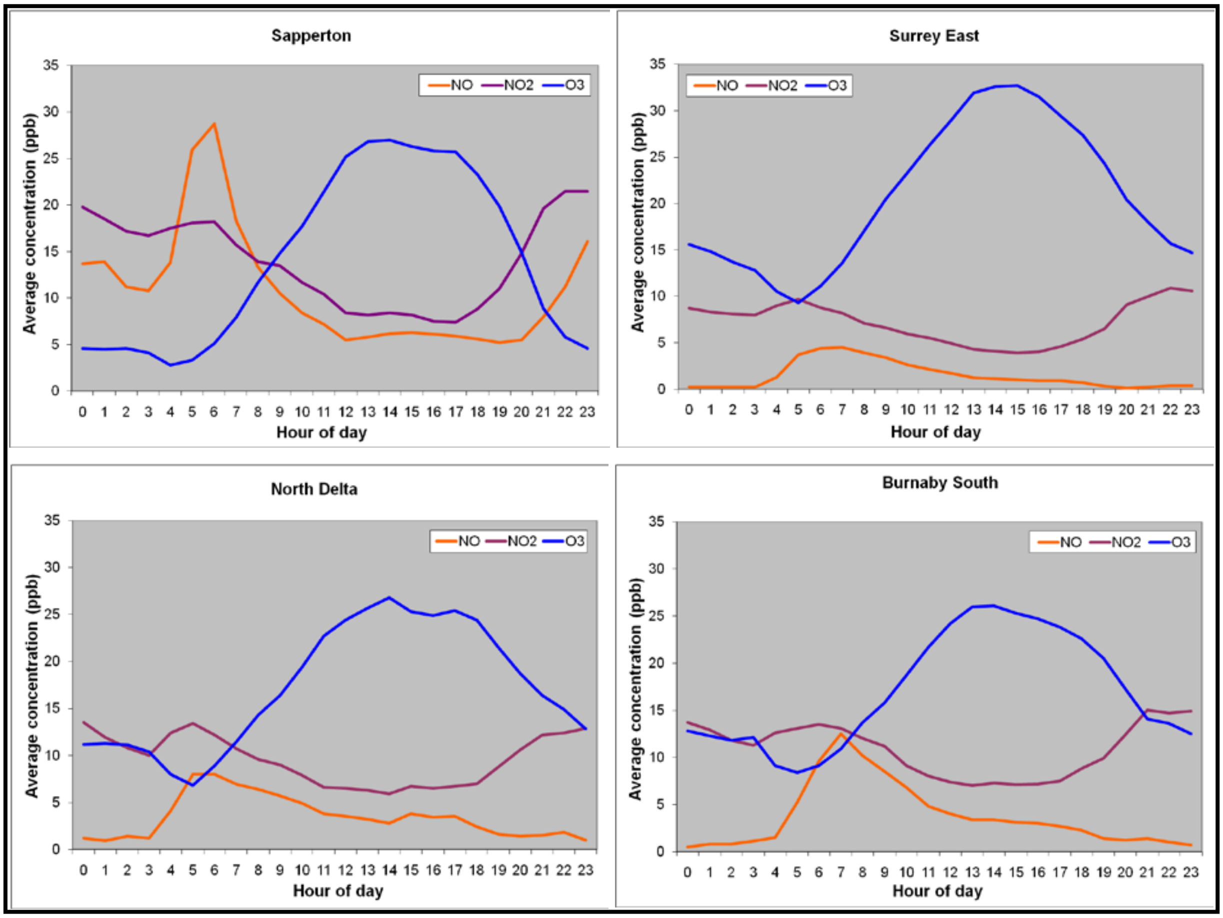


Figure 18. Diurnal profiles of nitrogen oxides (NO and NO_2) and ozone at Sapperton and three nearby air quality monitoring network stations. Each chart shows the average concentration of each pollutant for the period June 29th – July 31st, 2010.

The general shapes of the curves shown in Figure 18, indicating the times at which maximum and minimum concentrations occur on average, were similar for ozone and NO_2 at all stations. However, the profile for NO overnight was distinctly different at Sapperton compared to other nearby stations; at Sapperton a second concentration peak was observed that did not occur at the other three stations. This pattern is probably influenced by the elevated daytime concentrations at Sapperton compared to the other stations due to local sources such as traffic. The profiles also showed that ozone concentrations declined less overnight at network stations than at Sapperton. During the night, with the presence of higher levels of nitrogen oxides which are involved in reactions through which ozone is destroyed, ozone concentrations decline more overnight in Sapperton than at the other stations shown in Figure 18.

A correlation analysis comparing the data from the City Hall site with data from Sapperton, the Parkade site and the monitoring network station in south Burnaby was also performed (Appendix A). There was generally a strong correlation between air contaminant concentrations at City Hall and at Sapperton that was stronger than the correlations between Sapperton and the air quality monitoring network stations.

6 Air quality conditions in New Westminster

This study provided more intensive air quality measurements for New Westminster than are usually available in any municipality. The following section provides an assessment of air quality issues for New Westminster, based on this intensive monitoring study, how the identified issues may be addressed and considers what may change in future based on development projections.

6.1 Front Street

Air quality monitoring on Front Street was undertaken for an extended period to gain a better understanding of the magnitude and spatial extent of air contaminants concentrations in the vicinity of the multi-storey above-ground parkade on Front Street.

Measurements made in Sapperton provided a baseline against which to compare the measurements made on Front Street. The monitoring results showed that much higher average and maximum air contaminant concentrations were measured adjacent to the parkade at Front Street than at Sapperton and City Hall, which are areas more typical of the land-use and emissions characteristics throughout New Westminster. The concentrations measured at Front Street were also higher than those that are usually measured at air quality monitoring network stations in Metro Vancouver (Figure 16).

The monitoring data also showed that ambient air quality objectives for both NO_2 and $PM_{2.5}$ were exceeded occasionally throughout the year at the parkade on Front Street. A greater number of exceedances of the short term $PM_{2.5}$ objective occurred than of the short term NO_2 objective. When Metro Vancouver's ambient air quality objectives are exceeded air quality is considered degraded or poor; therefore the results of the monitoring carried out on Front Street for this study indicated that air quality near the parkade was poor at times.

$PM_{2.5}$ is one of the two contaminants that health experts are most concerned about in the ambient air. The other air contaminant of concern is ozone, which was not measured at this site (see discussion in section 6.2). Also, exceedances of Metro Vancouver's ambient air quality objective for NO_2 have rarely occurred in recent years in Metro Vancouver so exceedances in any location are notable departures from air quality typically expected in Metro Vancouver. For these reasons, it was important to determine why elevated air contaminant concentrations occurred in this location.

In looking for possible explanations for poor air quality events in the vicinity of the parkade, consideration was given to regional influences on air quality, the nature of the Front Street area and air emissions sources specific to the locale. Factors considered include:

- *Regional air quality degradation*

  Occasionally, air quality deteriorates across the region. This may be driven by meteorological conditions or by large sources of air contaminants outside the region. For example, during this study, in the summer months of both 2009 and 2010 elevated $PM_{2.5}$ concentrations occurred at air quality monitoring network stations throughout the Lower Fraser Valley due to smoke from forest fires transported from other regions in B.C. and the USA. In fact, air quality across the region deteriorated sufficiently in August 2010 that two region-wide air quality advisories were issued because of elevated $PM_{2.5}$ levels. However whilst exceedances of ambient air quality objectives in 2009 and 2010 at stations in other Metro Vancouver communities only occurred during these advisory periods, exceedances at the Parkade site occurred both during the advisories and at other times throughout the year. This important finding indicated that there are some unique factors that influenced conditions at the Parkade site.

- *Land use*

  Land use affects the types of activities carried out in an area. Some activities, e.g. manufacturing industry, may be associated with specific sources of air contaminants whilst others, e.g. residential housing, may contain many different sources of a range of air contaminants. In New Westminster a number of different land uses can be found on the Fraser River including industrial, residential and commercial areas as well as transportation routes.

  In terms of air contaminants, the monitoring was focussed on PM and NO_2, both of which are emitted into the air when fuel is burned through a variety of processes commonly found in different land uses. Although neither fuel combustion processes nor these air contaminants are unique to this area, due to the distinctive context of air quality on Front Street it is instructive to individually examine the sources contributing emissions in this area.

  ❖ *Area and mobile sources*

  The term ‘area sources’ refers to widespread emissions from light industrial, residential, commercial and institutional sources, such as emissions associated with heating buildings. Area sources do not generally require an air discharge permit from the regulatory authority (Metro Vancouver). Mobile sources include transportation (road, rail, marine and air) and non-road engines such as construction equipment. Due to the diffuse nature of these sources, many are not easily controlled by regulations or permits for each source, however, initiatives such as the AirCare program and federal fuel standards have been effective in reducing emissions of air contaminants from these sources. In addition, in February 2011 Metro Vancouver’s Board adopted a Non-Road Diesel Engine Emission Regulation Bylaw to reduce emissions of harmful air contaminants from industrial and construction equipment.

  Even though each individual source in the mobile or area source category may comply with all relevant emissions controls, the number of individual sources is not controlled by regulation and therefore as numbers increase, air quality may be adversely impacted. Collectively the emissions from area and mobile sources add up to a significant proportion of the total emissions in the region.

- *Industrial sources*

There are several industrial facilities in New Westminster and nearby communities from which emissions of air contaminants into the air are authorized by Metro Vancouver. Such facilities are regulated by Metro Vancouver and must comply with the relevant bylaws, regulations and permits that are designed to protect air quality and the environment.

Industrial sources are located in fixed positions and therefore tools such as analysis of wind data and dispersion modelling can be used to determine whether specific sites are a major contributing source of air contaminants in an area.

- *Meteorology*

Meteorological data is used to help interpret the impacts of known emissions sources on air quality and is collected at monitoring network stations routinely. The dispersion of air contaminant emissions from a source can be affected by meteorological conditions. During calm, stable conditions, atmospheric mixing is inhibited and therefore air contaminant concentrations can build up.

Meteorological conditions at the Front Street site were not recorded due to the difficulty in obtaining representative measurements amongst buildings along and adjacent to Front Street. However, meteorological data were available from nearby monitoring network stations.

- *Built environment*

The characteristics of buildings in an area can affect air quality by locally altering air flow and thereby restricting the mixing that is important for dispersion of air contaminants from emissions sources.

‘Urban canyons’ in which air contaminant concentration can vary widely within very short distances typically have very complicated air flows. Although the area in the vicinity of the parkade on Front Street is not a classic urban street canyon, Front Street runs under the parkade structure, which inherently restricts vertical mixing, and is adjacent to a row of tall buildings located at the bottom of a steeply rising terrain. The structures are likely to further inhibit dispersion of air contaminants emitted under the parkade.

6.1.1 The effect of sources on air quality on Front Street

Based on the 2005 emissions inventory, over one third of nitrogen oxides (NOx) emissions in Metro Vancouver can be attributed to light duty and heavy duty vehicles.[10] The proximity of this site to a major traffic route which is a designated truck route, the lack of clear seasonal pattern in exceedances and the absence of exceedances at other nearby monitoring sites all suggested that proximity to traffic and an artificial ceiling on contaminant dispersion probably had a significant influence on concentrations of air contaminants at this site.

In support of the influence of proximity to traffic, the similarities between the diurnal profile of air contaminant concentrations and historical traffic count data provided strong evidence. Looking at the diurnal profiles of pollutant concentrations from the Parkade site, a clear signature of high concentrations during the day on weekdays was apparent. Averaged over the entire study period there was a consistent difference between peak concentrations on all weekdays and any weekend day so it was very unlikely that meteorological influences could be the cause. It is clear that daytime emissions sources were likely to be strongly influencing air quality in this location. Typically sources expected to be more active during the day on weekdays than weekends are those related to business and commercial activities such as the transportation of goods.

The types of vehicles using the road influence the emissions and hence the air contaminants present in the immediate vicinity. Patterns in the absolute concentrations and relative proportions of various air contaminants can be instructive. Heavy duty vehicles, expected to be prevalent at this site due to the designation of the road as a truck route, are often powered by diesel engines, which are high emitters of $PM_{2.5}$ and black carbon. However, railway locomotives and marine vessels are also known sources of $PM_{2.5}$ and black carbon, both of which are present in this part of New Westminster.

Measurements of the black carbon fraction of $PM_{2.5}$ can provide a useful indication of the presence of diesel engine emissions. Analysis of the monitoring data showed that up to half of the $PM_{2.5}$ was attributable to black carbon. In addition, the diurnal profiles for NO_2, $PM_{2.5}$ and black carbon indicated that peak concentrations coincided with peak traffic volume. These results strongly suggested that diesel engines influenced average air quality under the parkade. However, during exceedances of the short term $PM_{2.5}$ objective, concentrations of black carbon were generally similar to the rest of the time, indicating that diesel engines were not the sole cause of poor air quality.

It was clear from the monitoring results that in the vicinity of the parkade there was a relatively high baseline of $PM_{2.5}$. At 4 $\mu g/m^3$ the long-term average concentration of black carbon alone was at a level similar to the long-term average values for total $PM_{2.5}$ expected at network monitoring stations. The presence of small additional amounts of $PM_{2.5}$ would cause objectives to be exceeded. This additional $PM_{2.5}$ may come from the other localized emissions associated with vehicles through secondary formation and suspension of very fine road dust, other emissions in the area such as heating and construction activities, or sources affecting the whole region such as transported smoke from forest fires occurring hundreds of kilometres away.

An interesting result from the monitoring was that during periods in which heavy-duty vehicle traffic volumes were expected to be lower than usual, e.g. December 25 – 27, 2009 (shown in section 5.1.3), as expected $PM_{2.5}$ contained a much smaller proportion of black carbon. In addition, measurements of UV absorbing particulate matter increased during this period. The presence of UV absorbing particulate matter at concentrations higher than concurrent black carbon concentrations has been associated in the literature with the presence of woodsmoke.[11] This could arise from activities such as residential heating or open burning, with the former being the more likely source in this particular holiday period. As the area around the parkade is dominated by commercial buildings, the roads, the railway and the river, this observation suggested that there may be some transport of $PM_{2.5}$ from surrounding residential areas in which wood burning from home heating is taking place.

A relatively small number of locomotives (30 trains per day) travelled on the tracks adjacent to Front Street whereas based on traffic volume surveys the number of vehicles on Front Street is fairly constant during the day. As the timing of train movements could not be determined, it was not possible to examine the data for evidence of locomotive emissions specifically and there was no clear indication from the data analysis of the relative significance of train emissions on air quality at the two sites.

Preliminary analysis of the monitoring data suggested that exceedances did not appear to correlate with a particular wind direction exclusively and therefore industrial facilities could not be associated with air quality objective exceedances specifically.

6.1.2 Dispersion of air contaminants and spatial extent of air quality degradation on Front Street

Between sunrise and sunset, conditions are generally expected to be more favourable for dispersion of air emissions than at night. Furthermore, lower mixing heights occur in the winter, restricting dispersion. Higher concentrations in diurnal profiles in the winter (Appendix B) for all measured air contaminants indicated that atmospheric mixing played a role in air quality conditions found here. However, since exceedances occurred throughout the year it was reasonable to look at factors that do not change seasonally. The most obvious seasonally fixed barrier to effective dispersion in this location was the presence of the parkade structure. Comparison of the data from the UFCW site with concurrent measurements from the Parkade site was used to investigate the hypothesis that the parkade structure may adversely affect air quality at that location.

Concentrations at the UFCW site were much lower than those measured at the Parkade site. A number of factors could have contributed to this observation, including a change in the distance of the sampling site to sources, such as vehicles on Front Street, and to differences in dispersion.

From reports in the literature on spatial concentration gradients of various air contaminants near roads it is known that concentrations can drop rapidly as distance away from the road increases.[12] The results from the Parkade and UFCW sites were generally consistent with these reports. However, it is also known from these reports that the behaviour of these concentration gradients is affected by other factors such as whether a sampling site is upwind or downwind of the source, time of day and season. In addition, few of these reports have sampled at multiple discrete distances less than 50 metres. Since the difference in distance from the road of the Parkade site and the UFCW site was approximately 20 metres there is some uncertainty about how large a decrease in air contaminant concentrations at the two sites due solely to distance should be expected. It therefore remained possible that the surrounding built environment had an effect on measured air contaminant concentrations at the two sites.

The UFCW site was situated further away from the road but closer to the railway tracks than the Parkade site. In addition, the railway track does not run within the confines of the overhead parkade and therefore there may be fewer meteorological conditions that would enable air emissions from locomotives to be trapped by the parkade, although no meteorological data were available from the parkade to investigate this in detail. It had to be considered whether locomotive emissions could have had a greater influence on air quality at UFCW than the Parkade site.

During temporary closures of the road where the train tracks cross the road at the end of the parkade, vehicles are generally queued on Front Street in both directions. Traffic count data from the 2009 survey indicated that eastbound and westbound volumes were approximately the same and so emissions due to idling vehicle engines were not expected to be significantly different beneath the parkade and on the stretch of road not covered by the parkade nearest to the UFCW site. Because engines are left running, traffic related emissions may not be significantly reduced when trains are passing.

It seemed likely from the results available that a combination of these factors including the absence of the parkade structure played a part in the reduced air contaminant concentrations observed at the UFCW site compared to the Parkade site. It should also be noted that the sampling carried out at the UFCW site was limited in duration and therefore under different meteorological conditions at a different time of year monitoring results may have provided a different picture.

No evidence of the impact of air quality adjacent to the parkade extending through the city to the City Hall was found. Data from City Hall and the Parkade site generally showed a weak to moderate correlation. In particular the correlation between City Hall and the Parkade (distance approximately 0.5 km) was generally weaker than the correlation between City Hall and south Burnaby (distance approximately 5 km). This suggests that although some common influences were seen at all of these stations, air quality at City Hall was not likely to be influenced by conditions on Front Street.

The extent of the impacts of traffic on air quality on Front Street appeared to be limited to a localized area and it was surmised from the considerably lower air contaminant concentrations at the UFCW site than at the Parkade site that the area affected by the worst conditions did not extend a large distance beyond the parkade structure.

It is likely that the parkade structure itself causes a build-up of air contaminant levels by suppressing dispersion of the emissions from vehicles on the road underneath the structure but a comprehensive assessment of air flow movement and dispersion within the parkade would be necessary to provide a complete picture. In addition to horizontal variation, considerable vertical variability is likely to occur such that air contaminant concentrations at different heights within the parking garage structure or at openings on different floors of the buildings on Front Street may be markedly different.[13] Due to the complexity of air flow in this location it is unlikely that further monitoring could provide more complete picture of air contaminant concentrations than was available from this study, with the possible exception of finer temporal analysis along with train movement timing information to determine whether a locomotive signature can be observed. Air quality modelling (i.e. computer simulation) of this complex location, although challenging, could provide more information on the extent of degraded air quality in the vicinity of Front Street and the relative importance of the sources.

6.2 Sapperton and City Hall

Air quality monitoring data from New Westminster at sites other than the Parkade site were in line with the air quality conditions generally expected to be observed in Metro Vancouver. The results from Sapperton and City Hall provided an opportunity to examine the factors most likely to be affecting air quality in the area.

6.2.1 Emissions sources and air quality in Sapperton and at City Hall

A complex air quality picture is to be expected in urban areas in which land use changes over very short distances and few large emissions point sources are present. The Metro Vancouver 2005 emissions inventory was used as a starting point for determining likely sources of the air contaminants monitored in the course of this study.

The 2005 emissions inventory indicated that in Metro Vancouver mobile emissions were the largest single source of emissions of nitrogen oxides (NOx) and were also a significant source of particulate matter. In terms of land-use, roads, lanes and rights of way account for 415 hectares in New Westminster. This represents 26.5% of the land area, the highest proportion for any municipality in Metro Vancouver. Furthermore, due to the location of New Westminster at the heart of Metro Vancouver sandwiched between the larger municipalities of Burnaby, Coquitlam, Delta and Surrey, in addition to the traffic associated with the movements of local residents and visitors, many vehicles pass through New Westminster. Therefore traffic was expected to be an important source of air contaminants and as such, traffic volume information was needed to better understand this potentially important source of air contaminants.

Traffic survey data were made available by the City of New Westminster for the purpose of examining traffic volumes in conjunction with the monitoring data collected during the study. Information from the City of New Westminster was also used to verify that the section of Columbia Street East that runs past Sapperton Park, the location of the Sapperton study site, is a designated daytime truck route. Therefore impacts on air quality from traffic, particularly heavy duty vehicles, had to be considered for this area.

Weekend air contaminant concentrations were generally lower than weekday concentrations which could have suggested an association with traffic, particularly commuter and business traffic, but these profiles were not fully consistent with the traffic count profiles. Traffic volume profiles from Columbia Street showed that on weekdays vehicle numbers rose quickly in the morning at around 7 am before increasing steadily to a peak in mid afternoon, whereas on weekends the increase in volume occurred later in the morning but peaked at approximately the same time with almost the same volume as on weekdays. In contrast, the study average air contaminant diurnal profiles for both $PM_{2.5}$ and NO_2 (Figure 15) showed distinct morning and evening peaks. Therefore a simple relationship tying air contaminant concentrations to traffic volume could not be assumed. It is likely that changing meteorological and dispersion conditions throughout the day confounded the relationship.

No vehicle classification data were available to determine whether commercial truck traffic dominated traffic volume. In lieu of vehicle classification data, as noted previously, heavy-duty vehicles are particularly associated with $PM_{2.5}$ while both light-duty vehicles and heavy-duty vehicles can be sources of NOx. Although measurements of black carbon particulate matter, which is particularly associated with diesel engines, were not made at the Sapperton site, $PM_{2.5}$ measurements can indicate whether heavy-duty vehicles are adversely affecting air quality in an area. Since $PM_{2.5}$ did not generally exceed ambient air quality objectives and average concentrations were similar to those found at air quality monitoring network stations, the results from this study indicated that commercial truck traffic did not have a major impact on air quality at the Sapperton site.

The seasonal diurnal profiles for NO were analyzed (Appendix B). These are particularly informative as NO is a primary pollutant strongly associated with fuel combustion emissions. NO is also rapidly transformed in the air in a complex series of reactions involving NO_2 and ozone as well as the presence of sunlight.

Diurnal NO concentration profiles showed one major peak in the morning related to the onset of daily vehicle traffic. A rapid decline followed in mid-morning due to a slight reduction in traffic volumes and more importantly increased dispersion and mixing. Furthermore, chemical processing during daylight hours acts to reduce NO concentrations. Therefore, the results were consistent with traffic sources but other sources of NO could not be excluded.

It was noticeable that in the comparison with data from other stations, ground-level ozone concentrations were generally lower than concentrations found at other locations in Metro Vancouver. This can be explained by considering the reactions that occur between ground-level ozone and NO which effectively reduce ground-level ozone concentrations in the presence of high concentrations of NO. This pollutant behaviour is characteristic of urban areas in which traffic emissions dominate. Therefore the study results indicated that traffic played a significant role in air quality conditions in the area.

The $PM_{2.5}$ concentration profiles at Sapperton during night-time periods were examined to help explain the role of other sources on air quality. As there was little difference between weekday and weekend overnight concentrations, business traffic could not provide an adequate explanation for the measurements. Consequently, given the mixed land use of the area and the monitoring results, other factors that could contribute to air quality conditions in New Westminster had to be considered.

Based on the emissions inventory, other major sources of $PM_{2.5}$ include heating, burning and construction as well as marine vessels and non-road engines. Non-road engines can be a significant source of $PM_{2.5}$ and specifically the black carbon fraction. However, these sources would generally be expected to predominate during the day, when equipment is being used for activities such as construction.

Due to the similarity of concentrations of $PM_{2.5}$ on weekend nights and weekday nights as well as the residential land use in the area, the most likely local source of $PM_{2.5}$ in the area was heating. As indicated in section 6.1, the presence of UV absorbing particulate matter can be associated with wood smoke, however measurements of UV absorbing particulate matter were not made at the Sapperton site. Wood smoke can be a significant source of $PM_{2.5}$ in areas predominantly consisting of single family homes but, in Sapperton, in addition to single family homes, high and medium density housing is present, as well as a major institution (Royal Columbian Hospital), all of which are less likely to be heated by wood. The range of building types in the area suggests that a variety of sources of heating related $PM_{2.5}$, including wood and natural gas, may contribute to air quality conditions.

The data from the City Hall site were available from a much shorter period than Sapperton but more species were monitored. In particular, particulate matter monitoring was enhanced by the addition of black carbon and UV absorbing particulate matter measurements. As Royal Avenue is a designated truck route, black carbon and $PM_{2.5}$ measurements were intended to be used to determine whether a signature from heavy duty vehicles was present and assess any effects on air quality in the area.

The monitoring results did not provide clear-cut evidence that commercial truck traffic was a significant source of air contaminants in the area. In addition, traffic survey data indicated that a greater number of vehicles used parts of Royal Avenue than Front Street and these appeared to be predominantly light duty vehicles. Although the vehicle classification survey was not carried out in the immediate vicinity of the City Hall, potentially causing some deviation from the survey in the actual vehicle types passing the site, the traffic profile at the City Hall site was not expected to be significantly different in terms of the volume of heavy duty vehicles passing the site.

6.2.2 Air quality in New Westminster

Since the monitoring periods at City Hall were limited, the data were compared from this site and Sapperton to better understand how much variability in air quality occurred in New Westminster. It is important to note that traffic survey data from Columbia Street East (near the Sapperton site) showed that the weekend traffic pattern was similar to Royal Avenue (near the City Hall site) but weekday traffic volumes increased sharply in the morning and continued to increase to a peak in the late afternoon before declining through the evening and overnight, i.e. only one clear maximum was present. In contrast, traffic survey data for Royal Avenue showed two peaks in traffic volume, one in the morning and one in the evening, that was not observed in Columbia Street survey data. This latter pattern is commonly associated with commuting activity rather than movement of commercial vehicles. Therefore it was an interesting finding that in spite of the linkage between traffic patterns and air contaminant concentrations and the differences in traffic profiles between the two sites, the correlation analysis and maximum and average concentrations of air contaminants in Sapperton and at City Hall indicated that air quality was similar in these two locations.

Factors such as similarities in temporal emissions profiles of localized sources, for example due to commuter traffic, may influence correlation so care must be taken to account for these factors when determining the representativeness of conditions in different locations. However, the monitoring results suggest that in general:

- Air quality in Sapperton and at City Hall is generally similar;
- People are exposed to similar emissions sources in Sapperton and at City Hall.

Given the observed differences in traffic patterns between the two locations, the similarity of the results from these two sites overall suggested that sources of air contaminants other than those already discussed and factors affecting the regional patterns of air quality behaviour probably also influence conditions more widely in New Westminster. These regional factors, which include the topography of the Lower Fraser Valley and the location of the region on the coast, are discussed in more detail in other publications.[14]

A comparison of monitoring results from New Westminster with other locations in Metro Vancouver was applied to determine whether the similarities between City Hall and Sapperton were obviously different from the general similarities expected to be observed at stations throughout the region.

Although contaminant concentrations were below the levels of concern that would be indicated by exceedances of ambient air quality objectives, concentrations of CO, NO and NO_2 were higher in Sapperton than other stations in Metro Vancouver. These air contaminants are related to fuel combustion sources and the elevated concentrations are most likely the result of slightly higher traffic sources in New Westminster. In contrast, the average ozone concentration was generally lower in Sapperton than those measured elsewhere in the network. This is probably due to the presence of high NO concentrations which reacts in the air to decrease ozone. In addition, the correlation between Sapperton and other monitoring stations was clearly weaker than between Sapperton and City Hall. This suggested that although it is believed that air quality in New Westminster is subject to region-wide influences, it has its own local characteristics and as a consequence data from nearby monitoring stations do not necessarily represent conditions in New Westminster well all the time.

6.3 Emissions projections

Although air quality is generally good in the region, at only moderately degraded levels, air quality is thought to start affecting people who are sensitive to the effects of air pollution. People who are considered most susceptible to the effects of air contaminants include infants, the elderly, and people with a variety of medical conditions such as heart disease, asthma or respiratory disease. Therefore it is important that the assessment of air quality in New Westminster based on monitoring results includes a consideration of population changes in the area as well as factors affecting current and future emissions.

Factors that may affect emissions in the future in this region, including New Westminster, are population growth, development, transportation plans and city planning activities. There is some uncertainty associated with emissions projections because improvements in technology or more stringent regulation of emissions sources may offset growth-related emissions. This is accounted for in emissions inventories by the inclusion of “high” and “low” emissions scenario forecasts, usually based on the state of knowledge (e.g. pending legislation) at the time the inventory is compiled but events and technological breakthroughs may occur that are not easy to predict accurately, if at all.

6.3.1 Traffic

Traffic count data from Front Street indicated that a large increase in traffic volume occurred between 2006 and 2009. Although traffic volume is expected to grow at 1-2% per year [8], the difference in the number of vehicles between 2006 and 2009 on Front Street exceeded this by a large margin. In contrast, traffic count data from Sapperton for 2007 supplied by the City of New Westminster showed that more than 13,000 vehicles travelled on Columbia Street in the vicinity of the Sapperton site whereas traffic counts carried out in 2010 on a section of Columbia Street just to the north of the Sapperton site indicated that daily vehicle numbers were just under 13,000, suggesting that volumes had remained steady.

It is clear from information about emissions for individual vehicles that in general vehicles have become cleaner over time. In spite of increases in vehicle numbers in the region, there have been improvements in air quality with respect to the air contaminants attributable to vehicles; long-term trends for NO_2 and CO show improvements across the region which have been attributed to the decrease in emissions from vehicles. Furthermore, the size and propulsion systems of vehicles on the road can change the amounts of air contaminants emitted. Therefore, it is not certain that if traffic volume increases significantly air quality will be adversely affected.

Another traffic issue that should be considered is alterations to road use brought about by planning changes. Traffic engineering or planning studies may be able to better assess whether reductions in vehicle idling through improvements in traffic flow could be beneficial to air quality. However, although a number of proposals that are relevant to traffic patterns in New Westminster, such as the North Fraser Perimeter Road project, have been suggested, insufficient information on these has been available to make any assumptions about what effect if any these proposals could have on air quality.

6.3.2 Population change

Population change has been considered in this assessment for two important reasons. Firstly, as population increases, the number of people exposed to air contaminants increases and also the number of people who are most susceptible to the adverse impacts of air contaminants may increase. Secondly, as population increases, sources of air contaminants may increase.

The municipality of New Westminster as a whole is one of the most densely populated municipalities in Metro Vancouver. Population growth is projected to be modest in many areas of New Westminster however some areas within New Westminster are expected to see considerable increases in population due to development activity. For example, in Sapperton redevelopment of two sites for residential housing and mixed-use development in the Brunette Avenue - Columbia Street East area are all expected to bring more people to live in the area. In addition, the development of business parks and other comprehensive development plans in Sapperton in particular may bring more people to the area during the day for work. With current air quality in Sapperton, the impact to the general population of exposure to air contaminants is not expected to differ significantly from other parts of the region.

On Front Street, in the vicinity of the parkade, air quality is occasionally significantly more degraded than other parts of the region. Although this area currently has a relatively low residential population, proposed development plans for the waterfront include the construction of high density housing which could increase the population in the area. Furthermore, since air contaminant concentration tend to be highest during the day, daytime visitors to the area, such as employees and shoppers, may be exposed to poorer air quality than people working in other parts of the region. Any development that encourages more visitors to the area around the parkade may increase the risk of adverse impacts from air contaminants unless air quality is improved in this area.

Facilities at which people most susceptible to air quality are found are of particular interest when considering the impacts of air quality. Locations in which the people most vulnerable to air contaminants are most commonly found include hospitals, senior centres, daycares, schools and play areas located next to busy roads. Examples of facilities in which the people most susceptible to the effects of air contaminants can be found are common in many urban and suburban areas including in New Westminster. Sapperton Park, located on East Columbia Street, was the location of the Sapperton monitoring site. On Front Street, the development of a waterfront park next to the parkade may include play areas and walkways.

Care should be taken to use the best available planning and development guidelines to both minimize exposure to degraded air quality and to minimize the sources of air contaminants. The BC Ministry of Environment's 'Develop with Care' document [15] provides specific guidance on maintaining a healthy environment with respect to air quality whilst planning for development to meet the needs of a growing population. Building on a Ministry of Environment initiative, actions contained within Metro Vancouver's 2011 Integrated Air Quality Greenhouse Gas Management Plan (IAQGGMP) will encourage collaborative projects between government agencies to develop locally relevant land-use planning and urban design strategies to protect the health of the general public with special consideration for the people most susceptible to health impacts from air contaminants. Strategies for reducing air contaminant emissions from a wide range of sources are also included in the IAQGGMP under Goal 1 – protect human health and the environment. Actions within Goal 1 will help to maintain emissions reductions as the region's population grows.

6.4 Study limitations

The effects of air quality on residents of New Westminster will depend in part on where they live, work and play. It is a limitation of this study that all measurements were carried out relatively short distances away from truck routes. Concentrations of air contaminants around roads due to vehicles tend to decrease with distance away from the road. Therefore it is possible that air contaminant concentrations are lower in more residential areas with quieter streets than measured at the Sapperton and City Hall sites.

With the exception of air quality hotspots such as the parkade area of Front Street, it is expected that overall air quality conditions are generally no worse in other parts of New Westminster than in Sapperton. The Sapperton site was somewhat typical of air quality monitoring network stations which are located to ensure that measurements are representative of the surrounding area with minimal influences from very localized sources. However, the Sapperton site was close to a busy road which is also a designated truck route. Therefore the monitoring results from the Sapperton site may provide a worse picture of air quality than residents and visitors in areas away from main roads are exposed to most of the time.

7 Conclusions

Air quality in Metro Vancouver is generally good but periods of degraded air quality occur occasionally, usually in the summer months. The results from this study suggest that, as the air quality monitoring network indicates for Metro Vancouver in general, air quality in most of New Westminster is not a serious concern most of the time. However, it is recognized that in some locations local sources exert an adverse influence that causes poorer air quality than is experienced in the region as a whole. This was particularly apparent in the vicinity of the parkade on Front Street.

Monitoring data collected over a period of 20 months indicated that in the vicinity of the parkade on Front Street ambient air quality objectives can be breached at any time of year, even when air quality conditions in the region as a whole are within ambient air quality objectives. Emissions from heavy-duty diesel vehicles on the Front Street truck route are a significant source of air contaminants. However, the parkade structure restricts dispersion of emitted air contaminants and therefore is also a major contributor to degraded air quality.

These results therefore confirm the findings of the study carried out near Front Street in New Westminster in 2004, namely:

- Exceedances of air quality objectives for fine particulates and nitrogen dioxide occur periodically.

- Concentrations of nitric oxide and fine particulates are higher on weekdays than on weekends.
- Levels of nitric oxide, nitrogen dioxide and fine particulates are higher than at the LFV network fixed monitoring stations.

The 2009-10 study work has resulted in a clearer understanding of the seasonal and spatial characteristics of air contaminant concentrations than could be obtained from the results of the 2004 study.

Although ambient air quality objectives were exceeded on Front Street on numerous occasions at any time of year, the highest concentrations of air contaminants occurred during the day on weekdays which suggested that sources related to business and commercial activities significantly influenced air quality in this location. Further assessment of conditions away from the confined area under the parkade indicated that the presence of the parkade structure probably played a significant role in restricting dispersion of emissions. It was shown that as distance increased away from the parkade and the road, concentrations decreased and therefore the air quality conditions around the parkade on Front Street are considered a localized issue.

Measured air contaminant concentrations in New Westminster during this study were better than Metro Vancouver's ambient air quality objectives most of the time. Away from the parkade on Front Street, degraded air quality, as defined by exceedances of ambient air quality objectives only occurred during the study when concentrations of fine particulates were elevated by transported smoke from forest fires in the interior of the province. The only exceedances of air quality objectives at the Sapperton and City Hall monitoring sites occurred during one of these periods, in contrast to the exceedances of the objectives for both nitrogen dioxide and fine particulates that occurred occasionally at the Front Street Parkade site throughout the year. Therefore it can be concluded that in most of New Westminster, air quality is generally acceptable when compared to air quality objectives.

Air quality conditions at the two locations investigated in Sapperton and at City Hall were found to be generally very similar but results suggested that air quality conditions in New Westminster differ slightly from those recorded by stations in the air quality monitoring network. Specifically, air contaminant concentrations in Sapperton compared to nearby stations in Burnaby and North Delta indicated that gaseous contaminant concentrations were not well represented. While the air quality levels appear to be quite similar in terms of long-term averages and short-term peak concentrations, there are likely to be local influences in the Sapperton area (and possibly throughout New Westminster) that cause the daily air quality patterns to differ from nearby stations.

Some strongly localized effects may occur in any location but air quality monitoring data from the network is considered to represent what a person may be exposed to in the area in general. There are indications from measurements of primary pollutants that local emissions influence air quality in the area. Therefore the results from this study suggest that air quality conditions in Sapperton could probably be better represented by locating additional monitoring in New Westminster for the gas phase air contaminants.

Based on the expected population growth and therefore the potential for increased numbers of people who are sensitive to air quality degradation it will be important to maintain a clear understanding of air quality conditions in New Westminster over the coming years.

8 Recommendations

Degraded air quality is of most concern when people or the environment may be adversely impacted. It may be difficult to improve air quality quickly due to the need to find the most effective solutions to address a complex issue, which may span across several areas of jurisdiction from local and regional government to provincial and federal government agencies to specialist organizations. Therefore interim actions may be useful to mitigate the effects of degraded air quality on human health.

Specific recommendations based on the results of monitoring carried out on Front Street, in Sapperton and near New Westminster City Hall have been provided below.

As an outcome of the 2009-10 New Westminster Air Quality Monitoring Study, the following recommendations should be considered:

1. Actions should be taken to reduce exposure of people to the air quality conditions present under the parkade on Front Street:
    a. Use of land use planning guidelines and best practices for development around the Front Street parkade may mitigate the effects of local emissions and help minimize exposure to air pollution in the area.
    b. Involvement in the cross-agency partnership developing urban design guidelines may be a useful means to explore further options for reducing exposure to traffic.
    c. Options to improve dispersion of air contaminants around the parkade may be evaluated. It is likely that this would involve major changes to the structure and therefore a modelling study may be a useful way of determining the effectiveness of different alternatives under this course of action.
2. Based on the study results and in recognition of New Westminster's high population density and the expectation for continued community growth, especially around Sapperton and the waterfront, Metro Vancouver should consider options for ongoing monitoring in New Westminster. This may be achieved through one or more initiatives, including:
    a. Periodic deployment of air quality monitoring equipment in New Westminster to compare conditions to the baseline established by this study. Metro Vancouver is increasing capacity for undertaking localized studies with portable or mobile monitoring equipment. These studies can allow for greater spatial coverage and more flexibility than a single fixed station.
    b. Establishing a fixed station as part of the longer-term planning for the coverage offered by the Lower Fraser Valley air quality monitoring network.
    c. Being part of a federal government pilot program (under Environment Canada's National Air Pollution Surveillance Program) to develop a

strategy for air quality monitoring near roadways and to better understand the population's exposure to emissions from traffic. As Metro Vancouver has just initiated discussions with the federal government on this program, the details are not yet clear.

Appendix A Correlation analysis

Correlation analysis provides an indication of how well concentrations at a given location can be predicted using data from another location. This analysis was carried out to determine how representative measurements from the ambient air quality monitoring network are of ambient air quality conditions in New Westminster.

Using the methodology developed by Reuten et al for the Lower Fraser Valley ambient air quality monitoring network review the influence of diurnal patterns on contaminant concentrations was removed by subtracting the mean diurnal profile from each data point prior to running the correlation analysis .[16] Samples of the data were also examined to ensure that the use of a statistical calculation based on a linear relationship was valid.

The results for Sapperton are shown in Table A-1 to Table A-5 below. Table A-6 shows the results from the correlation analysis performed with the data available from periodic sampling by MAMU at New Westminster City Hall.

Table A-1. Correlation data (r^2 values) for the comparison of measured seasonal NO_2 concentrations at the Sapperton station with selected air quality network stations.

	Burnaby South	North Delta	Surrey East
Jan-Feb 09	0.473682	0.447382	0.202858
Mar-May 09	0.557044	0.474192	0.412605
Jun-Aug 09	0.522741	0.468149	0.423647
Sep-Nov 09	0.53331	0.393654	0.34993
Dec 09 - Feb 10	0.510709	0.407876	0.374878
Mar-May 10	0.553551	0.481267	0.420178
Jun-Jul 10	0.503621	0.309531	0.303416

Table A-2. Correlation data (r^2 values) for the comparison of measured seasonal NO concentrations at the Sapperton station with selected air quality network stations.

	Burnaby South	North Delta	Surrey East
Jan-Feb 09	0.561652	0.648839	0.385656
Mar-May 09	0.282237	0.449548	0.382888
Jun-Aug 09	0.25828	0.335776	0.210229
Sep-Nov 09	0.396248	0.384416	0.387855
Dec 09 - Feb 10	0.460408	0.532654	0.456876
Mar-May 10	0.40739	0.44991	0.310297
Jun-Jul 10	0.169464	0.187395	0.196314

Table A-3. Correlation data (r^2 values) for the comparison of measured seasonal $PM_{2.5}$ concentrations at the Sapperton station with selected air quality network stations.

	Burnaby South	North Delta	Surrey East	Kitsilano	Port Moody
Jan-Feb 09	0.559732	*Not measured at this station*	*Not measured at this station*	0.104317	--
Mar-May 09	0.538088			0.40515	0.457368
Jun-Aug 09	0.631758			0.49851	0.555253
Sep-Nov 09	0.668424			0.534242	0.608544
Dec 09 - Feb 10	0.551222			0.272643	0.546424
Mar-May 10	0.564994			0.418034	0.513797
Jun-Jul 10	0.655981			0.428369	0.463561

-- no data available

Table A-4. Correlation data (r^2 values) for the comparison of measured seasonal CO concentrations at the Sapperton station with selected air quality network stations.

	Burnaby South	North Delta	Surrey East	Kitsilano
Jan-Feb 09	0.532604	*Not measured at this station*	0.363636	0.046664
Mar-May 09	0.375016		0.34203	0.456473
Jun-Aug 09	0.437684		0.41418	0.310828
Sep-Nov 09	0.408131		0.394336	0.439058
Dec 09 - Feb 10	0.395895		0.447381	0.264582
Mar-May 10	0.426256		0.403102	0.397006
Jun 10	0.361705		0.148816	0.155828

Table A-5. Correlation data (r^2 values) for the comparison of measured seasonal O_3 concentrations at the Sapperton station with selected air quality network stations.

	Burnaby South	North Delta	Surrey East
Jun-Jul 10	0.474948	0.429776	0.467981

Table A-6. Correlation data (r^2 values) for analysis of air contaminant concentrations at City Hall compared to Sapperton, Parkade and Burnaby South sites.

	Sapperton	Parkade	Burnaby South
NO_2 Nov-Dec 09	0.749874	0.423102	0.628636
NO_2 Jul 10	0.686793	0.252941	0.338183
NO Nov-Dec 09	0.790865	0.418111	0.605626
NO Jul 10	0.437683	0.156809	0.130547
$PM_{2.5}$ Nov-Dec 09	0.786851	0.385047	0.697496
$PM_{2.5}$ Jul 10	0.622676	0.474519	0.571201
CO Nov-Dec 09	0.658996	--	0.525486
CO Jul 10	--	--	0.299507
O_3 Nov-Dec 09	--	--	0.801266
O_3 Jul 10	0.783757	--	0.483132
SO_2 Jul 10	--	--	0.209749

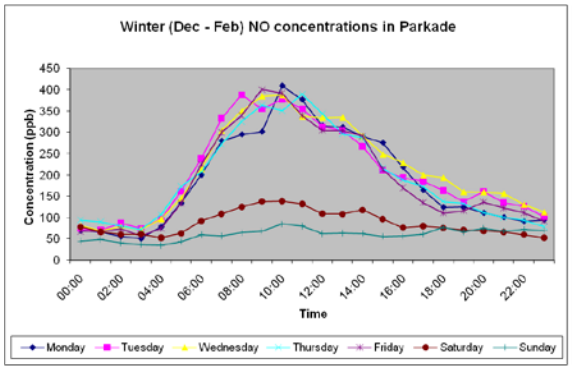
-- no data available

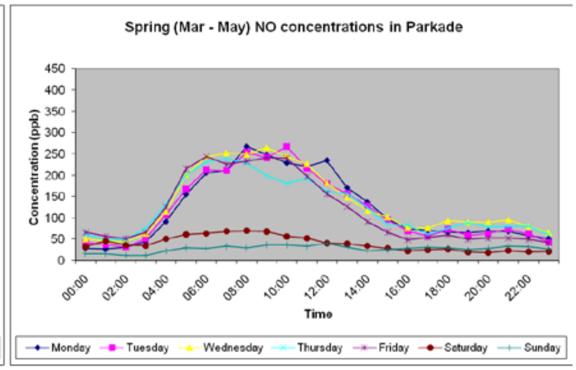
The values shown are the square of the Pearson product moment correlation coefficient (r^2) calculated from data divided into seasons (Table A-1 to Table A-5) or from each monitoring period (Table A-6). The r^2 values shown in the tables represent the proportion of variation in measurements at the study station (Sapperton or City Hall) that is explained by the variation in data from the comparison stations. For example from Table A-1, the analysis indicates that 45% of the variation in NO_2 concentrations at Sapperton in January-February 2009 can be explained by the variation in NO_2 concentrations at North Delta.

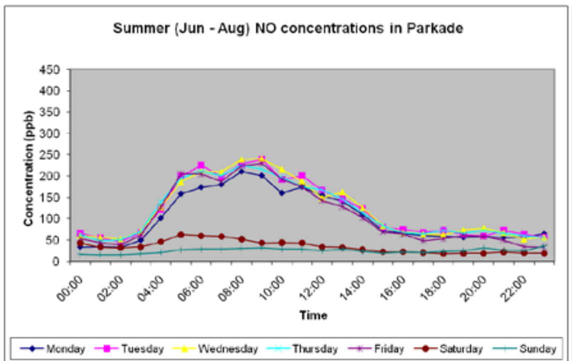
The square root of each r^2 value is the Pearson product moment correlation coefficient (r) of that value. The correlation coefficient values (not shown) were found to be greater than the critical value in all cases, i.e. the positive correlation between the study stations and the comparison stations is not random. A correlation coefficient value of 0.5 ($r^2 = 0.25$) will be considered to indicate a moderate correlation between the data sets. A correlation coefficient value of 0.8 ($r^2 = 0.64$) will be considered to indicate a strong correlation. A strong correlation increases the likelihood that the concentrations in New Westminster can be satisfactorily estimated from concentrations measured elsewhere in the network based on a simple linear relationship.

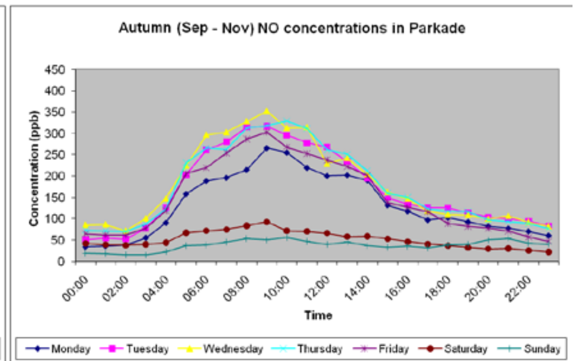
Appendix B   Seasonal Diurnal Profiles

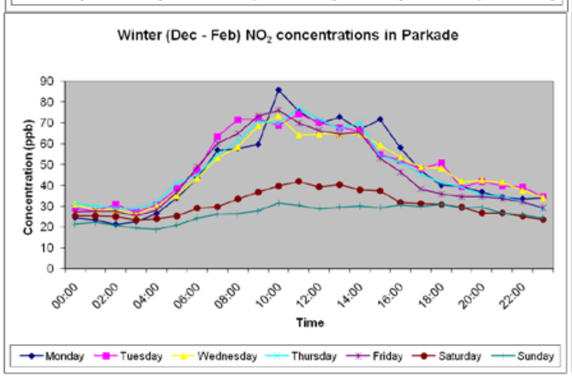
Seasonal diurnal profiles for individual air contaminants at the parkade and Sapperton sites are shown in the following charts.

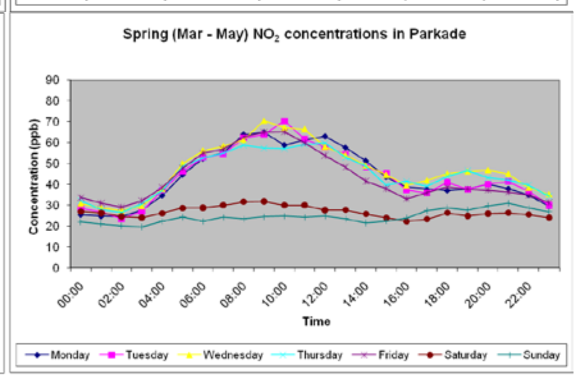


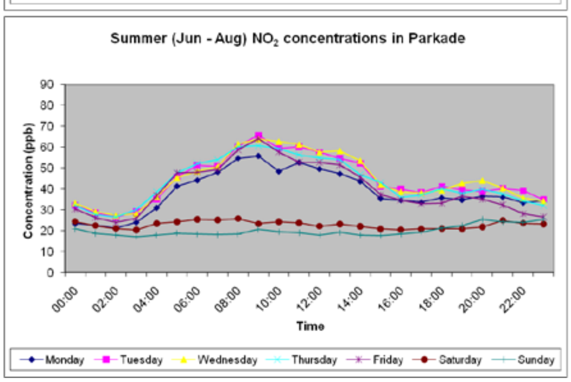


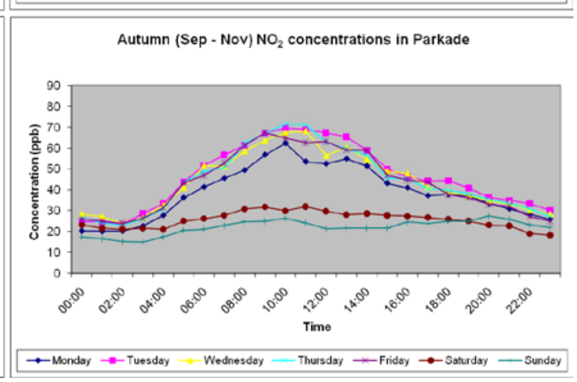


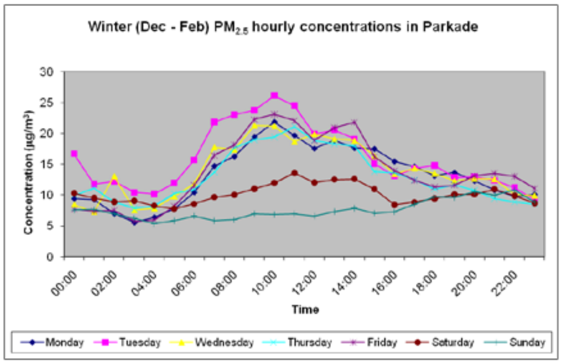


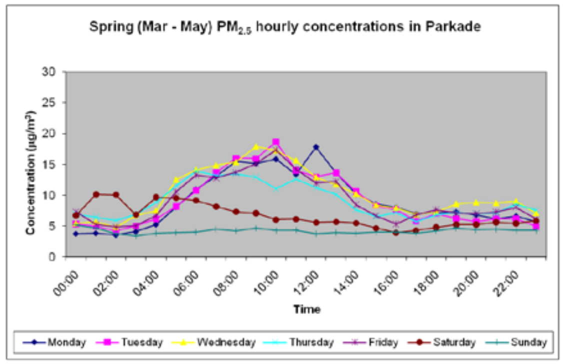


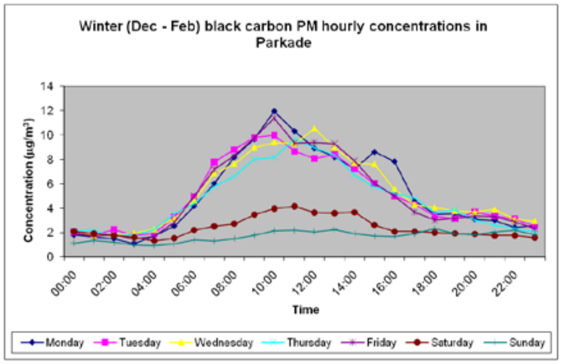


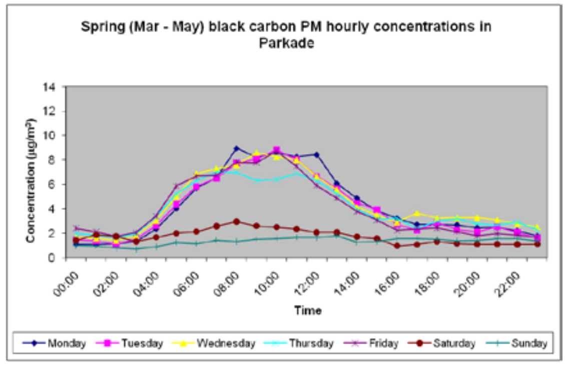


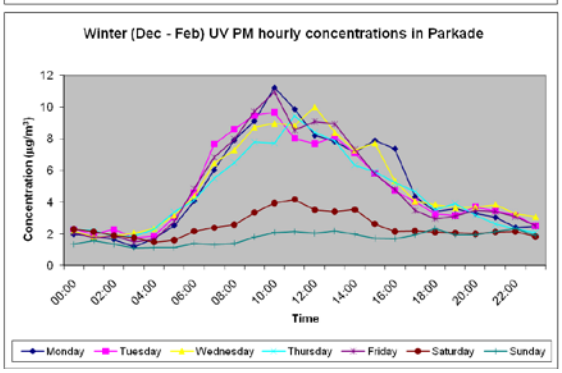


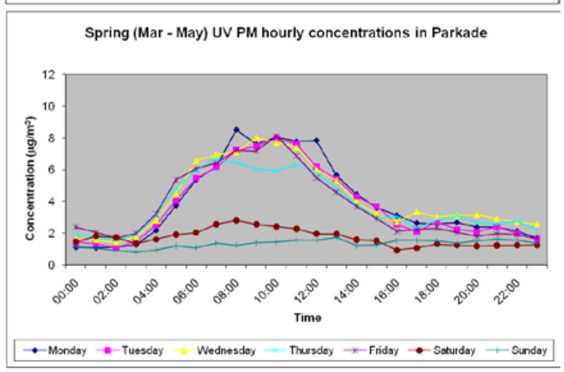

Winter (Dec - Feb) PM2.5 hourly concentrations in Parkade
Concentration (µg/m³)
Time
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday


Spring (Mar - May) PM2.5 hourly concentrations in Parkade
Concentration (µg/m³)
Time
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday


Winter (Dec - Feb) black carbon PM hourly concentrations in Parkade
Concentration (µg/m³)
Time
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday


Spring (Mar - May) black carbon PM hourly concentrations in Parkade
Concentration (µg/m³)
Time
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday


Winter (Dec - Feb) UV PM hourly concentrations in Parkade
Concentration (µg/m³)
Time
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday


Spring (Mar - May) UV PM hourly concentrations in Parkade
Concentration (µg/m³)
Time
Monday
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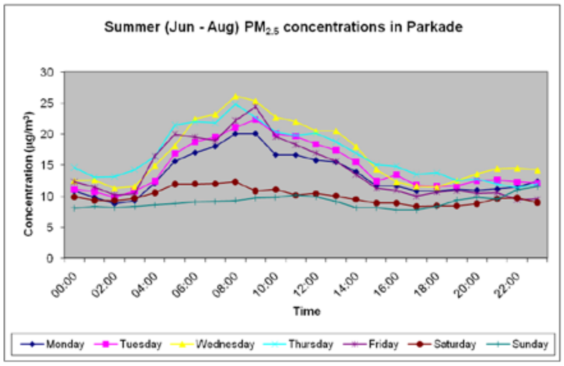
Thursday
Friday
Saturday
Sunday


Summer (Jun - Aug) PM2.5 concentrations in Parkade
Concentration (µg/m³)
Time
Monday
Tuesday
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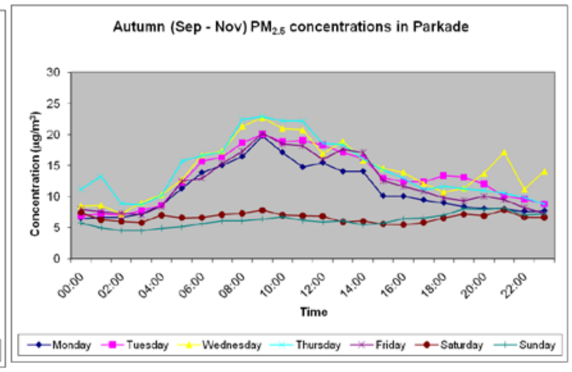
Thursday
Friday
Saturday
Sunday


Autumn (Sep - Nov) PM2.5 concentrations in Parkade
Concentration (µg/m³)
Time
Monday
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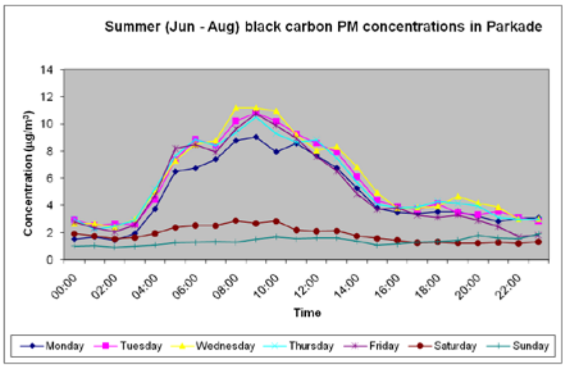
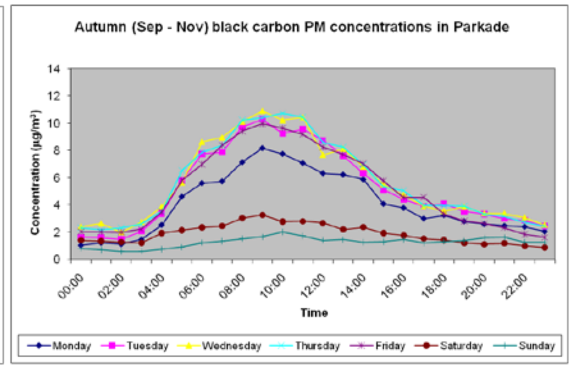
Thursday
Friday
Saturday
Sunday


Summer (Jun - Aug) black carbon PM concentrations in Parkade
Concentration (µg/m³)
Time
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday


Autumn (Sep - Nov) black carbon PM concentrations in Parkade
Concentration (µg/m³)
Time
Monday
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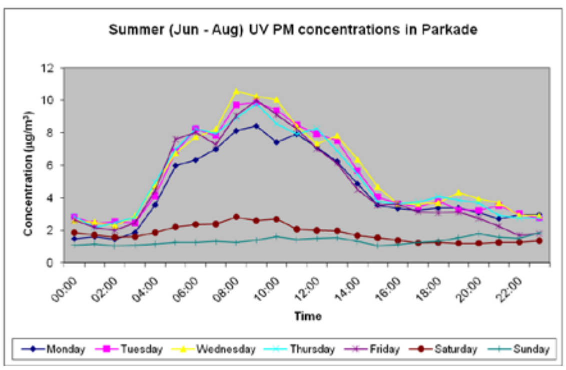
Saturday
Sunday


Summer (Jun - Aug) UV PM concentrations in Parkade
Concentration (µg/m³)
Time
Monday
Tuesday
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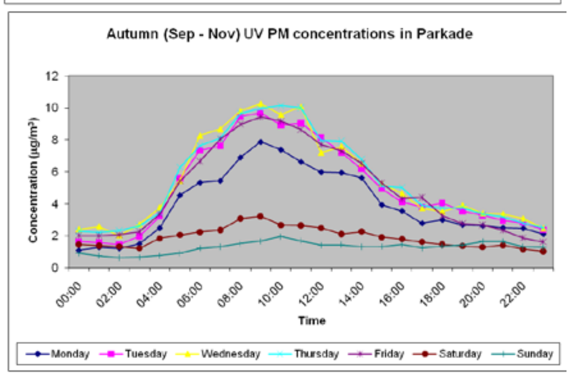
Thursday
Friday
Saturday
Sunday


Autumn (Sep - Nov) UV PM concentrations in Parkade
Concentration (µg/m³)
Time
Monday
Tuesday
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Thursday
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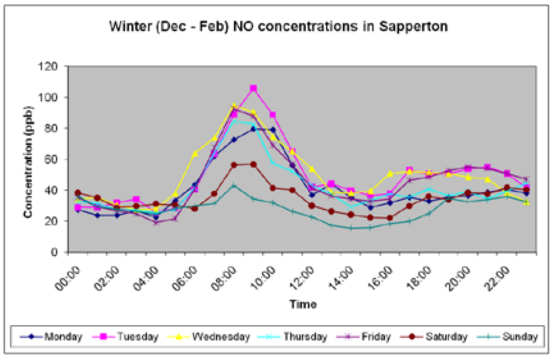
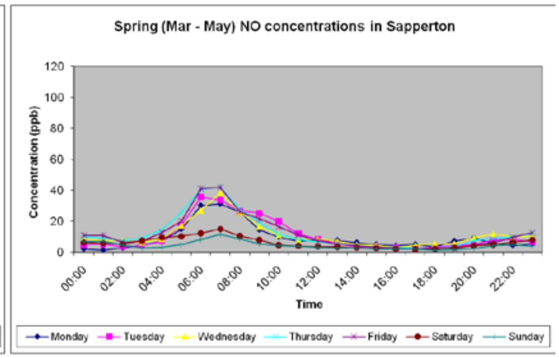
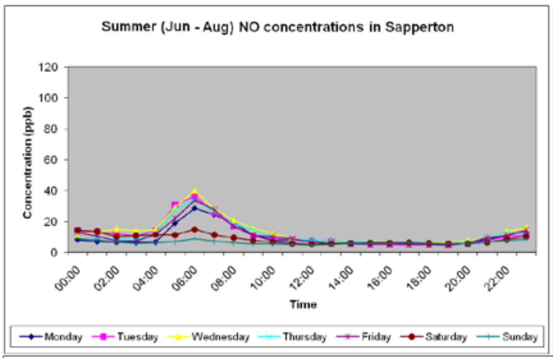
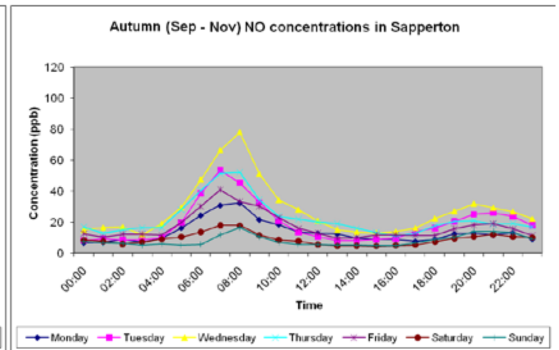
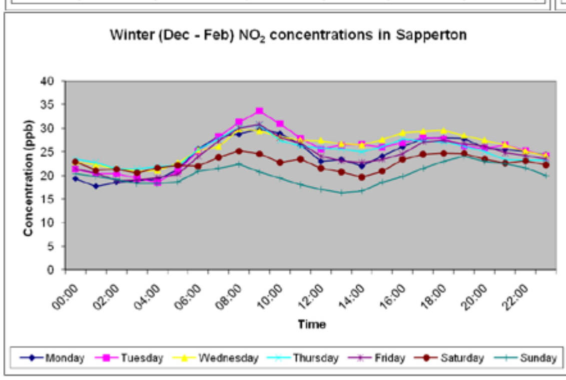
Saturday
Sunday

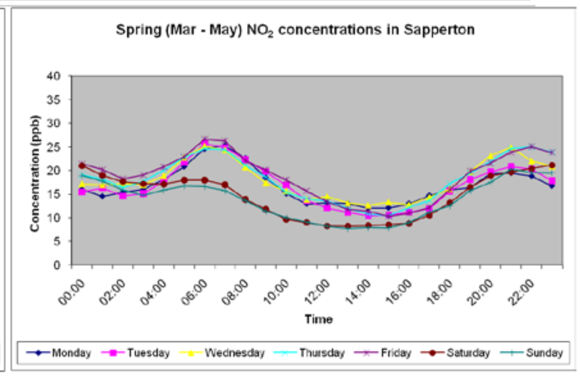

Winter (Dec - Feb) NO concentrations in Sapperton
Concentration (ppb)
Time
Monday Tuesday Wednesday Thursday Friday Saturday Sunday

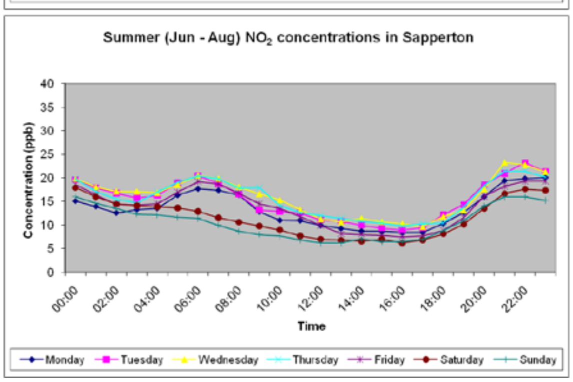

Spring (Mar - May) NO concentrations in Sapperton
Concentration (ppb)
Time
Monday Tuesday Wednesday Thursday Friday Saturday Sunday

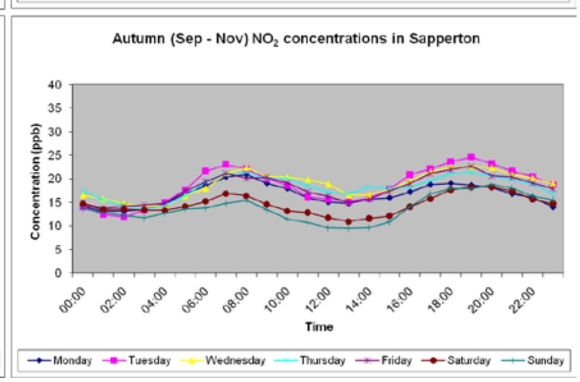

Summer (Jun - Aug) NO concentrations in Sapperton
Concentration (ppb)
Time
Monday Tuesday Wednesday Thursday Friday Saturday Sunday

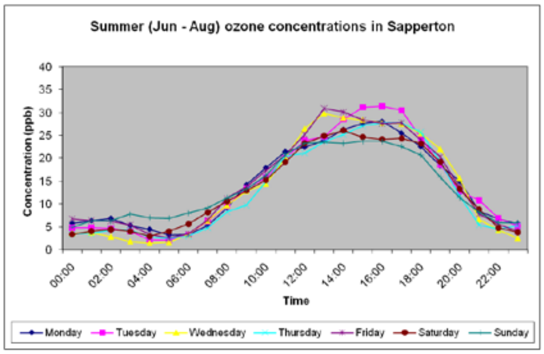

Autumn (Sep - Nov) NO concentrations in Sapperton
Concentration (ppb)
Time
Monday Tuesday Wednesday Thursday Friday Saturday Sunday

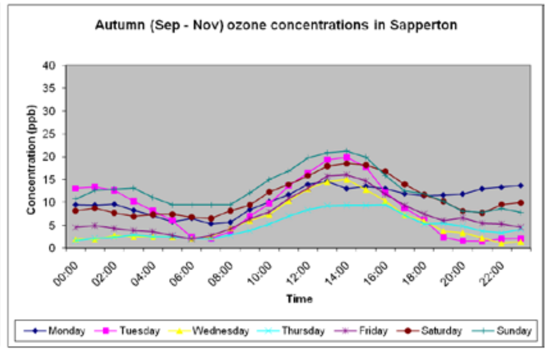

Winter (Dec - Feb) NO2 concentrations in Sapperton
Concentration (ppb)
Time
Monday Tuesday Wednesday Thursday Friday Saturday Sunday

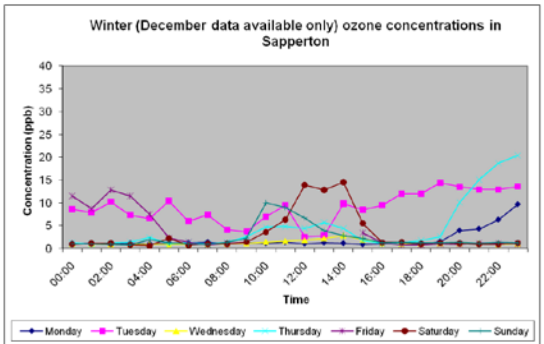

Spring (Mar - May) NO2 concentrations in Sapperton
Concentration (ppb)
Time
Monday Tuesday Wednesday Thursday Friday Saturday Sunday

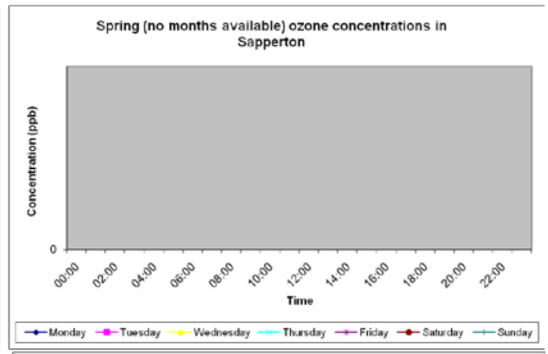

Summer (Jun - Aug) NO2 concentrations in Sapperton
Concentration (ppb)
Time
Monday Tuesday Wednesday Thursday Friday Saturday Sunday

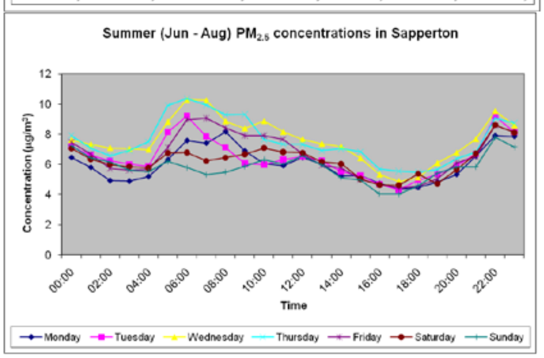

Autumn (Sep - Nov) NO2 concentrations in Sapperton
Concentration (ppb)
Time
Monday Tuesday Wednesday Thursday Friday Saturday Sunday

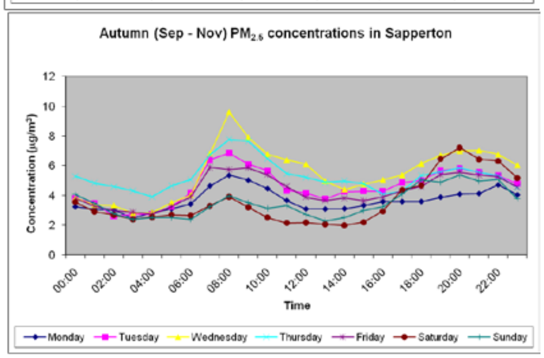

Summer (Jun - Aug) ozone concentrations in Sapperton
Concentration (ppb)
Time
Monday Tuesday Wednesday Thursday Friday Saturday Sunday

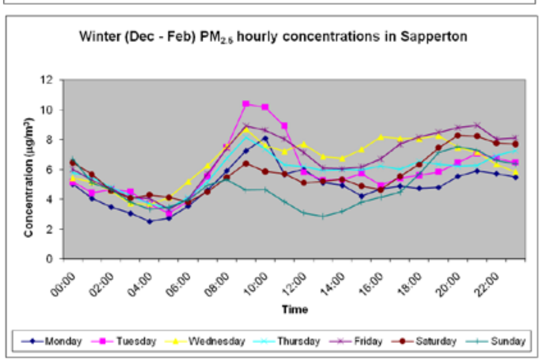

Autumn (Sep - Nov) ozone concentrations in Sapperton
Concentration (ppb)
Time
Monday Tuesday Wednesday Thursday Friday Saturday Sunday

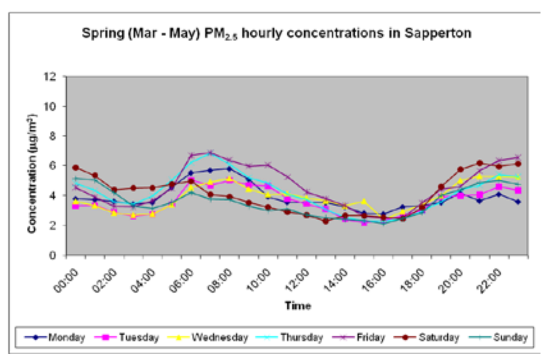

Winter (December data available only) ozone concentrations in Sapperton
Concentration (ppb)
Time
Monday Tuesday Wednesday Thursday Friday Saturday Sunday


Spring (no months available) ozone concentrations in Sapperton
Concentration (ppb)
Time
Monday Tuesday Wednesday Thursday Friday Saturday Sunday


Summer (Jun - Aug) PM2.5 concentrations in Sapperton
Concentration (µg/m³)
Time
Monday Tuesday Wednesday Thursday Friday Saturday Sunday


Autumn (Sep - Nov) PM2.5 concentrations in Sapperton
Concentration (µg/m³)
Time
Monday Tuesday Wednesday Thursday Friday Saturday Sunday


Winter (Dec - Feb) PM2.5 hourly concentrations in Sapperton
Concentration (µg/m³)
Time
Monday Tuesday Wednesday Thursday Friday Saturday Sunday


Spring (Mar - May) PM2.5 hourly concentrations in Sapperton
Concentration (µg/m³)
Time
Monday Tuesday Wednesday Thursday Friday Saturday Sunday

References

[1] **2009 Lower Fraser Valley Air Quality Report**, Metro Vancouver, *December 2010*.
[2] **2005 Lower Fraser Valley Air Emissions Inventory & Forecast and Backcast**, Metro Vancouver, *December 2007*.
[3] **2005 Lower Fraser Valley Air Emissions Inventory & Forecast and Backcast Detailed Listing of Results and Methodology**, Appendix D Table D.1, Metro Vancouver, *January 2010*.
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[9] **2009 Lower Fraser Valley Air Quality Report**, Metro Vancouver, *December 2010*.
[10] **2005 Lower Fraser Valley Air Emissions Inventory & Forecast and Backcast**, Metro Vancouver, *December 2007*.
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