Appendix J – Air Quality Assessment

Air Quality Assessment

for

Proposed Grand River Transit Bus Storage Facility

Northfield Drive
Waterloo, Ontario

Prepared for the
Region of Waterloo

by

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Executive Summary

This report examines the potential air quality impacts of the Region of Waterloo's Grand River Transit [GRT] new vehicle storage facility proposed for a site at the intersection of Northfield Drive and University Avenue East in Waterloo. This facility will house 200 vehicles used by GRT to provide public transportation services to the Region. The facility will also be equipped with maintenance facilities in the form of 25 bays where vehicles can receive a full range of servicing. The facility, measuring 255 m by 127 m, will be heated with natural gas fired roof top units equipped with heat recovery systems that will serve to recover energy from the fumes exhausted from the building. Two emergency diesel generators will be installed to allow the facility to continue to function in the event of a power grid failure.

Existing air quality in the Region is characterized by a provincial air quality monitoring station located in Kitchener. The most recent data from that network covers 2014. The annual data available for 2014 at the Kitchener site are summarized in the report as are the trends in air quality levels at that site for the 10 years prior to 2014. Generally, air quality in Kitchener and the province has been improving over the last 10 years.

This report considers emissions of oxides of nitrogen, [NO_x], as markers for the potential impacts on local air quality. Generally, the estimated concentration of NO_x resulting from emissions come the closest to the standard levels. Emissions from the heating systems, emergency generators, and vehicles operating on the site are considered in the report.

Emissions from the heating system were estimated on the basis of the maximum input capacity of the equipment using standard emission factors. The value for emissions from the heating systems was 1.185 g NO_x/s assuming all the equipment was operating simultaneously at the maximum input. Similarly, the generator emissions were based upon maximum power generation rates and the approved emission levels for such equipment and were estimated to be 1.45 g NO_x/s for each generator. Typically, these units would be tested separately at lower generation rates.

Vehicle operations have been assumed to be similar to those at other bus storage facilities in the province. Buses are stored inside the building. In the morning the operators start the engines on the buses and allow operating systems to reach safe operating levels before they proceed out of the garage and into service. At the end of their operating period the buses are returned to the site and parked in the storage garage. This can occur after the morning rush period when buses are removed from service because of reduced passenger volumes only to leave the facility again in the afternoon to service the afternoon rush. In the evening buses return to the facility and are parked in the storage area until retrieved for end of day cleaning and refuelling. These functions occur in a special area of the facility that is anticipated to operate on the afternoon and part of the night shift. Every day the maintenance facility will service a certain number of

vehicles, either for preventative maintenance designed to ensure reliable operation, or to repair systems that have failed during operation. It has been assumed that all the service bays will be used during the day shift with a reduced number being used during the afternoon and night shifts. Vehicle emissions are regulated by federal laws. These rules follow the lead of the US EPA which sets emission standards for diesel engines based upon the year of manufacture. Such standards have steadily been tightened since 1996 with the last major reduction in emission levels being for buses manufactured in 2010 and later. This means that as bus fleets are replaced with new vehicles the fleet average emissions will decrease. Based upon an average age of the buses operated by GRT a fleet emission level was estimated. Published reports were used to estimate emissions from the typical bus engine under three distinct operating conditions: idling, acceleration and coasting. The duration of operation in each of these categories was estimated and the total contaminant release for typical movements in the facility were determined. Based upon the pattern of bus operations, the worst case hour was determined to be in the evening when buses were returning and the service lanes were in operation. The estimated emission rate at this time is 0.0526 g NO_x/s.

The emission estimates were entered into the O.Reg. 346 dispersion model used to assess the effects of new facilities in the province during the Approval process. The model estimates the maximum one half hour average concentration around the site. Since the emission points for the heaters, generators and exhaust fans from the building will be close to the roof, or the building, the modelling assumed a worst case condition that all the emissions occurred from one point in the middle of the roof of the building. The standard applied to new sources for NO_x emissions is a level of 500 μg NO_x/m^3 at the point where the maximum level is predicted. The model showed that the maxima around the site were on the order of 280 μg NO_x/m^3 and these occurred on or near the western property line of the site. This value is 56% of the standard and would be considered acceptable under most situations.

The report discusses the conservative nature of the emission estimates used in the modelling suggesting that typical levels will be much lower. The generators are unlikely to be tested more often than every two weeks and would typically be run for no more than 15 minutes in testing mode. The heating system is unlikely to operate more than intermittently in different areas of the building except for the coldest days of the year. Given that buses emissions are only a small fraction of the total emissions, the average situation around the site will be much lower than predicted from the modelling.

The report concludes that there is sufficient margin between the estimated levels and the standards to suggest that the facility is unlikely to cause undue impacts on the environment.

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1.0 Introduction

The Grand River Transit (GRT) division of the Region of Waterloo (Region) completed an update to its Transit Facilities Strategy in 2012. That study identified a need to expand bus storage and bus maintenance capacity with a new 200 bus facility for both standard and articulated buses either in Waterloo or Cambridge. In 2014 The Region acquired additional lands at 300 and 350 Northfield Drive in Waterloo. The new property is 6.9 ha in size and contains an existing 4,180 square meter office and maintenance building.

The proposed GRT Northfield Facility will accommodate Mobility Plus vehicles, regular buses and articulating buses. Articulating buses are to be introduced to the fleet beginning in 2021. Initially GRT Northfield will be the only facility set up for the maintenance and service of articulating buses so this facility must be completed and operational by the end of 2020.

Northfield Drive is scheduled for widening in 2017 and The Region requested proposals for a preliminary design and environmental assessment of the proposed GRT Northfield facility to allow the results to be incorporated into the Northfield Drive widening. The IBI Group were retained by the Region of Waterloo to provide consulting engineering services for the study and in turn Preliminary Design and Environmental Assessment of the alternatives and A.J. Chandler & Associates Ltd. was asked to prepare an evaluation of the potential impacts this development might have on air quality in the area surrounding the proposed facility.

The air quality evaluation that follows considers the emissions of products of combustion from both the buses operating on the site and the heating equipment needed to maintain space temperatures in the building. Since no detailed design has been completed details of the position and configuration of the heating and exhaust equipment are very general. Assumptions had to be made concerning the emission rate for oxides of nitrogen from the facility and the means by which these releases would occur. Given the nature of the operation, the emissions can be modelled using the Ontario Regulation 346 models and comparing the results to Schedule 2 of O.Reg. 419/05. Oxides of nitrogen, or NO_x, is the compound most likely to approach air quality standard levels because the standard for this contaminant is relatively stringent compared to the other combustion products and NO_x emissions from diesel engines can be significant depending upon the engine installed in the buses.

1.1 Project Description

The proposed Northfield Drive facility is planned for an existing 6.9 ha site at the intersection of University Avenue East and Northfield Drive in Waterloo. The main entrance to the site will be from Northfield with a secondary entrance on University. The building, to be built parallel to University Avenue will contain, on the northern side the vehicle storage area, and on the south side the maintenance bays. To the west of the maintenance bays will be office, meeting room, lunchrooms and storage space. To the east end of the maintenance are will be the bus cleaning, fueling, and wash lane areas. Staff parking will be located in the southwest corner of the site accessible from Northfield Drive. The facility will provide overnight inside storage facilities for up to 200 vehicles of all sizes and 25 maintenance service bays. Buses returning daily will pass through the countdown lane for cleaning, fueling and washing prior to being stored inside the building. Out of service vehicles will be housed in the maintenance bays while being serviced.

1.2 Project Location

The Northfield site is bounded on the north by University Ave E, the dividing line between the City of Waterloo and Woolwich Township and on the south by Northfield Drive which serves the industrial area adjacent to the site. University Avenue E changes to Bridge St E west of the site. The nearest residentially zoned area is approximately 450 m northeast of the center of the proposed bus storage facility. This point is approximately 600 m north of the single residential zoned properties south of the industrial area. To the north of University Ave East it appears that the land is currently used for agricultural purposes.

1.3 Air Quality Assessment Approach

The operation of a bus storage and maintenance facility on the site would fit with the current zoning of the land which allows for transportation support facilities. Storing buses on site will result in some increase in vehicular emissions in the vicinity of the site due to buses arriving and departing from the site. Some bus circulation will occur on site as well leading to further increases in emissions. Staff vehicles will also add to vehicular emissions part these would be similar to those expected from employee parking lots at other industrial facilities in the area. Vehicular emissions are addressed in this assessment along with those associated with heating the building and the operation of the emergency generators.

To evaluate the potential changes, the combined anticipated emissions from the bus facility operations will be modelled to determine whether any significant changes in ambient air quality levels should be anticipated.

Since the highest frequency of bus movements into and out of the site will occur outside of the peak rush hour traffic periods, the potential for additional congestion on the roads was discounted and thus there is no screening assessment of local traffic effects.

The development of the bus facility will require construction activities. The existing buildings on site will be demolished, new buildings will be constructed and the site will need to be paved. Construction sites will have air emissions associated with the site specific construction operations but such activities are limited in duration. Given the separation from residential areas, the potential for dust emissions impacting residences is limited and thus no detailed modelling of these effects were completed.

This report updates a review of existing air quality issues in the Region that was included in the LRT Air Quality Assessment to allow the reader to understand how the emissions associated with the proposed development could influence local air quality.

2.0 Air Quality in the Region of Waterloo

2.1 Climate and Meteorology

Southern Ontario has a modified continental climate with a less extreme temperature range than the continental climate of the Prairies and less precipitation that one would expect in the Maritimes[1]. The climate of the area is moderated by the influence of the Great Lakes, and even though the Kitchener-Waterloo area is located some distance from the lakes the climate in the region is still influenced by them. The lakes tend to have a cooling effect throughout most of the warmer parts of the year, and to some extent moderate extreme cold periods while they delay the coming of spring and prolong warmer weather in the fall. Some authors suggest the area could be classified as a humid continental climate. The average January temperature in the Region is slightly below freezing with day time temperatures rising slightly above this level. In the winter snowfall averages 143cm (56") but like most of southern Ontario, this average is subject to wide fluctuations due to both lake effects when moisture is picked up from the open lakes and to severe winter storms that can be experienced. Such storms can bring more snow to an area in one to two days than might be seen in some years. The average July temperature is 22.5^{O}C with high summertime humidity levels.

Kitchener Waterloo, and indeed most of southern Ontario, has prevailing winds from the west with southwest winds dominating the summer and west and northwest winds in the winter. Easterly winds are the least frequent and the lightest. Observations have shown marked increases in NO_x or ozone levels in different locations in southern Ontario suggesting that the source of these pollutants, and the nature of the air masses moving over the area strongly influence the air quality impacts.

2.2 Regional Air Quality

Air flows coming into southwestern Ontario frequently pass over the Ohio Valley and other heavily industrialized areas of the United States and southern Ontario. This contributes as much as 50% of the air pollution burden seen in communities[2]. Other contributors include local

[1] David Phillips, 2006. The Climates of Canada. A publication of Environment Canada. Available at ftp://arcdm20.tor.ec.gc.ca/pub/dist/climate/THE_CLIMATE_PRODUCT/

[2] Ontario MMAH, 20004. Building Strong Communities: Municipal Strategies for Cleaner Air. Available at: http://www.mah.gov.on.ca/Page1307.aspx

industrial operations, fossil fuelled power generation facilities, and the high numbers of vehicles using roads in and around the city.

While trans-boundary air pollution and regional transportation corridors contribute to regional air quality, heavy industry has its own effects, typically using tall stacks to allow emissions to be dispersed and carried downwind. Another factor that can influence regional air quality are large concentrations of asphalt and urban development which gives rise to the "urban heat island" effect. Higher temperatures associated with urban areas, increase the potential for smog formation from the air emissions. In turn, higher temperatures prompt the use of more air conditioning and this leads to higher air emissions from fossil fuelled power generation facilities.

The MMAH report referenced above suggests that, compared to other communities in southern Ontario, Windsor, London and Waterloo have more frequent poor air quality than the Toronto area, due largely to the influence of trans-boundary transport issues.

2.3 Pollutants of Concern

A number of common air pollutants are addressed in this study:

- particulate matter [PM] and the inhalable fraction [PM_{10}] and respirable fraction [$PM_{2.5}$];
- oxides of nitrogen [NO_x];
- sulphur oxides [SO_2];
- carbon monoxide [CO];
- volatile organic compounds [VOC]; and,
- ozone [O_3].

The first four categories on the above list are typically referred to as Criteria Pollutants, or common air pollutants. They are classed as "criteria" pollutants because their emissions are regulated based upon human health-based and/or environmentally-based criteria (science-based guidelines) for permissible levels. The set of limits based on human health is called primary standards. A secondary set of standards limit emissions to prevent environmental and property damage.

Ozone would typically be categorized as a Criteria Pollutant because of its health effects, however, it is seldom released from sources, rather at ground level it is created by a chemical reaction between oxides of nitrogen and volatile organic compounds in the presence of sunlight. Ground-level ozone is the primary constituent of smog. Generally, ozone levels are higher in the summer when sunlight and hot weather increase the reaction rate between the chemical constituents. As noted above, these influences are exacerbated by elevated temperatures in large urban areas. Vehicular traffic contributes significantly to the NO_x and VOCs in the atmosphere although VOCs come from other sources. While local sources are responsible for ozone levels, there is also a considerable portion attributed to sources hundreds of kilometres upwind.

The list above is by no means all inclusive of contaminants that can be released into the atmosphere. There are a class of contaminants, frequently referred to as Air Toxics, that include a range of organic pollutants and metallic compounds[3]. Many of these compounds can have health effects if humans are exposed to high concentrations and for this reason they frequently receive attention from public health officials. In a report on the relationship between illness and traffic in Toronto the authors listed nine specific compounds associated with vehicle emissions:

> chromium; benzene; polyaromatic hydrocarbons, [PAHs]; 1,3-butadiene; formaldehyde; acrolein; acetaldehyde; nickel; and, manganese.

These compounds are on the short list of compounds that California identified as of concern from diesel engine exhaust[4]. One of the main reasons for addressing diesel engine emissions in that report was that diesel particulate matter [DPM] emissions were determined to be at least 20 times higher than particulate emissions from gasoline engines on an equivalent energy basis. The DPM was characterised as agglomerated spherical carbon particles coated with inorganic and organic substances. The inorganic fraction consisted of very fine particles 0.01 to 0.08 microns in diameter. The organic fraction consisted of soluble compounds and polyaromatic hydrocarbons [PAH] and PAH-derivatives that have been identified as mutagens or carcinogens. All diesel exhaust particles are smaller than 10 micron in size, with 92% of the mass being less than 1 micron in diameter. These are particles that can be inhaled and trapped in the bronchial and alveolar regions of the lung[5].

Within the context of this study, the potential to reduce the emissions of these "toxic contaminants" is small compared to the impacts that are made through the reduction of criteria pollutants. For this reason, these contaminants are not explicitly addressed in terms of air quality benefits of the project.

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3 Campbell, Monica, K. Bassil, C. Morgan, M, Lalani, R. Macfarlane, and M. Bienefeld, 2007. Air Pollution Burden of Illness from Traffic in Toronto, Problems and Solutions. Published by Dr. David McKeown, Medical Officer of Health, Toronto Public Health. Available at: http://www.toronto.ca/health/hphe.

4 California Air Resources Board, 1998. Report to the Air Resources Board on the Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant Part A Exposure Assessment. Approved by the Scientific Review Panel on April 22, 1998. Available at http://www.arb.ca.gov/toxics/dieseltac/part_a.pdf

5 California Air Resources Board, 1998. Executive Summary for the "Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant". April, 1998. Avaiable at: http://www.arb.ca.gov/toxics/dieseltac/finexsum.pdf

The priority contaminants, ozone and $PM_{2.5}$ because these have been associated with mortality, respiratory effects and cardiovascular effects according to the reviews in Campbell et al and Dimoulas-Graham et al[6]. The health concerns associated with these contaminants resulted in their inclusion in the CCME CWS for Particulate Matter and Ozone[7].

To monitor the levels of contaminants in the ambient environment, the Ontario Ministry of the Environment and Climate Change [MoECC] operate a network of air quality monitoring stations in the province. Data from these locations can be used to track trends in both the temporal and spatial variations in contaminant levels in the atmosphere. One such location is in Kitchener near West Avenue and Homewood Avenue. This location is characterised as representing the area where the local population lives, plays and works. Data from this station are available for the period from 2000 - 2014. Most of the data in the following sections were extracted from the 2014 Air Quality Report issued by the MOECC[8]. The report discusses the various contaminants presenting data for the last year available, 2014, and in a separate section looking at the trends in the various contaminants for the last 10 years.

2.3.1 Fine Particulate Matter

Particulate matter as defined above included all particles that could remain suspended in the air for any length of time, but the most interest relates to the respirable fraction that are less than 2.5 µm (micrometers or microns) in size and designated at $PM_{2.5}$. These particles have a diameter that are approximately 30 times smaller than the average diameter of a human hair. Their size means they can have significant effects on health because they enter the lungs and are not always removed through normal breathing. As noted above, these fine particles can consist of compounds that have varying effects from those on respiratory systems to cancer causing agents. Still thought to be important, but not targeted by the CWS are particles that are inhalable, PM_{10}.

The $PM_{2.5}$ in the atmosphere comes from two sources: primary emissions of fine particles and secondary formation through chemical reactions after they enter the atmosphere. Primary particulate matter in the atmosphere includes those particles emitted directly from a source be it re-suspended road dust, or emissions from internal combustion engines, space heating, or other combustion sources, as well as those from industrial processes. Recognizing that industrial

6 Dimoulas-Graham, P., S. Drew, L. Knowles, and A. Landry, 2008. Air Qualiity and Urban Health Impacts, Waterloo Region, A Preliminary Assessment. A report issued by Region of Waterloo Public Health, February.

7 CCME, 2000. CANADA-WIDE STANDARDS for PARTICULATE MATTER (PM) and OZONE http://www.ccme.ca/assets/pdf/pmozone_standard_e.pdf

8 http://www.airqualityontario.com/downloads/AirQualityInOntarioReportAndAppendix2014.pdf

processes have an impact on particulate matter emissions under the CWS national multi-pollutant emission reduction strategies were implemented for the following sectors:

- Pulp and Paper
- Lumber and Allied Wood Products
- Electric Power
- Iron and Steel
- Base Metals Smelting
- Concrete Batch Mix Plants
- Asphalt Mix Plants

Combustion sources emit $PM_{2.5}$ and vehicle emissions are a major contributor. Secondary particulate matter is largely comprised of ammonium nitrate and ammonium sulphate particles. These compounds are created when acids formed from gaseous sulphur and nitrogen oxides emissions react with ammonia in the atmosphere to create very fine solid particles. Such fine particulate matter effectively scatters light and can result in a reduction of visibility.

Since the implementation of the CWS, provincial agencies have increased the level of $PM_{2.5}$ monitoring that is undertaken. The CWS requires that daily 24 hour averages be calculated from hourly values recorded by the instruments. Meeting the CWS standard of 28 $\mu g/m^3$ requires evaluation of the 98th percentile of the 24 hour averages recorded over the last 3 years. To meet the standard, no more than 7 daily averages in any year can be in excess of the 28 $\mu g/m^3$ criteria level [2% x 365].

The $PM_{2.5}$ data for the Kitchener monitoring site: the mean 24-hour average, the maximum 24 hour average as well as the 90 percentile level for the 24 hour average, the level that 90% of all the readings were below, and the number of day in the year when the 24 hour average exceeded 28 $\mu g/m^3$ are shown in Table 1.

Table 1 Summary of Kitchener PM2.5 [$\mu g/m^3$] Data for 2014

Year	24-hr Mean	24-hr 90th Percentile	Maximum 24 Hour	Number of Days Value > 28 ug/m^3
2014	9.3	18	32	7

The 90th percentile is generally accepted as a reasonable estimate of background levels in an area, while the mean provides an average over the year and the maximum is the peak value. These values will vary depending upon both regional and local influences but the hourly values provide some indication of local variations.

2.3.2 Ozone

While not directly released from combustion sources, ozone levels can be influenced by releases of VOC and NO_x to the atmosphere. The MoECC Air Quality report notes that both the formation and the transport of ground-level ozone are strongly dependent on meteorological conditions. As noted in the discussion on trans-boundary pollution and the effect of lake breezes earlier, short-term and year-to-year differences in ozone concentrations are attributable to causes beyond emissions in the air shed. In most areas where ozone levels are notable, elevated concentrations of ground-level ozone are generally recorded on hot and sunny days. In Ontario, these occur between May and September. Furthermore, there is a diurnal variation in levels which tend to peak in the afternoon and early evening period.

Vehicular traffic is responsible for a large portion of the NO_x released into the atmosphere. While oxides of nitrogen, NO_x, a general term for nitrogen compounds released to the atmosphere, they are defined to be the sum of nitrogen dioxide [NO_2] and nitric oxide [NO]. Emissions of NO_x from internal combustion engines consist mainly of NO, with some NO_2. When released, NO emissions convert to NO_2 which has adverse health effects at a lower level than NO. One of the chemicals that NO reacts with to form NO_2 is ozone present in the atmosphere. Thus, vehicular emissions in the morning rush hour can result in a decrease in ambient ozone levels as the NO scavenges the ozone from the atmosphere. The production of ground level ozone continues throughout the day peaking in mid-afternoon when the sunlight is at its most intense level. The diurnal cycle shows levels starting to decrease after the sun sets.

The daily and seasonal variations in ozone levels must then be taken into account when reviewing ozone monitoring data. The MoECC reports mean hourly data for the year for ozone at monitoring stations as well as computing the maximum 1 hour and 24 hour averages. When considering the results for the province, the MoE looks at trends in the annual average of the maximum one hour values from year to year, as well as considering changes in the average of the maximum 1 hour readings on a seasonal basis. Table 2 provides the results for the Kitchener station for 2014.

Table 2 Summary of Kitchener Ozone [ppb] Data for 2014

Year	1 hr Mean	1 hr 90^{th} Percentile	Maximum 1 Hour	Number of Hours Value > 80 ppb
2014 Annual	27.3	43	76	0

Note: ppb = parts per billion

The Canada Wide Standard for $PM_{2.5}$ also contains a numerical target for ozone. In this case the standard is based upon the average of the 4^{th} highest 8 hour rolling average value of ozone for each of the last three years. The criteria value is 63 parts of ozone per billion parts of air [ppb]. The MoECC's 2014 Air Quality report shows that the Kitchener 8 hour rolling average level based upon taking the 4th highest annual value was approximately 68 ppb, over the standard. The report notes that this is not an exception as few locations in the province meet the standard. This level is similar to that found in many of the other monitoring locations in southwestern Ontario suggesting that these levels are influenced by outside effects such as long range transport.

2.3.3 Oxides of Nitrogen

The other parameter with long term data is NO_x. NO_x emissions from on-road vehicles have decreased in recent years due to the phase-in of new vehicles having more stringent emission standards and the implementation of the "Drive Clean" vehicle test program in southern Ontario in 1999.

NO_2 is the form of oxides of nitrogen that are most important from a health perspective. That species is monitor along with NO and NO_x. The NO_x 90 percentile and the NO_2 data are reported in this document, Table 3.

Table 3 Summary of Kitchener NO2 [ppb] Data 2014

Location	Annual Mean	1-hr 90th Percentile		1 hour Average		24 hour Average	
		NO_2	NO_x	Maximum	Times >200 ppb	Maximum	Times >100 ppb
2014	7	7	8.5	59	0	35	0

These levels are comparable to those in many other locations in the province.

2.3.5 Trends

The 2014 data in the previous sections is the latest available data. Trends in the levels of these parameters over the last 10 years are more illustrative of what might be expected to occur in future years. The 2014 Air Quality Report provides 10-year trend data for the parameters monitored at the Kitchener site. These are summarized in Table 4. The annual mean for each year is listed as well as the change in the mean over the 10-year period.

The percentage change for $PM_{2.5}$ is not reported because the monitoring method has been changed since 2012 data were collected. The new monitoring system overcomes some of the technical limitations experienced during winter sampling with the older instruments. The older instruments were retained and operated along side the newer instruments for several years. Comparing the trend in $PM_{2.5}$ with the older monitor showed that it was dropping and through the use of statistical techniques the MOECC state that it is still dropping even though the newer instrument registers higher values.

In 2014, Kitchener exceeded the 24h $PM_{2.5}$ reference level of 28 μg/m^3 on 7 occasions, more than any other station in Ontario. Most of these days at Kitchener were marginally above the 28 μg/m^3 reference level. It should be noted that Guelph had 6 occurrences of levels over 28 μg/m^3 in 2014 suggesting that there might have been activities in the region that influenced the fine particulate levels. In the 2013 Air Quality report occurrences of high levels of $PM_{2.5}$ were attributed to smoke from forest fires in Quebec.

Table 4 10 Year Trend in Annual Average Values in Kitchener

Parameter	Units	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	% Change
$PM_{2.5}$	[ug/m^3]	9.5	7.7	8	7.1	5.8	6.3	6.2	6	8.7	9.3	NA
Ozone												
Mean	[ppb]	28	26.6	26.6	28.1	27	29.4	27.6	28	28	27.3	0
Summer	[ppb]	34.3	32	34.2	31	28.8	31.6	30.2	33.5	29.8	28.5	12 down
Winter	[ppb]	23.4	22.7	24.6	26	25.9	37.8	25.7	24	26.7	26.5	12 up
NO_2	[ppb]	12.9	10.8	9.7	9	8.6	7.7	7.7	7.1	6.7	7	48 down
NO_x	[ppb]	17.4	14.3	12.4	11.5	10.8	10.3	9.6	9.2	8.3	8.5	52 down

The trends in ozone levels while flat for the annual average shows an increase in the winter and a decrease in the summer. The MoECC credit the reduction of NO_x emissions, especially from motor vehicles in Ontario and all sources in the US for the summer reductions, but note a trend in global increase of NO_x emissions that they suggest is reflected in the winter increase. Regardless values in the winter are still well below the criteria level. It should be noted that ozone levels tend to be lower in areas where there is a high vehicular population because the NO released from these sources scavenges the ozone from the air. While recognizing that the contribution of long range transport is a factor in summer levels, this is not quantified.

Trends in the concentrations of other criteria air pollutants in the Kitchener area cannot be plotted since the MoECC stopped sampling CO (2004) and SO_2 (2007) suggesting that the levels had declined to the point that they were not of concern. The MoECC suggest that provincially the CO levels have decreased consistently since 1971, and are down 40% in the last 10 years. Mean SO_2 levels in the province have declined by 49% over the last 10 years. This is attributed to a significant reduction in SO_2 emissions.

Overall, the rate of decline of most airborne contaminants is slowing, with, as noted above, some species increasing in concentration. If the trends of increasing population bring with it more vehicular traffic it is doubtful if these declining trends can be maintained, despite measures to reduce vehicular emissions. Clearly, other emission reduction strategies, such as increased use of public transport in large urban areas can only benefit the environment and those living in the city.

2.4 Emissions Inventory

Local air quality will depend largely upon the emission sources in a region, although as noted in earlier sections, in certain areas upwind sources can also influence the amount of contaminants found in the atmosphere. The emission inventory process attempts to determine what sources of air pollutants are present in the community and how much these sources contribute to emissions and hence the air quality conditions in the area under consideration. Inventories have been created on the national and provincial level, and in some cases inventories have been developed for the municipal level. The distribution of sources and their contributions to air emissions on a provincial basis provides an insight into potential emissions in the Region, but careful consideration is required before drawing definitive relationships. The MoECC 2011 Air Quality report provides a provincial inventory that defines the provincial emissions profile shown in Table 5, although the 2014 report provides an update for NO_x emissions.

The inventory indicates that on a provincial basis:

- the transportation sector: road vehicles, trains, airplanes, and ships which contributes the majority of the NO_x and CO released in the province.
- the residential sources are responsible for the highest percentage of fine particulate matter released;
- smelters and utilities account for 67% of the SO_2 emitted, down somewhat since 2009.

Table 5 Percentage of Annual Emissions By Sector and Criteria Contaminant

Sector	Oxide of Nitrogen [NO_x]	Fine Particulate [$PM_{2.5}$]	Carbon Monoxide [CO]	Sulphur Dioxide [SO_2]
Year	2014	2011	2011	2011
Road Vehicles	34	3	44	4 Combined between two groups
Other Transport	37	21	43	
Cement/Concrete	4	4		
Smelters	3	10	3	52
Other Industry	9	16	3	24
Utilities	5			15
Residential		39	7 Combined between two groups	
Miscellaneous	9	7		4

Clearly, the provincial emission inventory may not reflect the inventory of the Region of Waterloo. The absence of cement plants, smelters and electrical generating facilities burning fossil fuels in the Region would remove such sources from a Regional inventory and result in a re-distribution of the sources. This could raise the percentage of emissions from transportation and residential sectors in the Region, illustrating how important it is to encourage a transit mode shift to public transit as it could have a major impact on emissions. To accomplish this, new bus maintenance facilities must be built.

A spot check of how the provincial distribution might be redistributed in an urban community is provided by a detailed emissions inventory for both criteria air contaminants and greenhouse gas emissions created for the City of Toronto. While based upon 2004 data[9] the results show that transportation sources (Mobile in Table 6) were estimated to produce NO_x and CO at levels similar to the provincial inventory in Table 5, their contribution to $PM_{2.5}$ (16%), and SO_2 (1%) were lower than the provincial values. The contribution of the urban area, residential, commercial and small scale industrial facilities to the particulate matter emissions in Toronto would appear to be much higher than that shown by the industrial and residential sectors in the provincial inventory. These shifts reflect the fact that the major industrial sources, where the emissions are best categorized as point sources, identifiable stacks, make up a very small percentage of the sources from most of the contaminants in Table 5. The Toronto inventory specifically excluded construction related emissions. Such emissions are localized, that is they affect the immediate vicinity where the construction is underway. Furthermore, they are variable in nature even on a specific site, and can be in different locations on a year by year basis. Altering locations makes it difficult to apportion such activities across an urban area.

Table 6 Emission Inventory Percentages for City of Toronto

	Mobile	Area	Point
CO	85.4	13.3	0.1
NO_x	69.3	9.4	4.4
PM_{10}	38.6	56.3	2.4
$PM_{2.5}$	16.1	74.4	4.2
SO_2	1.3	94.9	3.4
VOC	4.2	95.5	0.2

Before leaving the comparison of the Provincial inventory data to that of the City of Toronto, some discussion of the differences between $PM_{2.5}$ data is important. One of the important contaminants associated with human health effects is $PM_{2.5}$ and the Toronto data uses emission factors for $PM_{2.5}$ for expressway, arterial or residential roads that show similar values. Such

[9] ICF International, 2007. Greenhouse Gases and Air Pollutants in the City of Toronto: Towards a Harmonized Strategy for Reducing Emissions. Prepared in collaboration with Toronto Atmospheric Fund and Toronto Environment Office. June. Available at http://www.toronto.ca/taf/pdf/ghginventory_jun07.pdf

emissions are the result of both engine emissions and the material liberated from the surface by the vehicles. In the Toronto inventory only the diesel bus and motorcycle emission rates vary between the three types of roads. It is not immediately apparent how these distinctions were made. There are data to suggest that the rate of $PM_{2.5}$ emissions is related to the speed and acceleration on any particular section of road[10]. This suggests that the split between PM_{10} and $PM_{2.5}$ deserves more attention. In Vancouver, 2002 data identified transportation sources as contributing 45% of the fine particulate matter released to the atmosphere, but this excluded the contribution of road dust.

Emission inventories should consider greenhouse gas emissions. The ICF report for Toronto suggests that mobile sources: road vehicles, accounted for 35% of the GHG emissions in Toronto in 2004. Not included in the inventory are emissions from aircraft and trains operating in the area. Of the transportation total, 74% of the emissions were estimated to arise from passenger and other light vehicles. Residential sources accounted for 25% of the emissions with industrial emissions at 36% and waste management activities at 4%. These percentages would be expected to be similar for the Region of Waterloo, although the exact proportion associated with waste management could be influenced by the type of waste disposal/processing operations in the Region.

2.5 Ambient Air Quality Criteria and Monitoring Results

The monitoring data discussed earlier in this report can be judged against a number of criteria or standards. While the Canada Wide Standards for Ozone and $PM_{2.5}$ have already been presented, a number of other criteria are summarized in Table 7.

In all cases these criteria are set to protect the general community. Monitoring locations do not always reflect the average seen in the community as they tend to be located in areas which, while they might have been reflective of the community in the 1970s when the site was established, are now heavily influenced by traffic on nearby roads. Should air quality around these highly exposed stations meet the criteria levels it would be anticipated that much of the community further removed from the heavy traffic areas would experience lower levels.

Introducing a facility such as the proposed bus maintenance building may have some effect on the local air quality close to the site due to the movement of buses into and out of the site, but since these are limited both by the total number of vehicles, and their use at different times of the day such movements are unlikely to effect 24 hour, or annual averages in a measurable way. Public transit that results in mode shift will help to reduce total emissions within the city. Such reductions preclude the need for a detailed analysis of the impacts with respect to air quality

[10] Soliman, Ahmed S. and R.B. Jacko, 2008. A Quantitative Approach to the Traffic Air Quality Program: The Traffic Air Quality Index. JAWMA, 58:641-646. May.

objectives, but some of the air pollution health effects studies referenced earlier would indicate that improving air quality will improve health in the community.

Table 7 Summary of Ambient Air Quality Standards

Oxides of Nitrogen [NO_2 in ug/m^3]				
	Level	1 Hour	24 Hour	Annual
National Standards	Maximum Desirable	-	-	60
	Maximum Acceptable	400	200	100
	Maximum Tolerable	1100	300	-
Ontario		400 [200 ppb]	200 [100 ppb]	-
World Health Org.	Proposed Guideline	200	-	-
Carbon Monoxide [CO mg/m^3]				
	Level	1 Hour		8 Hour
National Standards	Maximum Desirable	15		6
	Maximum Acceptable	35		15
	Maximum Tolerable	-		20
Ontario		36 [30 ppm]		16 [13 ppm]
World Health Org.	Proposed Guideline	30		10
Particulate Matter [ug/m^3]				
	Level	24 Hour		Annual
National Standards	Maximum Desirable	-		-
	Maximum Acceptable	120		-
	Maximum Tolerable	400		-
CWS $PM_{2.5}$	National Target	28 (22)		10 (8)
Ontario	TPM<44 um AAQC	120		60
	PM_{10} Interim Target	50		
Ozone [ppb]				
	Level	1 Hour	24 Hour	Annual
National Standards	Maximum Desirable	100	30	-
	Maximum Acceptable	100	50	30
	Level		4th Highest 8 Hour	
CWS National Target			63 (68)	
Provincial Target			63	

3.0 The Proposed Facility

3.1 Physical Arrangement

As noted in the Introduction, the construction of the new Northfield Drive facility will provide space to store 200 buses overnight and to maintain portions of Grand River Transit's fleet. The proposal calls for 16 lanes of storage that will accommodate the vehicles in 16 rows approximately 220 m in length in the garage portion of the building on the north side of the site parallel to University Avenue. To the south of the storage garage the maintenance area will measure approximately 53 x 245 m. At the east end of the building will be an enclosed driveway to move vehicles from the maintenance area or the cleaning and fuelling area to the garage. The cleaning and fuelling area will be in a 35 x 89 m enclosed area on the southeast corner of the maintenance building parallel to Northfield Drive. Surrounding the building will be suitable driveways to accommodate bus movement on site. The maintenance building will be approximately 9.7 m high with the garage area being 7.3 m high. A two storey office and meeting room space measuring 35 x 43 m with a 8.9 m roof height will be on the west end of the maintenance portion of the building. Exhaust fans and roof top heating and cooling equipment will be mounted on the roofs of the building.

3.2 Heating and Ventilating Requirements

The maintenance building will be heated and ventilated with heat recovery equipped gas-fired rooftop, heating and ventilation units (AHU). Each AHU will typically have a supply side sized for 90% of the unit exhaust capacity, and an exhaust side sized for winter operation. In order to achieve that, the supply side will include an air filter sized for maximum air flow, a supply fan, and two gas furnaces sized for the total supply air flow. The exhaust side includes an exhaust fan sized for 90% of the supply air flow, a 30% air filter and a heat recovery device (heat pipe) for winter operation. Any filters on these pieces of equipment are intended to trap particulate matter but will have no effect on gaseous contaminants released in the buildings.

In the summer months, the AHU units will provide outdoor air for heat relief to reduce worker heat stress. The AHU supply fan will provide 100% fresh air to the space. Exhaust will be accomplished by the AHUs themselves plus local exhaust and roof mounted exhaust fans. The balance of exhaust (for summer heat relief or containment building flushing) in such facilities is typically realized by individual exhaust fans actuated by inside temperature and carbon monoxide (CO), or oxides of nitrogen (NO_x) sensors. The AHU's exhaust fans in combination with operating process exhaust (considered for air balance purposes to be 50% in operation) and roof exhaust fans in summer will maintain a negative pressure inside the space of a minimum 10% to a maximum of 20%.

The exhaust fans would operate under automatic control based on temperature control and on monitoring carbon monoxide CO and NO_x. One temperature sensor and two concentration sensors for each type of gas are provided for each AHU, and an average value is used from each signal. In the event of a communications or sensor failure, the system will operate only on the good sensor. Using heat recovery, the amount of exhaust air through AHUs is constant and therefore the amount of heating demand during low use periods is considerably reduced, maintaining in the same time:

CO control set point: 25 ppm
NO_2 control set point: 3 ppm in the bus storage area and 0.72 ppm in the repair area
Space set point temperature, winter: 18°C

By using heat recovery units and avoiding re-circulation, both objectives, air quality and energy savings, can be met without compromising of inside air quality.

At this time the conceptual design calls for the following heating and ventilating equipment to be installed in the buildings:

Bus Storage portion
- 14 AHU at 22,000 cfm;

Service lanes
- 1 AHU at 22,000 cfm;

Office space
- 2 Rooftop AHU/AC at 4,000 cfm.

Maintenance area
- 7 AHU at 22,000 cfm;
- 2 Rooftop AHU/AC at 4,000 cfm
- 8 exhaust fans at 4,000 cfm;

Each service bay of the maintenance garage will be provided with a 150mm and a l00 mm tailpipe exhaust system, to minimize vehicle emissions in the work space (local tailpipe exhaust: 8 systems considered). These systems would typically operate continuously on a day schedule.

The offices in both the garage and maintenance areas will be served by gas heated, electrical cooled rooftop AC unit. Each system operates as a single zone.

3.3 Emission Estimates

The major combustion emission sources on the site are related to the products of combustion of natural gas used for heating the building and diesel engine exhaust associated with the buses. The main products of combustion of hydrocarbons are carbon dioxide and water vapour, however incomplete combustion typically gives rise to traces of carbon monoxide and non-methane hydrocarbons. The other compound created during combustion is oxides of nitrogen[NO_x] created when the nitrogen in the fuel and the air used for combustion are oxidized. Since NO_x emissions are generally related to flame temperature, they can be expected to be higher from the diesel engines operating at high rpm than from natural gas combustion in the direct fired makeup air heaters.

When assessing the acceptability of new industrial sources in the province, the Ministry of the Environment's Environmental Assessment and Approvals Branch utilizes air dispersion models to predict the impact of the new facility. The Branch employs a point of impingement standard for NO_x of 500 μg/m^3 making this the most stringent criteria for acceptance of typical combustion gas emissions. Carbon monoxide POI values are 6,000 μg/m^3. No standard exists for CO_2 point of impingement values. Thus NO_x has been designated as the contaminant of concern for this study. In short, if the standards for NO_x can be met, the standards for CO will also be satisfied.

A further assessment of emissions and impacts will be conducted when the HVAC and ventilation systems in the building have been designed and specific details of the stacks and operations on site have been determined. At that time all combustion contaminants will be examined and miscellaneous activities in the maintenance areas of the building will be included in the assessment.

3.3.1 Heating Equipment Emissions

Typically, emission estimates for the heating systems in a facility are based upon the fuel consumption. That is, the input capacity of the heating system is used to estimate the worst case emission rate. Emissions factors, the quantity of a contaminant released per unit energy released in the combustion process, for gas fired appliances are provided by the US EPA's AP-42 document[11]. For NO_x, the emission factor for large wall fired boilers with low NO_x burners was applied. This value, 0.14 lb/MMBtu, is higher than the residential gas fired furnace value of 0.092 lb/MMBtu but is midway between the lowest levels and the highest levels reported in the document. This was considered a reasonable estimate for an emission factor.

Table 8 Air Handling Unit Description

Building Portion	Number Required	Individual Performance Specifications			
		Maximum Flow [cfm]	Input [MMBtu/hr]	NO_x Emission Factor [lb/MMBtu]	NO_x Emission Rate [g/s]
Storage	14	22,000	3.00	0.14	0.053
Maintenance and Service Lanes	8	22,000	3.00	0.14	0.053
Rooftop Units	4	4,000	0.30	0.14	0.005

11 US EPA AP-42, Chapter 1.4 Natural Gas Combustion, July 1998. Available at http://www.epa.gov/ttn/chief/ap42/ch01/final/c01s04.pdf

Realistically, the AHU heaters will not run at the full rated capacity all the time. The fans are capable of operating over a wide flow range, with the burner firing rate being adjusted correspondingly to achieve the required performance. In fact, the two furnaces in the AHUs each have a 10:1 turndown ratio suggesting that the lowest heat input rate could be 150,000 Btu/hr. In the summer no additional heat would be required. For the sake of this assessment, no adjustment was included, the full emission rate was assumed to be applicable at any time. When detailed model calculations are completed after the engineering design is available, consideration of adjusted emission factors, at least based upon seasons, will be undertaken.

3.3.2 Vehicle Exhaust

Diesel engines release products of combustion during operation. The quantity of contaminants released is a function of the load on the diesel engine and thus the fuel feed rate during operation. Typically, diesel engine emission factors are expressed as g/bhp-hr, that is an emission rate that is a function of the horsepower being generated by the engine at any time. Such an emission factor suggests that emissions would vary directly as the load on the engine.

The emissions from the diesel engines used in buses are limited by regulation and are limited based upon the year the bus was manufactured. In Canada the standards follow those set by the US EPA. Up until 1998 emission standards for NO_x had remained the same for 7 years even as limits for contaminants such as particulate matter were dropped. In 1998 NO_x levels were lowered and they were lowered again in 2007 to levels that were 5% of the 1998 level. A summary of standards and changes since 1998 are shown Table 9.

Table 9 US EPA Heavy Duty Diesel Emission Standards by Year of Manufacture

Year	US EPA Emission Standard Heavy-duty Diesel [g/bhp-hr]			
	CO	HC	NO_x	PM
1998	15.5	1.3	4	0.05
2004	15.5	-	2.4 with HC[4]	0.05*
2007[1]	15.5	0.14	0.2	0.01
2015	15.5	0.14	0.02[3]	0.01

*-the permitted in service level was 0.07
1-in reality manufacturers had until 2010 to meet the NO_x limit use 1.2 for 2007-10
3-an optional California Low NO_x standard, unlikely to occur in Canada
4-typically listed as NO_x 2.5 g/bhp-hr

To develop an estimate of the potential maximum emission rates for bus engines at the site one needs to know the number of buses of different manufacturing years, and apply the above standards. The Region provided a list of buses anticipated to be housed at the site which is summarised in Table 10. The information supplied indicated that all the large buses are equipped with Cummins ISL engines rated at 275 HP. The majority of the small buses are based upon the GMC 3500 chassis and are presumed to be equipped with diesel engines rated at 260 HP. To estimate fleet average emissions all engines were assumed to be 275 HP.

Any changes in the fleet mix that might occur over the next few years will be the replacement of existing vehicles with new ones, thus it can be expected that the average fleet emission rate will be lowered.

Table 10 Summary of Fleet Age 2016 and Average NOx Emission Rate

Manufacture Year	Large Bus	Small Bus	Total	NO_x Emission Rate [g/bhp-hr]	Maximum NO_x Emissions [g/hr]
2004	9		9	2.5	6,187.50
2006	7	1	8	2.5	5,500.00
2007	18		18	1.2	5,940.00
2008	15	3	18	1.2	5,940.00
2009	4	2	6	1.2	1,980.00
2010	6	5	11	0.2	605.00
2011	21	2	23	0.2	1,265.00
2012	20	3	23	0.2	1,265.00
2013	31	3	34	0.2	1,870.00
2014	5	2	7	0.2	385.00
2015	24	18	42	0.2	2,310.00
	160	45	205		33,247.5
Weighted Maximum Emission Rate [g/s/bus]					0.0451
Idling Emissions from McCormick [%]					7.59
Idling emission rate [g/s/bus]					0.0035

The engine NO_x emission standard for each year is listed in the table above and the weighted average NO_x emission rate per bus was calculated.

The operating mode for most buses on site will be idling since they will be idling during warm up periods when the brakes and other operating systems are being brought up to the operating mode and during periods when various cleaning and fuelling operation are being completed. Other operating conditions will be discussed below, but the basis for the idling operating emissions is addressed in the following paragraphs.

There is only limited data on idling emissions from diesel vehicles, and even more limited data on emissions during cold start periods. It is known that NO_x emissions from internal combustion engines are affected by temperature in the combustion chamber[12] and many idling studies are done only after the engine had reached operating temperatures. The main contaminants that are measured in most studies are the regulated species, CO, PM, and NO_x. McCormick[13] notes that there was little difference between emission results for engines hot started, or cold started at 10^{O}C. Since the buses in this study will be stored inside, the cold start engine temperatures will likely be in this range, and it can be assumed that the emissions in the published literature will be representative.

McCormick collected emission rate data from engines installed in buses, unlikely some of the emission data in the literature which comes from engine dynamometer testing of stripped engines, and thus requires adjustment to the real world. McCormick's testing was done within 20 minutes of the vehicle being tested on a chassis dynamometer, meaning that any auxiliary equipment typically used on buses would have been operational for the testing. The data collected produced an average emission rate of 2.015 g NO_x /minute during idling. The testing details include the manufacturing year of the engine along with its manufacturer and specifications. Since individual data for idle emissions is available by engine and year of manufacture for the bus, the idling emission rate for each engine as a percentage of the anticipated maximum emission rate for that engine can be determined. The average idle emission rate as a function of allowable emissions was 7.59%.

To put McCormick's numbers in context, in a 2008 publication by the US EPA[14] they estimate that the US fleet average NO_x emission rate at idle is 1.019 g/minute [0.017 g/s]. Recognizing that the fleet would include vehicles that could have been 10-12 years old as well as brand new vehicles, the effect of lower emission standards is evident. Even newer fleets will have a lower emission value. Assuming McCormick's ratio of emissions to standards level holds for the fleet to be housed at the facility, the average idling emission rate at site would be 0.0035 g/s as shown in Table 10.

While the fleet average idling emission rate has been estimated, how does one translate the idling emission data to the conventional emission factor so it can be used for the vehicles at the Northfield facility?

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12 Internal Combustion Engine Fundamentals, Heywood, J.B. Published by McGraw-Hill Ltd. OSSBN:978-0-07-028637-5. 1988.

13 McCormick, R.L., M.S. Graboski, T.L. Alleman, J. Yanowitz, 2000. Idle Emissions from Heavy-Duty Diesel and Natural Gas Vehicles at High Altitude. JAWMA 50:1992-1998

14 US EPA, 2008. Average In-Use Emissions from Urban Buses and School Buses. An Emission Facts Sheet issued by the Office of Transportation and Air Quality, EPA420-F-08-026. Available at: https://www3.epa.gov/otaq/consumer/420f08026.pdf

Estimating the emissions from the buses is a function of how the buses are being operated at any time while on the site. Emissions while vehicles are moving on or off site outside the building have not been considered since these are outside the requirements for a Section 9 approval. Any bus movement will involve the bus accelerating from a stationary position to some speed followed by coasting and braking until it stops again. During acceleration the engine will be operating at a higher power level while during stopping power output would be minimal. When stopped it is assumed that the bus will be idling. During initial use on any day, it is also assumed that the bus will be started and allowed to idle for some period of time. The most consistent operating condition will be during this warm up cycle before the bus leaves the depot.

Information from Grand River Transit suggests that the operators are allowed 10 minutes to have their vehicles on the road after they clock in to work. This is the time management suggest is needed for drivers to obtain their assignment from the starter, walk to the vehicle, perform a circle check and then ensure that the brakes are up to pressure before leaving the garage. It is imperative that the vehicle is comfortable and safe to operate. The calculated idling emission rate is assumed to represent the emissions from buses in the garage. Being inside warm-up times should be minimal. The idling period is likely to be limited for a number of reasons. EGR equipped buses can only be operated at idling speed for short periods of time, 3 minutes, to protect the emission control system. The manufacturers of all diesel engines recommend short warm up periods. They realize that the engine warms faster when operated at higher output. Lastly, longer idling time means more fuel used, providing a financial incentive for supervisors to limit idling time. For this study, it was assumed that each bus in the storage area will idle for 3 minutes.

While the average bus can be assumed to operate for 3 minutes before leaving the garage, total emissions will relate to the number of buses operating at any time. This estimate starts with the bus schedules for departure and arrival by time of day as summarized in Table 3-4. These data were based upon data provided by Grand River Transit. They reflect the movement of the buses that would be housed at the facility. While the vehicle movements show the split between arrivals and departures, they are not directly related to site emissions because the actual operating time for vehicles on site are not included. To establish emission rates, some assumptions must be made about the number of vehicles operating at any time and this is a function of the number of vehicles leaving or arriving at site at any time. The actual emission rate used for the modelling must however recognize that all the buses entering or leaving the site in a given time period will not being moving at the same time. Indeed, the operating data from other facilities suggests that during the busiest morning hour the buses leave with almost equal frequency during any given period.

The air dispersion model used to predict the impacts of emissions provides a 30-minute average point of impingement value, thus the most appropriate way to consider the data is to look at each 30 minute period, or one half the hourly circulation to determine the total movements in any 30 minute period. Table 11 shows that there are 68 vehicles leaving site in the highest traffic period. If one assumes that each bus idles for 3 minutes and they are equally distributed throughout the hour, a total of 204 minutes of bus operation occur on site in the hour, or an average of 3 vehicles would be operating at any time during the hour. This would imply that the average idling emission rate would be 0.0034 g/s/vehicle the average idling emissions during the half hour would be 3 x 0.0034 = 0.01 g/s.

Table 11 Summary of Vehicle Movements – Northfield Facility

Time	Leaving	Returning	Time	Leaving	Returning	Time	Leaving	Returning
5:00 - 6:00	68	0	**13:00 - 14:00**	1	0	**21:00 - 22:00**	0	2
6:00 - 7:00	38	0	**14:00 - 15:00**	36	1	**22:00 - 23:00**	0	11
7:00 - 8:00	42	0	**15:00 - 16:00**	8	0	**23:00 - 24:00**	0	17
8:00 - 9:00	1	4	**16:00 - 17:00**	0	3	**0:00 - 1:00**	0	31
9:00 - 10:00	0	23	**17:00 - 18:00**	0	16	**1:00 - 2:00**	0	9
10:00 - 11:00	2	16	**18:00 - 19:00**	0	45	**2:00 - 3:00**	0	1
11:00 - 12:00	1	3	**19:00 - 20:00**	0	10	**3:00 - 4:00**	0	1
12:00 - 13:00	0	0	**20:00 -21:00**	0	4			
						Totals	197	197

Returning vehicles will also influence the total emissions on site, however not to the same extent. A review of the data in Table 11 shows that the combined hourly traffic movements for any hour in the day are less than the early morning movements each day.

Having determined a representative idling emission rate per bus, the next step is to determine the number of vehicles operating at any time and relate their operating mode to emissions that occur when operating under those circumstances. Most movements on site will be of relatively short duration as distances are not large. During acceleration the engine operates at a higher power level than idling: during coasting and stopping power output would be minimal. Considering the need to manoeuver the buses into relatively restricted spaces it unlikely that the acceleration period will be very long, and it would be followed by a coasting period and a return to idle.

Data for emissions from various operating modes for diesel vehicles is available from the MOVES data published by the USEPA[3]. This report shows that coasting emissions are typically 1.5 times the idling level and short term acceleration at low speeds are approximately 5 times the idling emission rate.

Assuming that any movement of a bus in the building results in the engine of the bus operating in any of the three modes, it is possible to estimate the total emissions for that operation by

3 US EPA, 2009. Development of Emission Rates for Heavy-Duty Vehicles in the Motor Vehicle Emissions Simulator (Draft MOVES2009). Assessment and Standards Division, Office of Transportation and Air Quality US EPA. EPA-420-P-09-005. http://www.epa.gov/oms/models/moves/techdocs/420p09005.pdf

assigning durations in minutes to each type of activity. The calculations are summarized in Table 12. The following paragraphs define these durations.

Storage Area

The largest potential source in the building is the initial starting and warming of buses leaving the building in the early morning as discussed previously. The average emission rate for idling buses was discussed above. Other bus activities in the storage area also create emissions. Each bus must acceleration to move out of the garage. The full length of the storage garage is 220 m. Assuming the bus gently accelerates through the space and averages 10 km/h [2.8 m/s] over the period it would require 80 seconds to move from one end to the other of the garage. Since the 1st of the buses in any lane moves 20 m to exit the building, the 2nd 40 m, the average bus in any lane would leave the building in under 40 seconds. For this study it was assumed that each bus would accelerate/cruise at low speed for 40 seconds to exit the building. It was assumed that at no time would the bus be braking or coasting while leaving the building. Table 3-5 shows that each bus would thus release 1.33 g of NO_x during warmup and leaving the building in the morning and the average emission rate for the period would be 0.0251 g/s.

The buses return to the site at various times. The peak hour for return activity will be after 6 pm when it was assumed that the peak hourly return rate would be 45 buses per hour. Upon return the buses go directly into the garage, and are stored there until retrieved for service lane procedures, the need to turn into a storage lane will involve coasting and braking followed by driving down the lane. Assuming movements in the lanes are similar to those of buses leaving the lanes in the morning, added time will be necessary to park in the garage. Using calculations similar to those for the leaving buses, but with less acceleration, it was estimated that the average time to park a bus would be 2 minutes. Assuming 45 buses return in any 60 minute period the average emission rate is 0.0127 g/s, about 51% of the morning level. This is largely a function of reduced idling times.

Service Lanes

At the end of use for the day vehicles need to be cleaned and refuelled in the service lanes so they are ready for the following day. There are 2 lanes dedicated for this purpose, plus a bypass lane that can be used for detail cleaning. Operations in the bypass lane have not been addressed given the infrequent use of this area for cleaning. Buses will be retrieved from storage driven to the service lanes refuelled, cleaned and washed and returned to storage.

A returning bus's entry movements are discussed in the previous section, and detailed in Table 12 so this section addresses the movement from storage to the refuelling or cleaning station and back to storage. Leaving storage to go to the service lanes is assumed to be similar to the early morning departures, except that the buses would not idle in the garage for as long as they do in the morning.

Assuming a total of 10 minutes to complete servicing, garage back to garage, the time in the service lanes will approximately 7 minutes. It was assumed that 5.7 minutes were spent idling, 0.5 minutes coasting and 0.5 minutes accelerating/cruising partly because there could be stops as the bus moves down the lane and the effective speed will be on the order of 4 km/h.

Given the actual time in the service lanes, 17 buses can be serviced every hour. If all the vehicles stored in the building are serviced in this manner, the service lanes will need to operate for 12 hours per day, likely starting with the afternoon shift.

Table 3-5 summaries a set of movements for any bus through any lane including the emissions arising from taking the buses out of storage and driving them back to storage. The total emissions per bus is 3.91 g for refuelling and cleaning. The average emissions over the 12 hour period are 0.0184 g/s. These emissions will be spread over both the storage and service lane areas.

Maintenance Operations

Operations in the maintenance bay area of the building includes the contributions from vehicle movement into and out of that area and emissions from bus engines that are operating during maintenance activities.

Buses need to move in and out of the service bays. It has been assumed that all movements are under power so exhaust emissions will be created. These emissions go into the general building space and are exhausted by the heat recovery equipped exhaust fans.

There are a total of 21 active service bays as well as 3 grease and lube bays, a portable hoist bay and a tire bay. These bays will be used to service buses housed in the building. Typically, approximately 33% of the fleet could be serviced on any day. Thus 66 buses could go through the service facility each day. Since the facility will operate on three shifts, but with a reduced complement of mechanics on the overnight shift, emission estimates were based upon 25 buses being serviced on each of the day and afternoon shifts and 16 overnight. To accomplish this rate of service, an average of 3 buses need to move in and out of the maintenance area each hour of the day.

It was assumed that each movement will be similar to moving a bus from the garage to the refuelling/cleaning area, and returning it to the storage garage after servicing. Movements onto the service floor and exiting the storage area are estimated to take a total of 3 minutes. As with entering the storage garage it is assumed that the bus will move slowly into the building but emissions associated with getting it moving will occur outside the building. The differences shown for the in and out movements in Table 12 relate to the need to accelerate from a stationary position to move out of the building versus coasting and braking to get into the service bay. During the day 25 buses will be serviced, each resulting in 6 g/hour of emissions inside the building, for an average emission rate of 0.0018 g/s.

The building will be equipped with specialized exhaust fans that will enable ducting to be connected to the exhaust of a bus so it can be run during servicing. These fans have a number of pickup points so they can provide exhaust capacity for a number of service bays. It should be noted that bays designated for operations that are unlikely to involve engine operation are not equipped with exhaust equipment. These include the lube/inspection bays; brake/tire bays; body work repair bays; and the climate control bay.

Table 12 Summary of Bus Related Emissions from Building

Function	When	Operation	Idle Emission Rate [g/s/bus]	Cycle Mode	Duration [minutes]	Emission Multiplier	Emissions [g/bus]	Number Buses per Hour	Total Emissions [g/h]	Average Emissions [g/s]
Storage Bus	Morning	Out	0.0035	Idle	3	1	0.632			
				Coasting	0	1.5	0.000			
				Acceleration	0.66	5	0.695			
				Total Emissions	3.66		1.327	68	90	0.0251
	Evening	In	0.0035	Idle	1	1	0.211			
				Coasting	0.5	1.5	0.158			
				Acceleration	0.5	5	0.526			
				Total Emissions	2		0.895	51	46	0.0127
Vehicle Movement	Day	Move to Service	0.0035	Idle	1.5	1	0.316			
				Coasting	0.5	1.5	0.158			
				Acceleration	0.75	5	0.790			
	Day	Move to Garage	0.0035	Idle	1	1	0.211			
				Coasting	0.5	1.5	0.158			
				Acceleration	0.5	5	0.526			
				Total Emissions	4.75		2.159	3	6	0.0018
Daily Cleaning/Fuelling	Evening	Move to Lanes	0.0083	Idle	0.5	1	0.105			
				Coasting	0.5	1.5	0.158			
				Acceleration	0.66	5	0.695			
		Clean or Fuel	0.0035	Idle	5.5	1	1.158			
				Coasting	0.5	1.5	0.158			
				Acceleration	0.8	5	0.842			
		Move to Garage	0.0035	Idle	0.5	1	0.105			
				Coasting	0.5	1.5	0.158			
				Acceleration	0.5	5	0.526			
				Total Emissions	9.96		3.906	17	66	0.0184
Tailpipe	Day	Testing	0.0090	Idle	1	1	0.211			
				Coasting	1	1.5	0.316			
				Acceleration	13	5	13.688			
				Total Emissions	15		14.215	5.00	71	0.0197

The emission rate from buses connected to these fans was assumed to be predominantly at higher speeds similar to those encountered for acceleration. But some idle operation and some change in speed were included for a realistic situation, as shown in Table 12 under tailpipe emissions. This average emission rate was assumed to be short lived since maintenance activities are unlike to require the engines to be run at high output for long periods of time. For this evaluation it was assumed that these fans would only discharge the exhaust from any bus for a maximum of 15 minutes out of each hour, and the effective emissions for this period would be 25.2 g/bus. Assuming all bays were occupied by buses connected to the system, operating only 15 minutes out of any hour means that on average of 5 buses in the 21 bays would be operating over any hour. The total emission rate for these sources during the day/afternoon shifts would be 0.0197 g/s. As with the movement associated emissions, this rate would be reduced during the evening shift.

Summary of Bus Related Emissions in Building

Since some of the bus operations outlined in the previous section occur coincidentally, the maximum estimated emission rate should be determined based upon what is operating at any time. Table 13 identifies simultaneous activities and provides totals for select hours during the day.

Table 13 Summary of Hourly Emission Levels from Buses

Activity	Worst Hour	NO_x Emission Rate [g/s]	Morning Maximum 5 am	Evening Maximum 6 pm	Afternoon Maximum 2 pm	Peak Morning 9 am	Midnight
Leaving	5-6 am	0.0251	0.0251		0.0133		
Returning	6-7 pm	0.0127		0.0127		0.0064	0.0087
Refuel/Clean	4-12 pm	0.0184		0.0184			0.0184
Maintenance	4-12 pm	0.0018	0.0012	0.0018	0.0018	0.0018	0.0012
Tail Pipe	4-12 pm	0.0197	0.0130	0.0197	0.0197	0.0197	0.0130
			0.0393	0.0526	0.0348	0.0279	0.0413

The worst case emissions appear to occur in the early evening as the bulk of the buses return and are processed through cleaning and refuelling. For modelling the worst case hour for internal building emissions, Table 3-6 was combined with the maximum emissions from the generator and the heating systems.

3.3.3 Diesel Generators

The plans call for the installation of 2 diesel powered emergency generators. It was assumed that these units are each 600 kW output units, and that the generators are driven by 900 HP diesel engines that meet the US EPA Tier 2 non-road diesel performance levels. The NO_x emissions from each of these engines are estimated to be 1.45 g/s, based upon an emission factor of 5.8 g/Bhp-hour.

3.4 Maximum NO_x Emission Rate for Complex

Combining the heating equipment, with an estimate maximum NO_x emission rate of 1.185 g/s, with the maximum internal bus emission rate in Table 3.6 or 0.0526 g/s and the generator emissions, 1.45 g/s assuming that the generators are tested separately, results in a total emission rate of 2.69 g/s.

3.5 Refuelling Emissions

Before leaving the operations in the building, it is appropriate to look at the re-fuelling operations that will take place. The buses are assumed to have fuel tanks that hold 424 L (112 US Gal) of ultra-low sulphur diesel fuel. The current US EPA refuelling emissions standard is

0.20 g/US gallon of fuel transferred (0.053 g/L). This standard applies to both gasoline and diesel fuelled equipment, but in California diesel vehicles are not required to prove they meet this standard. This is based upon the fact that diesel fuel has a higher boiling point than gasoline, thus refueling emissions from diesel equipment tend to be much less significant than those from gasoline vehicles. Dolce[4] notes that because of these characteristics there had been little effort to study diesel refuelling emissions when he was trying to define emission factors for non-road vehicles. The author reports that an emission factor of 0.041 g/US gal for vapour displacement from diesel equipment was selected to apply for all conditions. It is noted that this rate was based on a study conducted at fuel tank temperatures of approximately 27^{O}C, but the number could be different at lower temperatures.

Assuming that the average bus will use about 75 gallons of fuel during the daily run, this will need to be added to each bus in the count down lanes. This will result in VOC emissions of 3.075 g/bus during refuelling. Assuming 25 buses per hour, it is estimated that the VOC average emission rate would be 0.021 g/s during the hours that the refuelling lanes are operating. There is no specific standard for diesel aromatics so these emissions are ignored.

4 Dolce, Gary J., 1998. Refueling Emissions for Nonroad Engine Modeling. Report NR-013. A report from the US EPA Office of Mobile Sources. http://www.epa.gov/otaq/models/nonrdmdl/nr-013.pdf

4.0 Modelling Procedures

The effects of emissions on local air quality can be assessed by modelling the movement of the emissions from a source to any receptor located around the source. This movement varies as a function of the temperature and velocity of the gases leaving the source, the height of the source and the wind conditions at the time. For sources associated with a building, the physical location and elevation are fixed, although the emission rate, temperature and velocity can vary with amount of fuel being burned in the equipment. When buses are being warmed up in the storage facility the exhaust system closest to the operating vehicles will have higher emission rates than those further away. Weather conditions: wind speeds, wind direction, the amount of solar energy hitting the earth's surface and even precipitation events, vary continuously and further add to the dispersion of contaminants released on the site. Were all these factors well characterised for the site, advanced dispersion models could be used to predict the impacts from the emissions. However, without details on the exhaust configurations this assessment uses a preliminary level of analysis to ascertain the local impacts of the facility.

The study utilized the MOECC's O.Reg. 346 model to ascertain the impacts of building operations. The model allows different configurations of stacks and buildings to be treated in different ways, depending upon the relationship of the height of the exhausts to the height of the building. If the exhausts are not location 1.5 times the height of the building above the roof the method requires that the user treat the emissions as coming from the wind oriented center of the building. This is a more conservative approach resulting in estimated levels being higher in the vicinity of the building. The plan area of the building and a representative roof height data were used to establish the emission characteristics for the model. The details are shown in Figure 1.

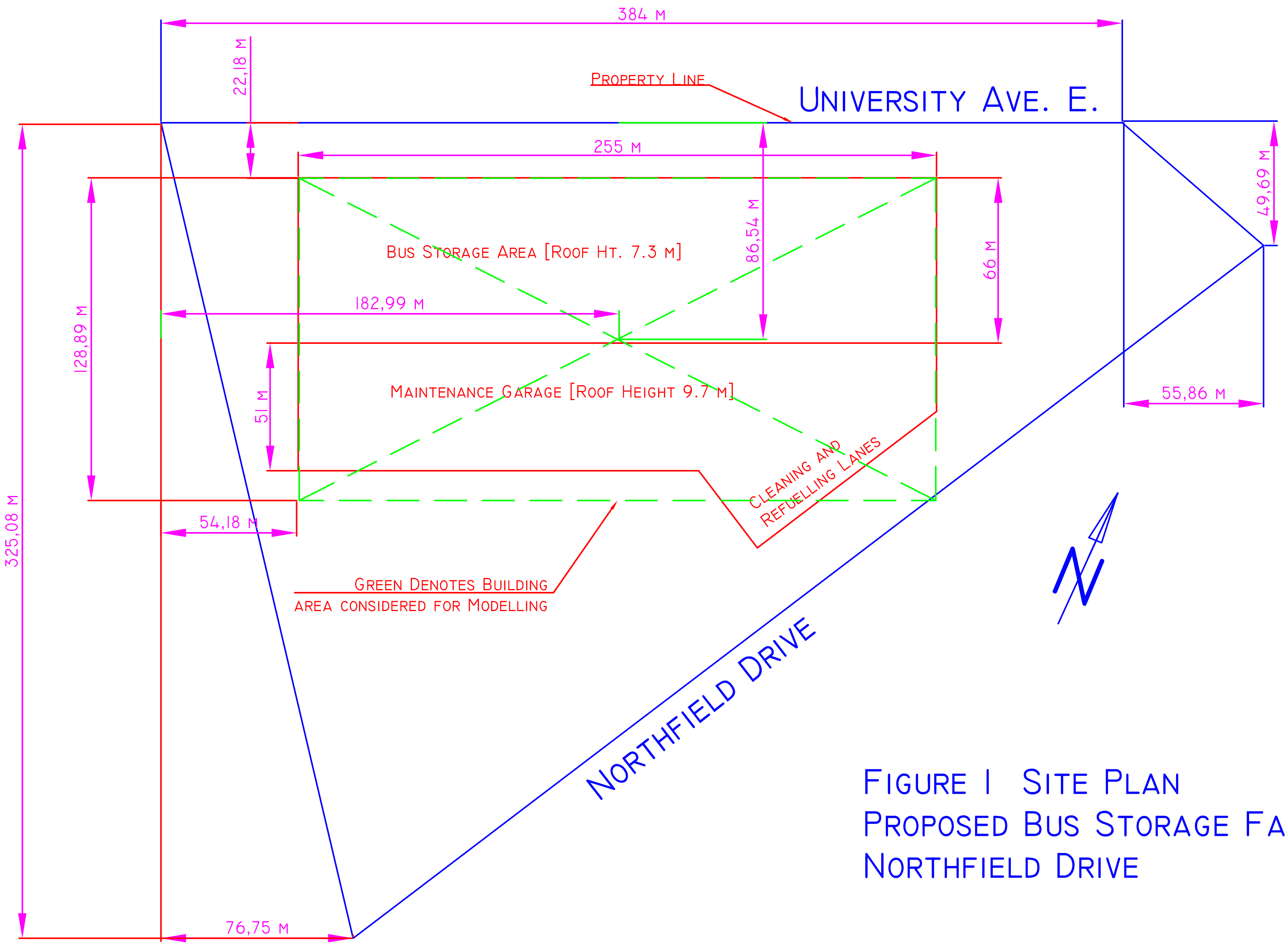

Figure I Site Plan
Proposed Bus Storage Facility
Northfield Drive

5.0 Modelling Results

The estimated emissions listed in §3.4 were modelled with the MAXGLC portion of the O.Reg. 346 model package. This provides an estimate of the maximum concentration at locations on the property boundary and off site. The output of the model is a 30-minute average concentration. Such values can be compared to the point of impingement standards, 500 μg/m^3 for NO_x, commonly used to ascertain the acceptability of new sources in Ontario.

The origin of the site, 0,0, was established at the northwest corner of the property. The source was defined as a virtual source oriented with the long dimension E-W on the coordinate system and comprised of a rectangular structure that covered the storage and maintenance portions of the building including the office structure portion. The building dimensions, shown in Figure 1 were used for the virtual source. The building height used for the model was 8.5 m, which provides a more conservative estimate of the point of impingement values than would be obtained by using the higher roof height of the maintenance portion of the building.

The results of the modelling are summarized in Table 14.

Table 14 Summary of Maximum NOx Point of Impingement Values [μg/m3]

Location	NO_x	Coordinates	POI NO_x Limit
Maximum Property Line	284	17, -85	500
Maximum Off Property	279	21, -87	500

The results show the highest concentrations to occur along the western property line. This is not surprising since the algorithm provides higher estimated concentrations along the axis that has the narrower building dimension.

The results show, that for the assumptions included in this report, the predicted maximum concentrations around the site are below the 30 minute. The maximum 30 minute NO_x value will be about 57% of the applicable POI standard. The facility would thus be considered acceptable.

When undertaking such an evaluation there are a number of conditions that can give rise to unrealistic predictions of the impacts of a facility. Most critical is the emission rate data employed. If the estimated emissions are too low, the results will fail to be representative. Conversely if the estimated emissions are too high, the model will over predict the impacts. Establishing an accurate emission rate is thus a major component of determining reliable predictions of impacts.

In this study, the emission values for all the combustion sources are considered above average in quality and should not be exceeded. Typically building heating equipment will not operate simultaneously at full input yet the model assumed it does. Heating equipment emissions would represent the maximum that would be expected.

The emissions for the diesel generator assume maximum rated output from the generator, whereas the condition that is generally considered for permitting purposes are the emissions from testing of such units. Testing is generally done at lower output levels, and will result in lower emissions. Moreover, testing is typically of short duration, frequently less than 30 minutes. Testing can also be done at the discretion of the operator, at times when the maximum emissions from buses on site, or the heating system are not occurring.

The emission factor for the bus engines is comprised of a number of factors, many of which can be considered conservative, ie. should result in higher predicted emission rates. The regulatory emission levels for engines from different years of manufacturer were applied to determine a weighted average emission rate for all the engines involved. Some vehicles might have newer engines, but this was not taken into account. Individual engine power ratings were not available however a value of 275 HP was chosen for the average engine size. The maximum power New Flyer list on their web site for the ISL engine is 330 HP but a 10% increase in the power level, would represent less than 4% increase in the overall emissions, will not change the point of impingement values significantly.

The biggest impact on idling bus emissions is the length of time the buses run during the morning warm up period. Moreover, it was assumed that the vehicles leaving the site do so in a uniform manner, rather than having large numbers of vehicles leaving at one point in the hour and none operating during other parts of the hour. Keeping in mind that the predicted concentrations are for 30 minute periods, it was assumed that an average emission rate could be obtained by taking the total number of buses, multiplying by the number of minutes they were idling and dividing that by 60 minutes to get the average number of buses operating at any time. Since the building design criteria suggest that the temperature inside will be minimum of 18°C there should be no reason for engines to idle more than the three minutes used in the calculations.

The other factory that influences the predicted point of impingement values is the configuration of the emissions. All emissions, heating systems, bus exhaust, and diesel generator emissions were assumed to be exhausted at an elevation equal to the average roof height of the two sections of the building. In actual fact the rooftop heating units exhaust at some point above the roof. The proposed units have a height of 2.7 m and the combustion exhaust is elevated above the top of the units. The units are also distributed over the top of the building to minimize internal ductwork, thereby providing some initial dispersion of the exhaust. The generators are mounted at ground level on the eastern end of the building, and are likely to have a more pronounced effect at that end of the property, than at the points the model determined to be the maxima.

All these factors suggest that the assumptions included in this assessment are conservative.

6.0 Conclusions and Recommendations

While the results of the preliminary modelling suggest that the maximum 30-minute average predicted NO_x values on and near the property are well below the standard for NO_x used by the MOECC to evaluate new stationary sources, the results should be considered as preliminary. The results are associated with specific activities on site and an emission arrangement that accounts for all the emissions, but does not address the specific configuration of stacks and vents. The predicted emissions and impacts can be adjusted when the facility's detail engineering design is completed and all equipment is identified.

That said, the source terms used in the model should be considered to be conservative as discussed in the previous chapter.

To ensure that the model is not under predicting impacts at other times of the day, the operating regime of buses on the site, whether they are being warmed in the morning, cleaned when they return to site, or serviced on site, should be confirmed and specific guidelines developed by Grand River Transit for operations of the facility. Should these differ greatly from those assumed in this evaluation, the modelling could be repeated to assess what changes might result.

The engineers charged with the design of the facility need to consider several factors too. The exhaust configuration for all process exhaust systems that ventilate the various operating spaces in the building should be arranged to provide a vertical discharge. Velocities should be kept as high as practical. These exhausts should be in stacks that terminate some distance above the highest point on the building to ensure good dispersion. These systems should also ensure that air is not re-entrained into the fresh air supply ducts for the building as this could affect workers on site. It should be remembered that all measures that increase dispersion in the atmosphere will lower the predicted concentration estimates.