Airport Road Improvements

APPENDICES

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Municipal Class Environmental Assessment
Airport Road
from 1.0km north of Mayfield Road to 0.6km north of King Street

October 2015

Region of Peel
Working for you

M AIR QUALITY

A.J. Chandler & Associates Ltd.

AIR QUALITY ASSESSMENT

FOR THE

AIRPORT ROAD ALTERATIONS
CALEDON ONTARIO

Prepared for

The Region of Peel

BRAMPTON, ONTARIO

September 30, 2013

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Executive Summary

This Air Quality Assessment document examines the potential changes in local air quality that will result from the construction and operation of Airport Road between a point 1 km north of Mayfield Road to a point 0.6 km north of King Street in Sandhill, ON. The Region of Peel is seeking to upgrade this stretch of road to alleviate congestion and improve safety. When completed the road could be configured with two lanes each northbound and southbound and a centre left turn lane to facilitate entry to driveways on the section of road. For this evaluation a number of alternatives for intersection operations are considered as these are the areas in the study corridor that are the most likely to see changes in air quality. Existing operations, and the do nothing option of leaving the road as it is are considered along with various alternatives for the intersection of Healey Road, Old School Road and Airport Road, and enlarging the intersection at King Street and Airport Road.

This assessment focuses on the impacts of the common contaminants released from automobiles and trucks as they traverse the road and undertake turning movements at the intersections. Detailed modelling of hourly impacts was initially conducted for the AM peak hour traffic period given that meteorological conditions were expected to be less favourable between 7 am and 9 am. The PM peak hour traffic emissions were also predicted and modelled, and those results are compared to the AM results. The study compares estimated airborne concentrations of NO_2 emitted from the vehicles with existing air quality levels measured at the MoE's Brampton monitoring station some 13 km due south of the center of the study area. NO_2 was chosen for the modelling because typically modelled levels of this contaminant more closely approach the standard than do other contaminants.

The maximum hourly predictions of contaminant concentrations were predicted for both the 7 am to 9 am period for each morning hour and the 4 pm to 6 pm afternoon period for a 5 year period using historic weather data. Each period required nearly 5,500 calculations for each of over 4000 receptors sited along the study area. The results were evaluated to determine predicted concentrations around the two major intersections in the study area so the Do Nothing estimates for 2011, 2021, and 2031 could be compared to alternatives including traffic signals and re-alignment at one intersection and the addition of auxiliary lanes and widening Airport Road could be considered. These results for NO_2 were also compared to monitored levels from the Brampton area.

For NO_2 the maximum hourly average concentrations surrounding the intersections were expected to drop even with increased traffic and congestion due to improved emission control systems on vehicles. The addition of auxiliary lanes and the widening of Airport Road to four through lanes is anticipated to result in a reduction of the concentration of NO_2 at locations around the intersections when compared to the Do Nothing case. Some alternatives may lead to elevated NO_2 levels in 2031 as a result of the specific traffic volumes and patterns that were modelled. The data used for the evaluation results in more uncertainty for projections further into the future and when more precise data are available these estimates could be refined to confirm predicted levels.

Traffic activity in the afternoon peak period differs from that in the morning. Modelling showed that some receptors experienced different levels in the afternoon than the morning, but the differences were shown to be in both directions, higher and lower than the morning values. Comparing the results they are well within the 46% plus or minus levels found when AERMOD was compared to extensive field data sets, suggesting that afternoon traffic activities, combined with afternoon meteorology produces no significant difference in the predicted levels.

At no time, regardless of the option or the limited data, is it predicted that levels will exceed the current ambient criteria levels of NO_2. Moreover, most situations suggest that future levels will be below the maximum currently experienced in the more urban setting of Brampton.

The evaluation considered the potential changes in greenhouse gas emissions with respect to the various alternatives and the results suggest that implementing the widening with auxiliary lanes will allow GHG emissions to be maintained at current levels or reduced slightly even though traffic volumes are expected to rise.

Overall, the assessment suggests that compared to the "do nothing" case, future air quality in the vicinity of Airport Road would be improved by the implementation of the proposed alternatives.

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1.0 Introduction

This report provides an assessment of Air Quality Issues associated with the re-alignment of intersections and the upgrading of Airport Road between Mayfield Road and north of King Street. This study is in support of an Environmental Assessment being conducted for the Region of Peel.

1.1 Project Alternatives Description

According to the Caledon Transportation Needs Study Update[1], Airport Road from north of Mayfield Road to north of King Street is to be widened from two lanes to five lanes by 2019. The Traffic Needs Assessment for the Airport Road EA[2] indicates that major deficiencies in capacity could occur on Airport Road by 2031 if no changes are made. Indeed, the capacity deficiency is estimated to be on the order of 900 Vph at Mayfield and Airport Road.

This deficiency arises in no small part from significant population growth in the Town of Caledon and the Region of Peel. The Town of Caledon population and employment growth on a town-wide level has been projected at 29% and 36% respectively from 2011 to 2021 and at 65% and 74% respectively from 2011 to 2031. Furthermore, the Airport Road corridor is planned to support growth on adjacent lands along the corridor. The corridor right of way is designated as 45 metres in the Regional Official Plan (ROP) which is sufficient to support a four lane cross-section.

Immediately south of the study area is the Tullamore South Industrial Park, which upon completion could contain 431,000 square metres of industrial and retail lands by 2018. Traffic impact, specifically site trips, documented in the Tullamore Secondary Plan Transportation Impact Study prepared by IBI Group in February 2009 were incorporated into the Traffic Needs Assessment referenced above.

The Town of Caledon is also finalizing an Official Plan Review for the Sandhill Commercial/Industrial Centre (Sandhill Land Use Study), located at the northerly limits of the study area. A series of development applications have been received by the Town and Region pertaining to highway commercial and trucking uses, all of which will ultimately impact the capacity and operation of Airport Road in the future.

1.2 Study Area

The air quality study for Airport Road in Caledon addresses the air quality impacts from vehicles operating on the road, and undertaking turning movements at intersections in the study area. The study area extends from a point 1 km north of Mayfield Road to a point 600 m north of King Street as shown in Figure 1. The width of the study area for this AQ is approximately 1 km either side of the centreline of Airport Road, extending somewhat further away from Airport Road at the intersections.

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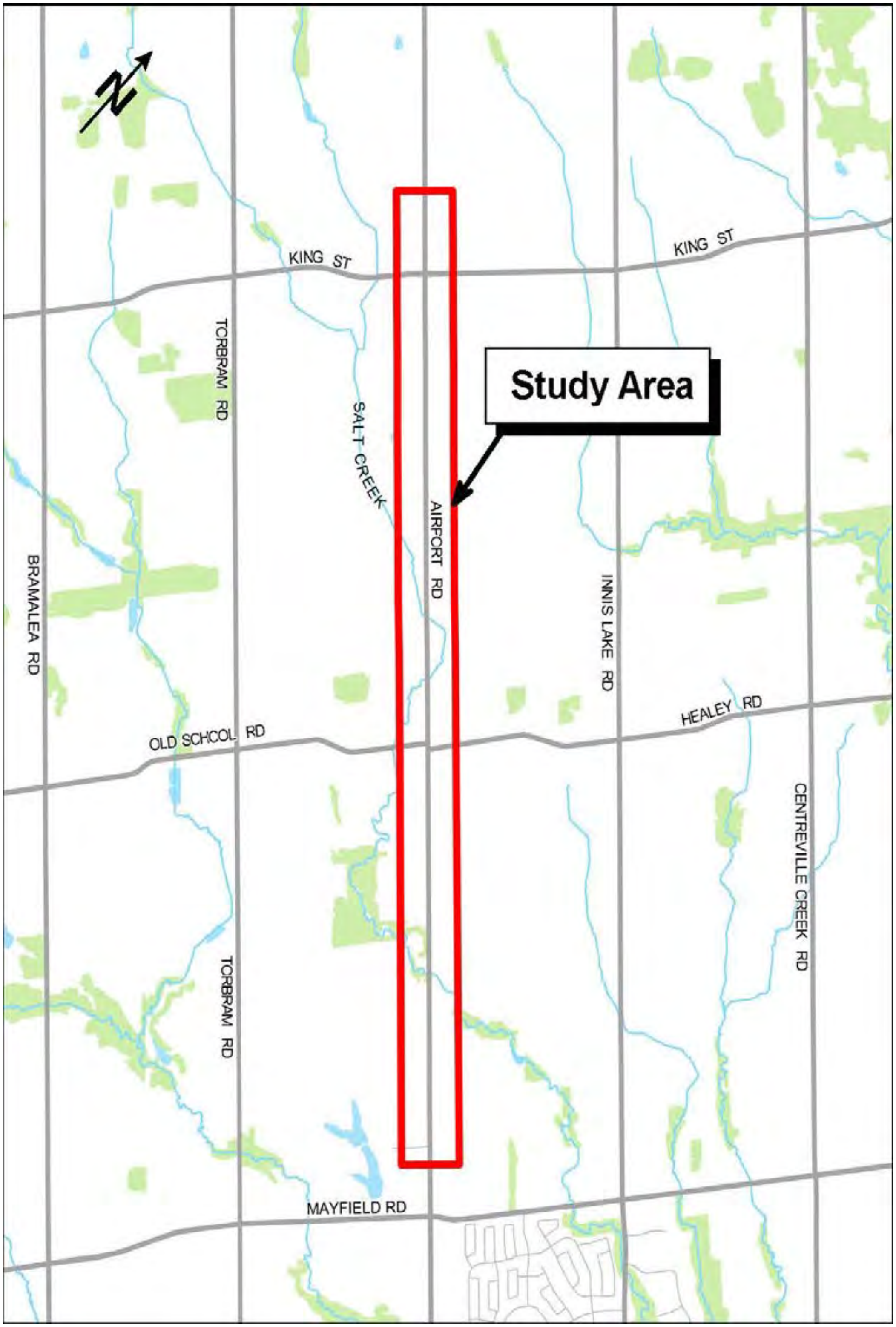
1 http://www.peelregion.ca/planning/residents/transportation/projects/pdf/catsu-report-mar-23-09.pdf
2 Region of Peel, 2013. Airport Road EA – Traffic Needs Assessment. Caledon, Ontario.

Figure 1 Study Area



1.3 Air Quality Assessment Approach

To evaluate the potential changes that would result from the anticipated increase in traffic volumes, emissions from vehicles on the major roads in the study area were considered. The Do Nothing alternative, allowing the traffic volumes to increase without changing the configuration of the road, was evaluated for 2011, 2021 and 2031, the horizon years in the Traffic Needs Study. In addition, based upon the recommendations of that study, various alternatives to Airport Road intersection operations were evaluated. These alternatives which all assume widening Airport Road to 5 lanes, 2 through lanes north and south and a center left turn lane, include:

1. Realignment of the Old School Road, Healey Road, Airport Road intersection and introducing signals at the intersection. Evaluated for both 2021 and 2031.
2. Adding auxiliary lanes at the King Street and Airport Road intersection to facilitate better traffic flow. Evaluated for both 2021 and 2031.
3. Converting both the Old School Road, Healey Road and Airport Road intersection and the King Street and Airport Road intersection to dual lane roundabout operations. Evaluated for both 2021 and 2031.

It should be noted that should traffic move at or near the speed limit through much of the study area there will only be minimal impacts to air quality at points along the route. While the full extent of Airport Road in the study area was modelled for the Do Nothing situation and a limited number of the alternatives, the emphasis was placed upon activity within 300 m of the center of the various intersections. In these areas vehicles will undergo a change in velocity due to traffic control measures, or turning movements. Any traffic control point will result in some, if not all, of the traffic being forced to stop at the signal and wait until the way is clear to proceed. This results in the vehicle decelerating, idling and accelerating away from the intersection until it reaches cruising speed. A vehicle sitting at an intersection will likely not emit as much as it does at cruising speed, but it would be present at a single location for much longer than a car moving at the posted limit. Airport Road is posted at 80 km/h which means a car will cover 22.22 m/s. If the car emitted only ¼ of the contaminants at idle that it did at cruising speed, any delay in traversing a given location on the route that exceeds 4 seconds would result in emissions that would be greater than emitted in the same area at cruising speed. Thus it is critical to determine the time that the vehicle would spend in each of the operating modes in the area of the intersection. Since emissions are related to the power generated by the engine in each of the modes assumptions about the nature of the emissions can be developed and the total contaminant release rate in any portion of the intersection can be determined. These emissions, expressed in the units of g/s can be used to model the impacts on surrounding areas.

The predicted levels can be compared to the existing air quality levels as defined by data from MoE operated monitoring station in Brampton some 13 km south of the mid-point of the study area. It should be noted that the Brampton monitoring location is in the vicinity of Main Street and Williams Parkway which are both 4 lane arterial roads. This area is much more densely populated. The buildings and these roads would be expected to contribute more contaminants to the air than one might expect to see in the study area.

2.0 Existing Air Quality in Brampton

2.1 Introduction

Air quality levels in any community are a function of the sources of air contaminants in the vicinity, and the rate at which winds bring contaminants into the area from other regions, or flush contaminants out of the area. Southern Ontario is under the influence of both local and more distant sources and to a certain extent the different areas of the province are affected by these factors[3]. Air quality in the Greater Toronto Area [GTA] that encompasses Brampton and Caledon is an example of these effects as prevailing winds move local source pollution beyond the GTA and bring in pollution from the U.S. and other southern Ontario city regions. Adding to the local air quality burden are industrial operations; large amounts of personal vehicle traffic and congestion; heavy concentrations of truck and rail freight; and high levels of air traffic. Compared to other locations in southern Ontario though, the GTA experiences fewer poor air quality days than communities to the west.

The Ontario Ministry of the Environment operate a network of air quality monitoring stations in the province and data from these locations can be used to track trends in both the temporal and spatial variations in contaminant levels in the atmosphere. This ambient air monitoring data can be used as a basis to describe the existing situation and assess the potential impacts that changes in vehicular emissions in the study area might have on air quality.

2.2 Pollutants of Concern

The air pollutants addressed in this study include:

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

The first three contaminants in the 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

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3 Ontario Ministry of Municipal Affairs and Housing [MMAH], 2004. Building Strong Communities: Municipal Strategies for Cleaner Air. Available at: http://www.mah.gov.on.ca/Page1307.aspx

weather increase the reaction rate between the chemical constituents. 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 health concerns associated with $PM_{2.5}$ and ozone have resulted in them being targeted by the Canada Wide Standards [CWS] for Particulate Matter and Ozone[4].

The closest MoE run Air Quality monitoring station is located at Peel Manor on Main Street N. in Brampton. This station has been in operation since 2007 although prior to its installation there were other monitoring stations in Brampton. Data from the Peel Manor site provides a point of reference to existing air quality in the Region. As noted in the previous section, local sources around this monitoring location are more numerous that those in the study area and thus levels would be expected to be lower in the study area. The most recent data available is from the MoE's 2010 report[5] and it is summarized in the following sections.

2.2.1 Fine Particulate Matter

Particulate matter as defined earlier included all particles that could remain suspended in the air for any length of time, but those of most interest are the respirable fraction that are less than 2.5 um (micrometers or microns) in size and designated as $PM_{2.5}$. These particles have a diameter that is 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.

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. In rural areas, particularly where there are large open fields, it is not unusual to have periods where high winds and dry conditions can lead to wind erosion of soils from the surface. Such particulate emissions consist of materials that are larger than $PM_{2.5}$. 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 to include: 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 days in the

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4 Canadian Council of Ministers of the Environment [CCME], 2000. CANADA-WIDE STANDARDS [CWS] for PARTICULATE MATTER (PM) and OZONE http://www.ccme.ca/assets/pdf/pmozone_standard_e.pdf

5 MoE, 2012. Air Quality in Ontario, 2010 Report. Available at http://www.ene.gov.on.ca/publications/8640e.pdf
Similar reports dating back to 2001 are available at http://www.airqualityontario.com/press/publications.php

year when the 24 hour average exceeded 30 ug/m^3) and the 98th percentile values for 3 years. These data are shown in Table 1.

Table 1 Summary of Brampton PM2.5 [ug/m3] Data for 2007 – 2010

Year	24-hr Mean	24-hr 90th Percentile	Maximum 24 Hour	Maximum 1 Hour	Number of Days Value > 30 ug/m^3	CWS 98th Percentile for 3 years (year ending)
2007	7.4	17	39	65	5	28
2008	6.8	16	36	49	1	24
2009	5.6	12	32	37	1	22
2010	5.8	14	27	54	0	19

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 with the hourly values providing an indication of local variations. The criteria value for $PM_{2.5}$, 30 ug/m^3 is based upon the 98th percentile of the daily averages over the last 3 year. These values are in the last column of Table 1. The trend in this data has been downwards from 2007 largely following the trend in the annual maxima.

2.2.2 Ozone

While not directly released from combustion sources, ozone levels can be influenced by releases of VOC and NO_x to the atmosphere. The MoE 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. Oxides of nitrogen, NO_x, the general term for nitrogen compounds released to the atmosphere, include both 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 MoE reports mean hourly data for the year for ozone at monitoring stations as well as computing the maximum 1 hour and 24 hour averages. Table 2 provides the results for the Brampton station for 2007 - 2010. The Canada Wide Standard $PM_{2.5}$ also contains a numerical target for ozone. In this case the standard is based upon the average of the 4th highest 8 hour rolling average value of ozone for each of the last three years. The criteria value is 65 parts of ozone per billion parts of air [ppb]. The MoE's 2010 Air Quality report shows that the Brampton average level based upon taking the 4th highest annual value was approximately 69 ppb, over the standard. The report notes that this is not an exception as few locations in the province meet the standard; however, the levels are decreasing indicating air quality is improving in the province.

Table 2 Summary of Brampton Ozone [ppb] Data for 2007 to 2010

Year	1 hr Mean	1 hr 90th Percentile	Maximum 1 Hour	Maximum 24 Hour	Number of Hours Value > 80 ppb
2007	26.8	46	106	60	37
2008	26.6	47	83	60	9
2009	25.2	43	90	65	7
2010	27.5	45	77	60	0

Note: ppb = parts per billion

2.2.3 Oxides of Nitrogen

Trends in the concentrations of oxides of nitrogen at the Brampton monitor are presented in the MoE report. NO_2 is the form of oxides of nitrogen that are most important from a health perspective. That species is monitored along with NO and NO_x. The NO_x and the NO_2 90th percentile data are shown in Table 3. The 2010 Air Quality report suggests that the annual average NO_2 levels in province have decreased by approximately 34 per cent over the 10-year period of 2001 to 2010, and 39 per cent. There is insufficient data to track this parameter for 10 years in Brampton, but the annual average dropped in 2010. The decrease has been attributed to more stringent emission standards for on-road vehicles.

Table 3 Summary of Brampton NO_2 [ppb] Data 2007 to 2010

Location	Annual Mean NO_2	1-hr 90th Percentile		1 hour Average		24 hour Average	
		NO_2	NO_x	Maximum	Times >200 ppb	Maximum	Times >100 ppb
2007	13.9	30	44	62	0	38	0
2008	13.1	28	42	68	0	43	0
2009	13.3	29	44	57	0	38	0
2010	10.7	24	29	62	0	40	0
Average	12.75	27.75	39.75	62.25	0	39.75	0
Average NO_2/NO_x		0.698					

2.2.4 Carbon Monoxide

Carbon monoxide [CO] is created when incomplete combustion does not allow total oxidation of carbon in fuels to CO_2. Carbon monoxide is colourless, odourless, tasteless, and at high concentrations, a poisonous gas. The gas can enter the blood stream and impair oxygen delivery to organs and tissues, thus it is a criteria contaminant with the MoE standards being for the 1 hour average CO below 30 ppm and for the 8 hour average CO below 13 ppm. The provincial data suggest that the levels of CO are not of concern. The MoE suggest that provincially the CO levels have decreased consistently since 1971, being down nearly 90% on average. There is no data for CO levels in Brampton.

2.2.5 Mobile Source Air Toxics

As the name suggests Mobile Source Air Toxics [MSAT] are compounds released into the air from highway vehicles and non-road equipment. There is guidance from the US EPA for addressing the potential effects of Mobile Source Air Toxics which are a subset of the 188 air toxics defined by the US Clean Air Act. Some toxic compounds are present in fuel and are emitted to the air when the fuel evaporates or passes through the engine unburned. Other toxics are emitted when there is incomplete combustion of fuels. Still others are formed as secondary combustion products. Metal air toxics could also be included but since they are the result from engine wear or from impurities in oil or gasoline they are difficult to quantify for mobile sources and are ignored at this time. Currently the US EPA are targeting of 6 priority MSATs:

- Benzene - characterized as a known human carcinogen;
- Acrolein - the potential carcinogenicity of acrolein cannot be determined because the existing data are inadequate for an assessment of human carcinogenic potential for either the oral or inhalation route of exposure;
- Formaldehyde - a probable human carcinogen, based on limited evidence in humans, and sufficient evidence in animals;
- 1,3-butadiene - characterized as carcinogenic to humans by inhalation;
- Acetaldehyde - a probable human carcinogen based on increased incidence of nasal tumors in male and female rats and laryngeal tumors in male and female hamsters after inhalation exposure;
- Diesel exhaust (DE) - likely to be carcinogenic to humans by inhalation from environmental exposures. Diesel exhaust is the combination of diesel particulate matter and diesel exhaust organic gases. Diesel exhaust also has been linked to chronic respiratory effects, and is possibly the primary non-cancer hazard from MSATs. Prolonged exposures may impair pulmonary function and could produce symptoms, such as cough, phlegm, and chronic bronchitis.

Even though these substances are targeted as part of the MSATs, the latest data about each substance noted on the US EPA's Integrated Risk Information System site[6] shows that only formaldehyde has been undergoing detailed re-assessment since 2003. In the US, the EPA is the lead Federal Agency for administering the Clean Air Act and has certain responsibilities regarding the health effects of MSATs. Their studies suggest that between 2000 and 2020, the programs to reduce vehicular emissions will result in the reduction of on-highway emissions of benzene, formaldehyde, 1,3-butadiene, and acetaldehyde by 57 percent to 65 percent, and will reduce on-highway diesel PM emissions by 87 percent. The Federal

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6 http://www.epa.gov/iris/

Highway Agency [FHWA] projects that even with a 64 percent increase in the number of vehicle miles travelled [VMT] the effect of these reductions will be realised.

The FHWA[7] developed a tiered approach for analyzing MSATs. Depending on the specific project circumstances, FHWA identified three levels of analysis:

1. No analysis for projects with no potential for meaningful MSAT effects;
2. Qualitative analysis for projects with low potential MSAT effects; or
3. Quantitative analysis to differentiate alternatives for projects with higher potential MSAT effects.

The FHWA suggests that the threshold in meaningful increases in MSATs is the addition of a new highway with capacity for over 114,000 AADT. The existing AADT on Airport Road is under 9,000 vehicles combining both north and south traffic. Even with the 3% annual growth to 2012 and 2% to 2013 the total is anticipated to be less than 15,000 vehicles per day in 2013. On this basis, the anticipated volume does not warrant a quantitative analysis, but according to the guidance, a qualitative analysis should be done.

The following qualitative analysis provides a basis for identifying and comparing the potential differences among MSAT emissions, if any, from the various alternatives. The qualitative assessment presented below is derived in part from a study conducted by the FHWA[8]. For minor widenings, such as anticipated with this project, the suggested evaluation is as follows:

For each alternative in this study, the amount of MSAT emitted would be proportional to the vehicle kilometers traveled, or VKT, assuming that other variables such as fleet mix are the same for each alternative. The VKT estimated for each of the evaluation years is higher than that for the existing situation based upon historic growth rates. No allowance has been made for additional traffic based upon the anticipated capacity increases and increased efficiency of the roadway. That is it is not anticipated that the widening and other alterations will attract trips from elsewhere in the transportation network. The increase in VKT would lead to higher MSAT emissions along the corridor and if additional traffic were to be rerouted from parallel routes they would see a corresponding decrease in MSAT emissions. The emissions increase is offset somewhat by lower MSAT emission rates due to increased speeds; according to EPA's MOVES2010b model, emissions of all of the priority MSAT decrease as speed increases. Also, regardless of the final configuration, future emissions will likely be lower than present levels as a result of national emission control programs that, in the US, are projected to reduce annual MSAT emissions by over 80% between 2010 and 2050, even with a doubling in the total number of VKT travelled in the US in 2015. Since Canadian vehicle emission standards are similar to those in the US MSAT on Airport Road would be expected to decrease too. Local conditions may differ from the national projections by the US EPA in terms of fleet mix and turnover, VKT growth rates, and

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[7] FHWA, Interim Guidance on Air Toxic Analysis in NEPA Documents, February 3, 2006. Most recent version available at: http://www.fhwa.dot.gov/environment/air_quality/air_toxics/policy_and_guidance/aqintguidmem.cfm including Appendix B which provides prototype language for a qualitative assessment

[8] FHWA, A Methodology for Evaluating Mobile Source Air Toxic Emissions Among Transportation Project Alternatives, found at: www.fhwa.dot.go/environment/air_quality/air_toxics/research_and_analysis/methodology/methodology00

local control measures. On the whole it is expected there will be a drop in MSAT emissions between the current level and those expected for 2031 even with an increase of 63% in the number of VKT because most of the reduction in anticipated to be realised by 2030.

The additional travel lanes contemplated as part of the project alternatives will have the effect of moving some traffic closer to nearby homes, schools, and businesses. However, the magnitude and the duration of these potential increases compared to the No-Build alternative cannot be reliably quantified due to incomplete or unavailable information in forecasting project-specific MSAT health impacts. In sum, when a highway is widened, the localized level of MSAT emissions for the Build Alternative could be higher relative to the No Build Alternative, but this could be offset due to increases in speeds and reductions in congestion (which are associated with lower MSAT emissions). Also, MSAT will be lower in other locations if traffic shifts away from them. However, on a regional basis, new vehicle and fuel regulations, coupled with fleet turnover, will over time cause substantial reductions that, in almost all cases, will cause region-wide MSAT levels to be significantly lower than today.

Even though it might be more satisfying to include a basic analysis of the likely MSAT emission impacts of the project in this report, the US EPA has determined that while the potential for these emissions exists, the currently available technical tools do not enable the prediction of project-specific health impacts of the emission changes associated with such projects. To address these deficiencies, the US EPA and the FHWA recommend that the following general discussion of the issues be included and that the discussion specifically address incomplete or unavailable information.

Information that is Unavailable or Incomplete

Evaluating the environmental and health impacts from MSATs for a proposed project would involve several key elements, including emissions modelling, dispersion modelling in order to estimate ambient concentrations resulting from the estimated emissions, exposure modelling in order to estimate human exposure to the estimated concentrations, and then a final determination of health impacts based on the estimated exposure. Each of these steps is encumbered by technical shortcomings or uncertain science that prevents a more complete determination of the MSAT health impacts.

Emissions The US EPA tools to estimate MSAT emissions from motor vehicles are not sensitive to key variables that can influence emissions of MSATs for the alterations to Airport Road, particularly with respect to local effects. This is because the method used to predict vehicle emissions, while valuable for assessments at a regional level, has limited applicability at the project level. The procedure is based upon modelling trips typically about 10 km in duration at some average speed. This approach does not allow the researcher to predict MSAT emission factors for a specific vehicle operating condition at a specific location at a specific time. For particulate matter, the model results are not sensitive to average trip speed, although for the other MSATs emission rates do change with changes in average speed. Maybe most importantly, the emissions rates used in emission factors approach are based on a limited number of tests of mostly older-technology vehicles. While the emissions model is an adequate tool for projecting emissions trends and performing relative analyses between alternatives for very large projects, it is not sensitive enough to capture the effects of travel changes tied to smaller projects or to predict emissions near specific roadside locations.

Dispersion The tools to predict how MSATs disperse are also limited. The US EPA's current regulatory models, CALINE3 and CAL3QHC, were developed and validated more than a decade ago for the purpose of predicting episodic concentrations of carbon monoxide to determine compliance with the NAAQS. The performance of such dispersion models is more accurate for predicting maximum concentrations that can occur at some time at some location within a geographic area. This limitation makes it difficult to predict accurate exposure patterns at specific times at specific project locations surrounding a given roadway to assess potential health risk. Research was underway in 2006 to determine best practices for applying models and other technical methods in the analysis of MSATs. Those results have not been published to the present time. Moreover, investigations are also faced with a lack of monitoring data in most areas which limits the ability for the researcher to establish project specific MSAT background concentrations.

Exposure Levels and Health Effects Finally, even if emission levels and concentrations of MSATs could be accurately predicted, shortcomings in current techniques for exposure assessment and risk analysis do not allow one to reach meaningful conclusions about project-specific health impacts. Exposure assessments are difficult because they require an accurate calculation of annual concentrations of MSATs near roadways coupled with a good understanding of how much time in a year people are actually exposed to those concentrations at a specific location. These difficulties are magnified for 70-year cancer assessments, particularly because unsupportable assumptions would have to be made regarding changes in travel patterns and vehicle technology (which affects emissions rates) over a 70-year period. There are also considerable uncertainties associated with the existing estimates of toxicity of the various MSATs because of factors such as low-dose extrapolation and translation of occupational exposure data to the general population. Any calculated difference in health impacts between alternatives would likely be much smaller than the uncertainties associated with the calculation of the impacts. Therefore, the results of such assessments would not be useful to decision makers, who need to weigh that information against other project impacts that are better suited for quantitative analysis.

Summary of Existing Credible Scientific Evidence Relevant to Evaluating the Impacts of MSATs

Research into the health impacts of MSATs is ongoing. For different emission types, scientific studies show that MSATs are statistically associated with adverse health outcomes through epidemiological studies (frequently based on emissions levels found in occupational settings) or that animals demonstrate adverse health outcomes when exposed to large doses. These studies do not examine the low or chronic doses expected to occur in the environmental setting. The effects of exposure to toxics have been a focus of a number of US EPA efforts. Most notably, the US EPA conducted the National Air Toxics Assessment (NATA) in 1996 to evaluate modelled estimates of human exposure applicable to the county level. While not intended for use as a measure of or benchmark for local exposure, those estimates best illustrate the levels of various toxics when aggregated to a national or State level.

The US EPA is in the process of assessing the risks of various kinds of exposures to these pollutants. The US EPA Integrated Risk Information System (IRIS) is a database of human health effects that may result from exposure to various substances found in the environment. The IRIS database is located at http://www.epa.gov/iris.

Relevance of Unavailable or Incomplete Information

It is important to consider the quality of the data that might be available to evaluate reasonably foreseeable significant adverse impacts on the environment. Moreover such an evaluation should be based upon theoretical approaches or research methods generally accepted in the scientific community. Because of the uncertainties outlined above, a quantitative assessment of the effects of air toxic emissions impacts on human health cannot be made at the project level. While available tools do allow us to reasonably predict relative emissions changes between alternatives for larger projects, the amount of MSAT emissions from each of the project alternatives and MSAT concentrations or exposures created by each of the project alternatives cannot be predicted with enough accuracy to be useful in estimating health impacts. Therefore, the relevance of the unavailable or incomplete information is that it is not possible to make a determination of whether any of the alternatives would have "significant adverse impacts on the human environment."

The project may result in increased exposure to MSAT emissions in certain locations, although the concentrations and duration of exposures are uncertain. Because of this uncertainty, the health effects from these emissions cannot be estimated, and no further consideration will be made of these contaminants in this study.

2.3 Ambient Air Quality Criteria and Monitoring Results

Ambient air quality levels can be judged against a number of criteria or standards including the Canada Wide Standards for Ozone and $PM_{2.5}$. A number of criteria are summarized in Table 4. In all cases these criteria are set to protect the general community. There is a range of anticipated health outcomes associated with air pollution. Short term exposures to high levels can lead to mortality as can long term exposures to somewhat lower levels of air pollutants. Cardiac patients, both the elderly and others, can be admitted to hospitals as the result of exposure to air pollutants, or simply need to visit emergency rooms. Respiratory emergency room visits followed by chronic bronchitis attacks in adults and then children represent the next level of effects. Asthma symptoms and the number of acute respiratory symptom days reported increases with air pollution levels. At the bottom of any list of health effects are restricted activity days when the effects of air pollution reduce the ability of residents to undertake their normal activities.

The MoE assists the public in interpreting existing air quality in communities by publishing an Air Quality Index [AQI] number for every hour of the day. The AQI is a relative number that relates adverse human health effects and pollutant levels. The index looks at O_3, $PM_{2.5}$, NO_2, CO, SO_2 and total reduced sulphur [TRS] compounds. By taking the concentration of each pollutant at the end of the hour and converting it to a number ranging for zero upwards on a common scale, each pollutant is assigned a sub-index value for the hour. The highest sub-index for any given hour becomes the AQI reading for that hour. Since the numbers for each pollutant are calculated on a a relative scale, the lower the index, the better local air quality is in that area.

For 2010 the AQI numbers for Brampton are shown in Table 5. Over 90% of the readings are in the Good to Very Good range.

Table 4 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)	-
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]
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	30		
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			65	
Provincial Target			65	

Table 5 Air Quality Index Summary for Brampton 2010

Valid Hours	Percentage of Valid Hours AQI in Range					Number of Days with at least 1 hour >49
	Very Good	Good	Moderate	Poor	Very Poor	
	0-15	16-31	32-49	49-99	100+	
8747	33.7	59.2	7.1	0	0	0

3.0 Evaluation of Air Quality Impacts of Proposed Project

To evaluate the air quality impacts of any project it is necessary to determine the quantity of emissions released into the atmosphere and their distribution both spatially and temporally. The emissions considered in this report are those related to vehicular activity on Airport Road and the intersecting roads. The major emissions from vehicular engines are the priority pollutants: $PM_{2.5}$, NO_x, and CO. Estimates were developed based upon the peak traffic volumes in the morning and the afternoon as presented in the Traffic Needs Assessment report.

3.1 Anticipated Emissions

3.1.1 Criteria Pollutant Emission Factors

As would be expected traffic volumes on Airport Road and the intersecting roads are highest during the morning and afternoon rush hour periods. These periods represent the most critical times for congestion on the road. Congestion leads to delays, and delays result in the potential for higher emissions, particularly in the vicinity of the intersections. The longer a vehicle spends on any given portion of the road the higher its emissions will be in that area. The other factor that affects the quantity of contaminants released from a vehicle's engine is the amount of power the engine is producing at any given time.

As explained in Appendix A, there are other factors that influence the rate of emissions. The age of the vehicle, regardless of the size of the engine, is a major factor. Newer vehicles will have lower emission rates largely because emission regulations are forcing cleaner engines to be manufactured. The trend in emissions is shown in Table 6 which highlights the data for the criteria pollutants derived from the UTEC calculator. Over the 20 year period CO emissions are anticipated to drop by 37%, NO_x by 71% and $PM_{2.5}$ by 7%. As shown in Table 9, the reduction in $PM_{2.5}$ emissions for trucks is anticipated to be much more dramatic than that for passenger vehicles.

Table 6 Comparison of Anticipated Automobile Emissions [g/s at cruise speed of 70 km/h] for Different Years

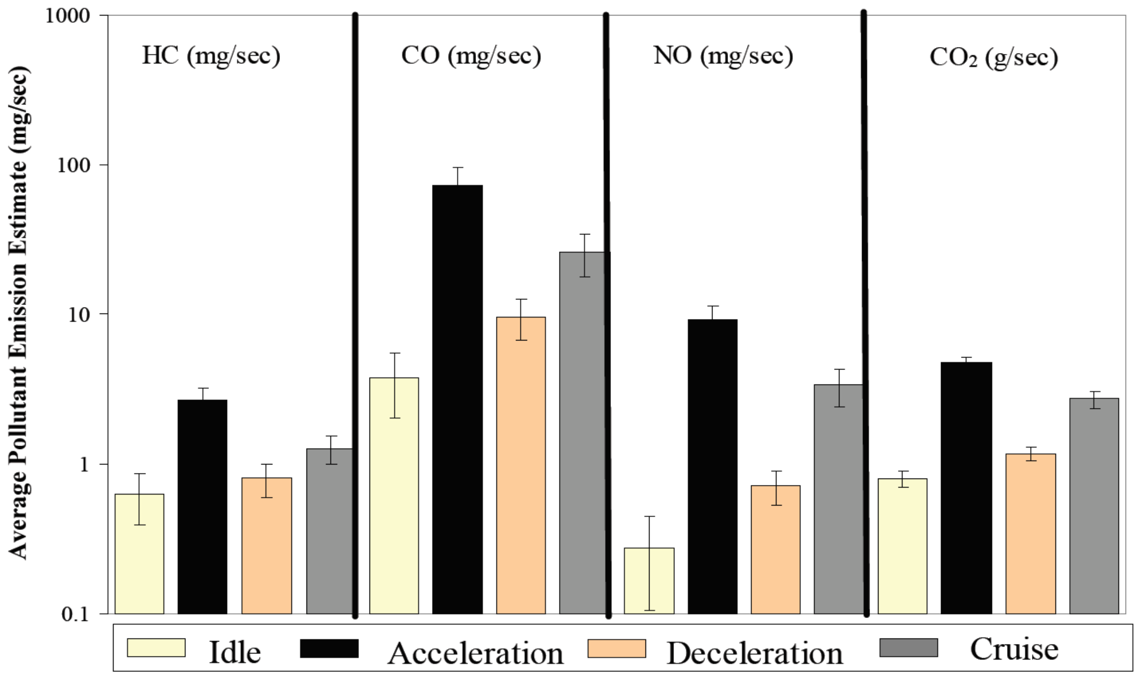
Year	2011	2021	2031
CO	0.16707	0.11516	0.10515
NOx	0.00770	0.00287	0.00225
PM2.5	0.00014	0.00013	0.00013

The emission rates shown in Table 6 represent the estimated emissions at cruising speed for the fleet of vehicles likely to be in operation in Ontario at the various years. Considering that vehicles are likely to stop at intersections, one would expect a range of power output would be needed during such actions and emissions will vary under these conditions. Frey et al.[9], during their work in developing the basis of the MOVES approach to predicting vehicular emissions, illustrated the emission rate differences

[9] Frey, H.C., J. Zheng, Y. Zhao, S. Li, and Y. Zhu (2002), Technical Documentation of the AuvTool Software for Analysis of Variability and Uncertainty, Prepared by North Carolina State University for the Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC. February 2002.

associated with different modal activities. Figure 2[10] shows an example of the variation in emission rate as a function of the operating mode of the vehicle. This early work was extended to the VSP model which is used to define emissions associated with particular modes of operation. The equation for VSP is provided in Appendix A however it is important to note that the value is a function of the instantaneous acceleration and the instantaneous speed of the vehicle at any time.

Figure 2 Average Modal Emission Rates for LDGVs (Source: Frey et al., 2002)



As discussed in Appendix A, Papson et al. undertook a study at signalized intersections to evaluate the impacts of different configurations on air quality. Utilizing a more up to date form of the MOVES model, the researchers showed that if the rate of cruise emissions are designated as 1, acceleration is 1.7, deceleration is 0.5 and idling is approximately 0.25 of the cruise value. Thus the cruise emissions in any horizon year in Table 6 can be pro-rated for operations on Airport Road. Since vehicles would be expected to be in these different modes for different periods of time, in order to apply these values one needs to estimate the amount of time the vehicle would be expected to be in a particular operating mode. This is generally referred to as the Time-in-Mode [TIM] for vehicle activities.

Essentially the TIM defines the expected amount of time that a vehicle will be in each of the 4 modes of travel: cruise, deceleration, idle, acceleration. Appendix A discusses how these data were developed from traffic assessment data available in the Traffic Needs Assessment document and applied to different configurations of the intersections in the study area.

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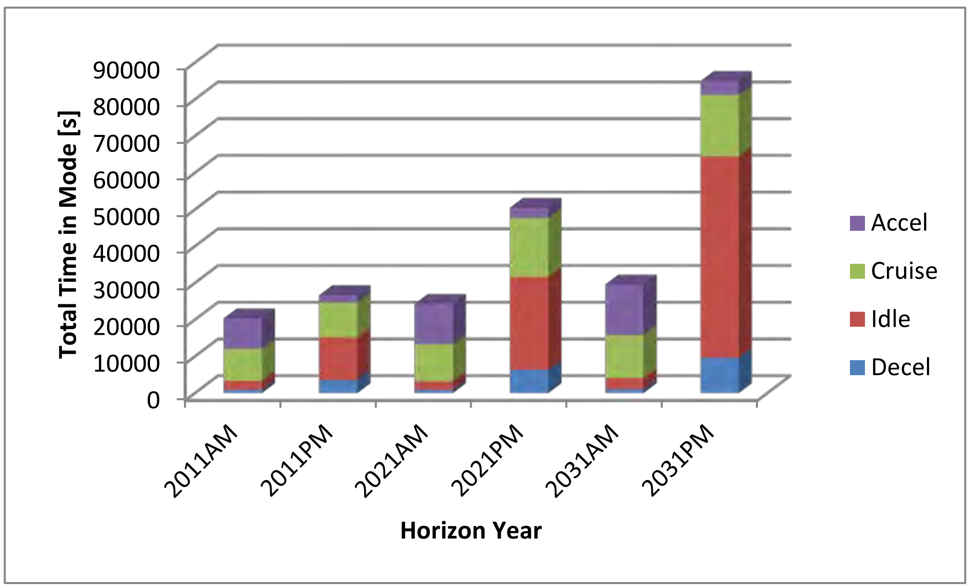
10 North Carolina State University, 2002. Methodology for Developing Modal Emission Rates for EPA's Multi-Scale Motor Vehicle and Equipment Emission System. A report to US EPA Assessment and Standards Division, Office of Transportation and Air Quality. Report # EPA 420-R-02-027. October. Available at: http://www.epa.gov/oms/models/ngm/r02027.pdf

The calculations were completed for each type of traffic movement in the intersection. First one must define the possible actions of a vehicle entering an intersection. An example of movements at a four way intersection such as King Street and Airport Road can be used to illustrate the process. There is traffic approaching the intersection from each of the four directions. On the northbound approach vehicles arriving in the intersection can proceed through the intersection, or turn left or turn right. In the southbound lane leaving the intersection the traffic is comprised of the eastbound right turns, the southbound through traffic and the westbound left turn traffic. The total amount of time spent by cars arrive at the intersection on the approach is the sum of cruise time, deceleration time, and idling time waiting for the light to change. The departing traffic is assumed to essentially accelerate out of the intersection to reach cruising speed. By summing the amount of time spent by each car for each type of movement, the TIM for the approach is determined. The results of the TIM evaluation for each approach to the intersections for both AM and PM peak traffic, and for the 3 horizon years and each option are provided in Appendix A.

The results of the analyses are illustrated by the Do Nothing condition on the northbound approach to the King Street and Airport Road intersection shown in Figure 3.

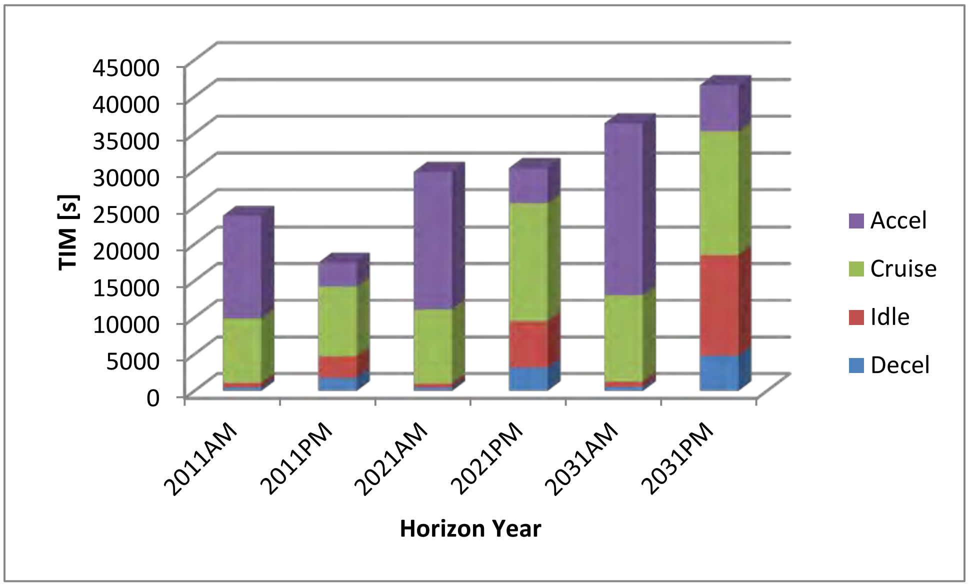
Figure 3 Plot of TIM for King Street and Airport Road Northbound Approach



The figure shows that the time it takes traffic to go through the intersection is greater in the afternoon than in the morning, largely because there is more northbound traffic in the afternoon rush hour. More noticeable is that without any changes to the intersection the increase in traffic over the period will result in an increase in the total time for all the cars to clear this intersection. This duration rises by nearly a factor of 4. Much of this change relates to the increased idling time in the intersection. As a result of having to wait in the intersection, the average time for an afternoon rush hour northbound through vehicle to enter, wait and depart the intersection would double between 2011 and 2031 if no changes were implemented.

The effect of the change in the TIM on emissions was assessed by multiplying the time for each mode by the appropriate factor for deceleration, idling and acceleration noted earlier. Essentially the time in seconds is multiplied by the appropriate emission scaling factor to create cruise equivalent emissions on the approach. The Do Nothing results for the King and Airport intersection are shown in Figure 4. The contribution of the large proportion of idling time to total emissions is reduced, while the acceleration and cruise contributions become more dominant. This would be expected since these modes have the highest emissions associated with them.

Figure 4 Normalised TIM for Northbound Approach King Street and Airport Road



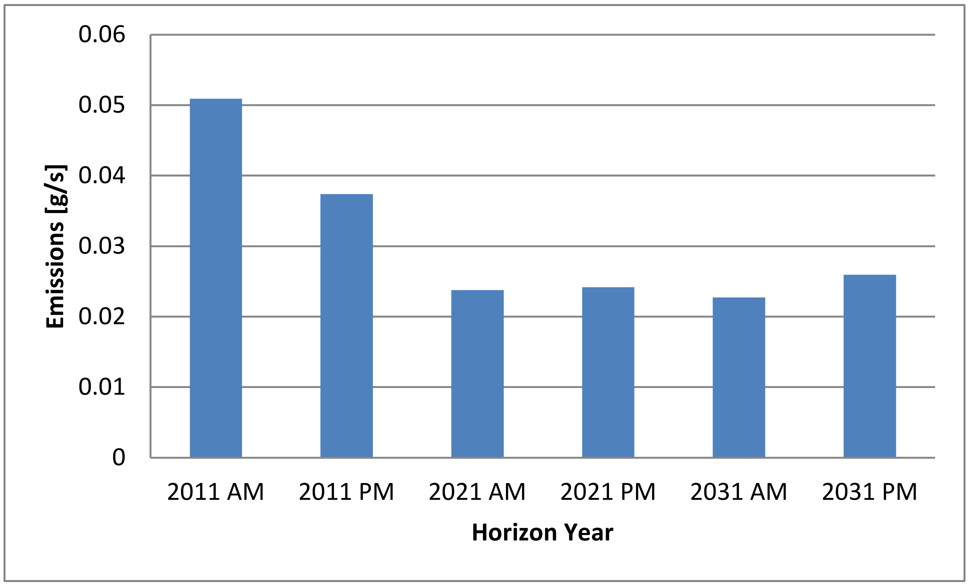
To extend this approach the NO_x on the northbound approach over the years is shown in Figure 5. This figure illustrates the combined effect of vehicles spending more time in the intersection in later years mitigated somewhat by the reductions in NO_x as the fleet is replaced with vehicles with improved emission levels.

As noted earlier the Traffic Needs Assessment report recommends that Airport road be widened to 5 lanes, so a center left turn lane is created and traffic can move in 2 northbound and 2 southbound through lanes. Several alternatives were recommended for the two major intersections in the study area:

1. Realignment of the Old School Road, Healey Road, Airport Road intersection and introducing signals at the intersection.
2. Adding auxiliary lanes at the King Street and Airport Road intersection to facilitate better traffic flow.
3. Converting both the Old School Road, Healey Road and Airport Road intersection and the King Street and Airport Road intersection to dual lane roundabout operations.

For this study the effects of these intersection alternatives were evaluated for both 2021 and 2031. Emissions for NO_x, CO and $PM_{2.5}$ for these years are provided in Table 11 in Appendix A.

Figure 5 Comparison of Do Nothing NOx Emissions Northbound Approach King and Airport



3.1.2 Greenhouse Gas Emissions

The combustion of fossil fuels is the chief source of greenhouse gases in the atmosphere. All gasoline and diesel powered vehicles emit greenhouse gases, mainly carbon dioxide [CO_2], when they are operating. The amount of CO_2 emitted is directly correlated with the amount of fuel being burned at any time. As noted earlier, the energy generated and the fuel burned will vary by power delivered to the wheels of the vehicle. Using the weighted time in the intersection the tonnes of CO_2 emitted for the different options can be compared as shown in Figure 6.

Figure 6 shows a comparison of GHG emissions at the King and Airport intersection. The GHG hourly emissions for the AM and PM rush periods are shown for the Do Nothing alternative in all three horizon years. Also shown are the effects of widening Airport Road and improving the signalised intersection, and the installation of a roundabout at the intersection. Since the upgrading of the intersection was not evaluated with the 2011 traffic volumes, a zero value is shown in the figure. Other similar comparisons can be derived from the data in Appendix A. Similar data for the Old School/Healey/Airport intersection can be seen in Figure 7 where the Do Nothing cases and the alternatives for that intersection are provided.

The amount of GHG emitted in the various years reflects the anticipated emission reductions in the two horizon years, as well as the effect of the alternatives. At King Street alterations to the lanes will reduce emissions compared to the Do Nothing situation, although the effect is not as great as will be seen at Old School/Healey and Airport Road because the re-alignment of the intersection will have to be addressed with longer cycle times. At either intersection the calculations suggest that the emissions may be increased with the introduction of the roundabout situation. This finding could be the result of using the effective stop rate from the aaSIDRA model which addresses the creep that occurs in the approaches as cars move towards the stop line. The TIM calculations for signalised intersections make the

Figure 6 Comparison of Greenhouse Gas Emissions at King Intersection by Alternative [tonne/hr]

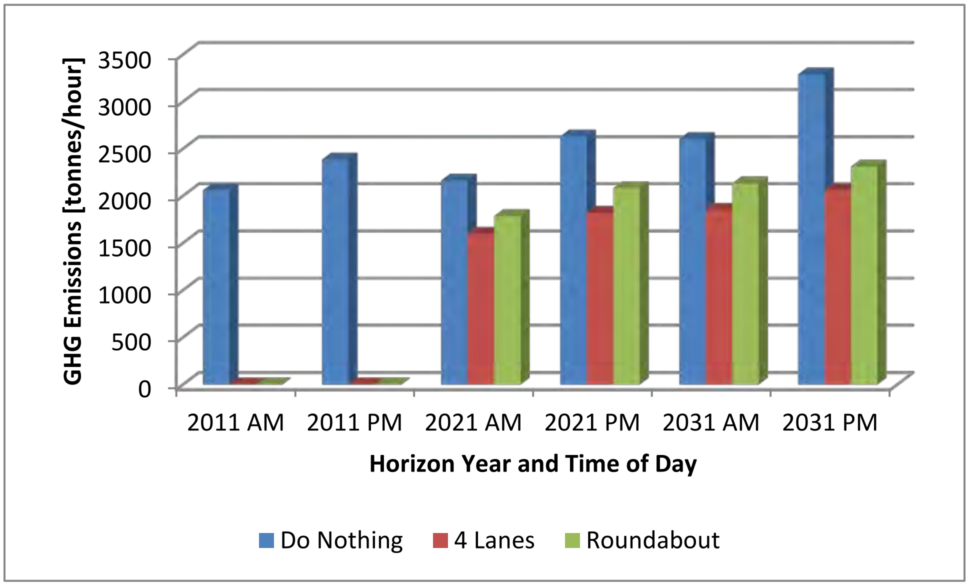
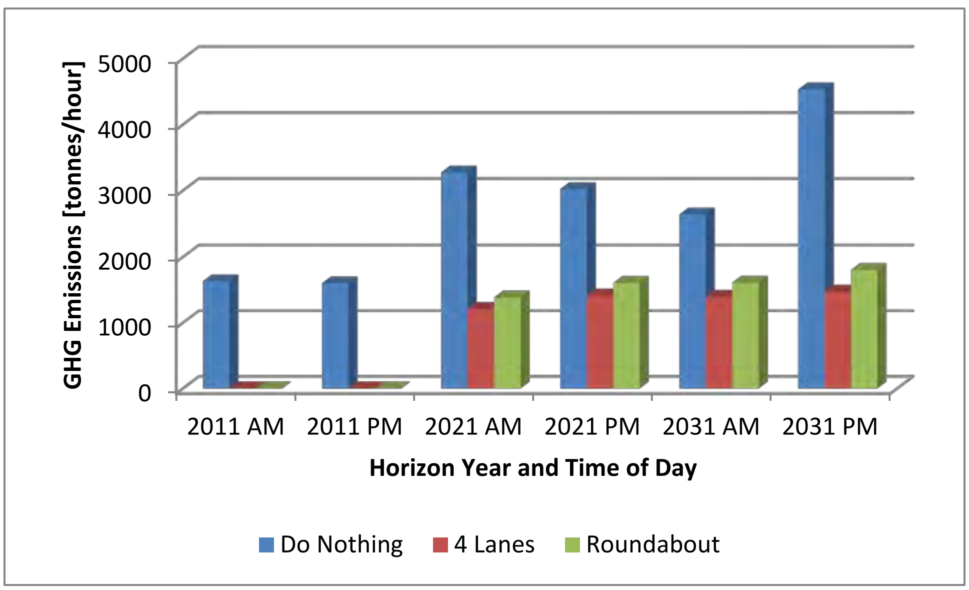


Figure 7 GHG Emissions at Airport/Old School/Healey Intersection with Alternatives



assumption that all cars stopped at the intersection clear the intersection during the next green light sequence, and neither the left or right turn lanes creep up as the car in front accomplishes the desired turning movement.

3.3 Local Impacts

In evaluating the air quality impacts of the project it was assumed that the emissions outlined in the Appendix are responsible to the majority of the contaminants found within 500 m of the centreline of Airport Road. By modelling the dispersion of the contaminants released from the road it is possible to develop a prediction of the highest concentrations of contaminants that could be created by the project, and by adding these to the existing levels discussed in §2.2 ascertain if the projected levels in the atmosphere approach the criteria levels provided in §2.3.

3.3.1 Modelling Emissions for Various Alternatives

To predict the impact of the emissions in the study area they must be modelled using algorithms that describe how emissions might behave after being released to the atmosphere. The model selected for this evaluation was the MoE approved AERMOD model created for the USEPA. This model and considerations for modelling are addressed in Appendix B. The specific parameters used for the modelling are discussed in this section.

As noted in Appendix B the emissions on the road network were modelled as line sources and three inputs are used to characterise the initial size of a roadway plume[11]. The first is the initial lateral dispersion coefficient which defines the initial width of the plume generated by the traffic. It is suggested that the basis for this should be the average vehicle width plus 6 meters for a single lane of traffic, or the road width multiplied by 2 – in this case a value of 7 m, or a set width of 10 m per lane. This width is divided by 2.15 to ensure that the overlapping distributions from adjacent volume sources simulate the line source. The second parameter is the initial vertical dispersion. This parameter is generally set as 1.7 times the vehicle height to account for the effects of vehicle induced turbulence. For light duty vehicles this is 2.6 meters based upon the average vehicle height of 1.53 m or 5 feet. The third parameter is the source release height or the height at which the wind starts to affect the plume. For moving light duty vehicles this is 1.6 m or half the vertical source height.

There are some limitations in the model which result in estimated values at receptors that are closer to the volume source than the distance between the sources being suspect. To overcome this it is recommended that the spacing between the sources be reduced. Since the source spacing for a line source in the Lakes version of AERMOD is dependent on the source width, a smaller source width will decrease the spacing.

For modelling of the Airport Road EA study area all roads with two lanes were modelled as 7 m volume sources. For the final 5 lane configuration, modelling was completed as though it was a 4 lane alternative with the source width for the cruise sections of the road set at 10 m. This was anticipated to have the effect of raising levels close to the road, a conservative approach.

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[11] U.S. EPA, 2010. Transportation Conformity Guidance for Quantitative Hot-spot Analyses in PM2.5 and PM10 Nonattainment and Maintenance Areas. A report prepared by Transportation and Regional Programs Division Office of Transportation and Air Quality. US EPA Report EPA-420-B-10-040. December. Appendix J. Available at: http://www.epa.gov/ttnnaaqs/aqmguide/collection/cp2_old/20101201_otaq_epa-420_b-10-040.pdf

The modelling was conducted utilizing the Lakes version of AERMOD with the MoE regional data set that is appropriate for study area. This data set was based upon the Toronto Pearson Airport meteorological data. That data set contains hourly meteorological values for a 5 year period, or over 43,000 hours of data. The peak traffic hours occur in both the morning and the afternoon rush hour periods. Initial comparison modelling was based upon the morning conditions, 7 am to 9 am since winds tend to be lower in the morning creating more restricted dispersion conditions. Because there is more traffic in the afternoon peak period, the model was re-run for the afternoon period to determine if there were any significant differences between periods. In both cases the modelling was accomplished by restricting emissions to the period of interest and assuming traffic was similar every day for the 5 year period.

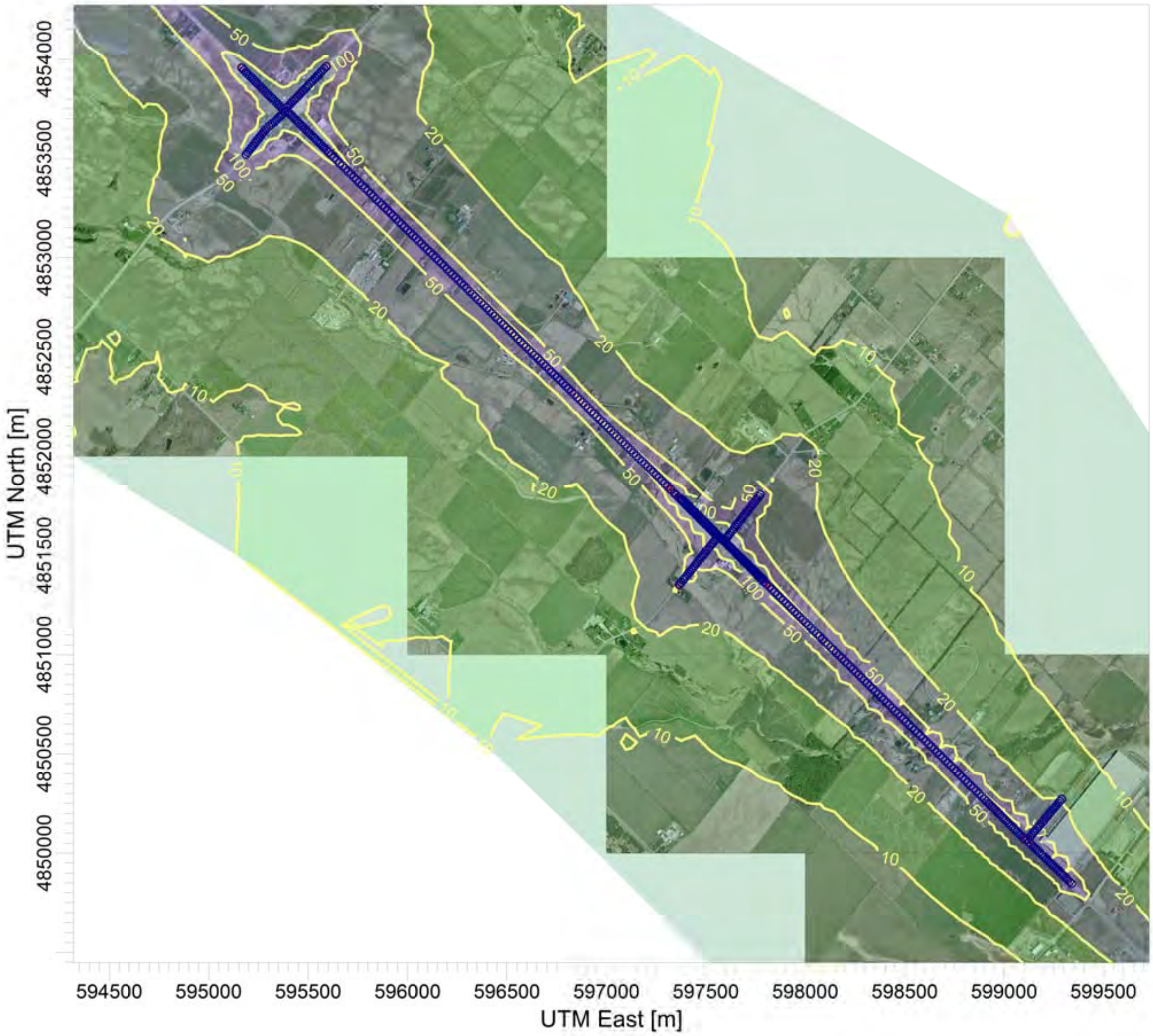
The study area stretches for nearly 6 km along Airport Road. In order to maintain a workable time for the modelling, receptors were laid out on a 60 m by 60 m grid extending approximately 1.2 km in all directions from the center of the intersections. This creates a grid of approximately 1600 receptors centered on the intersection. With this approach the midpoint of the cruising section north of Old School Road contained a limited number of receptors on either side of the road. This occurred because Airport Road is oriented at approximately a 45^{O} angle to reflect its relationship to wind directions. To provide better receptor coverage, additional receptors were added for some modelling runs.

The model was run to determine the contribution at each receptor for each source for each hour under consideration. For the intersections each of the north, south, east and west approaches were modelled as an average of 22 volume sources oriented along the road. The cruising sections were comprised of either 100 volumes sources distributed in the two zones, or 200 volume sources for the existing 2 lane operation distributed in the appropriate areas. For the Do Nothing evaluations at Old School and Healey additional volume sources were superimposed to address the effect of the turning movements in the existing stop controlled intersections.

The results of the modelling are retained so that the highest value at each receptor can be used to assess effects at the end of the run. Points of equal concentration can be joined to provide a plot that denotes zones of similar concentration around the sources. The areas of most concern are those somewhat removed from the centreline of the roads as these are the points where the predictions are the most accurate, and they are also the locations where people could be working or living in buildings along the highway. As will be discussed in the next section, the general patterns produced from the modelling are bands that radiate out on both sides of the road with the highest concentrations closer to the centreline. A typical model output with the lines of equal concentration is shown in Figure 8.

PROJECT TITLE:

Airport Road EA
Figure 8 Do Nothing 2011 AM NO2 Results



PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL ug/m^3

4.164 5.000 10.000 20.000 50.000 100.000 200.000 271.649

COMMENTS:	SOURCES: **15**		
	RECEPTORS: **4057**		
	OUTPUT TYPE: **Concentration**	SCALE: 1:34,000 0 — 1 km	
	MAX: **271.64946 ug/m^3**	DATE: **07/05/2013**	PROJECT NO.:

While the various contaminants emitted from vehicles are considered in Appendix A, the comparisons derived from the modelling undertaken for this study were restricted to the NO_2 results. It was assumed that all NO_x was released as NO_2 to provide a conservative assessment. NO_2 is frequently the contaminant of choice for modelling considerations because the ratio of NO_x released to the 1 hour ambient standard for NO_2 is the highest of the criteria contaminants. Looking simply at the 2011 cruise related NO_x emissions in Table 6, 0.0077 g/s compared to the 1 hour standard in Table 4, 400 ug/m^3 the ratio is 52,000 ug/m^3/g/s. For CO the ratio is 36000/0.167 or 216,000. For $PM_{2.5}$ there is not a 1 hour standard in Table 4 but if the 24 hour standard is converted to a 1 hour value using the methods in O.Reg. 419/05 the 1 hour level would be 73 ug/m^3 and the ratio would be 521,000. This illustrates that NO_x is the most restrictive of contaminant assessed.

3.3.2 Effects of NO_2 Emissions for the Alternatives

Modelling results for NO_2 are expressed as 1-hour concentrations in ug/m^3. As noted in Table 4 the one hour criteria level for NO_2 is 400 ug/m^3 or approximately 200 ppb. Table 3 shows the average maximum 1 hour value for NO_x in Brampton to be 62 ppb or 124 ug/m^3. These levels can be compared to the maxima predicted concentrations from the model. These occur around the intersections and along the cruising sections of Airport Road. As noted earlier, predicted values on the roadway will be disregarded since they could be suspect due to the model's limitations for areas in close proximity to the sources.

Figure 8 shows the modelling results for the 2011 AM modelling results for the existing situation. The aerial view of the land adjacent to the road was obtained from the Region's air photographs. Superimposed on the roads are the line sources that were considered for this situation including three approaches at Street A; four in the Healey and Old School intersection with Airport Road and four at King Street and Airport Road. Also shown are the cruising areas between the intersection approaches on Airport Road. The plot shows lines joining the points of equal concentration with higher concentrations closer to the roads. On Airport Road a 50 ug/m^3 NO_x contour is seen approximately 100 m either side of the centerline. A 20 ug/m^3 contour is seen approximately 300 – 400 m from the centerline. Further away from the centerline there is a 10 ug/m^3 contour. The exact shape of the 10 ug/m^3 is undetermined because receptors did not extend beyond the airphoto coverage area north of Old School.

Note that the 20 ug/m^3 contour is wider to the north where there is an interaction between the emissions at the intersections and the cruising emissions. To the south this effect is not as noticeable presumably because the majority of the idling at Street A is associated with the westbound approach.

The extent of the 100 ug/m^3 contour around the intersections denotes the influence of congestion and higher emissions at the intersections. These areas are of the most interest when comparing alternatives for the intersections. It must be remembered that while traffic volumes and congestion increase as the region's population grows, the emissions of NO_x are reduced due to more stringent emission controls legislation. This will dampen the effect of the increased traffic volumes.

At the bottom of Figure 8 the highest predicted concentration is shown. The maximum concentration for the existing AM case is shown as 272 ug/m^3. This is predicted to occur at a receptor in the middle of Airport Road between the Healey and Old School T junctions. This is the area where vehicles making right and left turns to continue in eastbound or westbound directions have been accounted for by adding extra sources of deceleration and acceleration. The receptor, being located in the middle of the sources, would be expected to produce a higher concentration. It should not be considered a significant finding though as the absolute maximum predicted is only about 68% of the criteria level.

As noted earlier, three Do Nothing alternatives were modelled, along with two alternatives for each of the Old School/Healey intersection and the King Street intersection. Plots of the output from modelling the AM traffic conditions for the alternatives are not presented in this report due to the repetitive nature of the results. It is easier to compare predicted levels around the two intersections by comparing the absolute values at a fixed location in each quadrant of the intersections.

The locations considered at each of the intersections were the residential properties deemed to be closest to the roads. The list of locations and their separation from the roads are shown below:

King and Airport	NE	1st house on N side 160 m E of Airport and 30 m N of King
	SE	1st house on N side 160 m E of Airport and 50 m S of King
	SW	1st house on S side 55 m W of Airport and 64 m S of King
	NW	1st house on N side 101 m W of Airport and 22 m N of King
	Extra	house on E side 17 m E of Airport and 140 m S of King

Old School, Healey Road and Airport Road

	NE	1st house on N side 35 m E of Airport and 41 m N of Healey
	SE	1st house on S side 100 m E of Airport and 35 m S of Healey
	SW	1st house on S side 35 m W of Airport and 175 m S of Old School
	NW	1st house on N side 33 m W of Airport and 84 m N of Old School

The modelling results for each intersection and option are shown on separate figures.

Figure 9 shows the highest estimated concentrations of NO_2 at the different receptors for the Old School Road /Healey Road /Airport Road intersection. The receptor locations correspond to those listed above with the various results grouped by receptor. A similar plot, Figure 10, is provided for the King Street and Airport Road intersection. There are seven alternatives shown in each figure. As the legends indicate the columns are grouped by year, the Do Nothing 2011 followed by the 3 alternatives for 2021: Do Nothing, Roundabout or the 4 Lane intersection condition, and a similar grouping for 2031.

Regardless of the intersection values would be expected to be slightly different in the different quadrants based upon the relative separation distance between the sources and the receptors and the meteorological conditions associated with the highest values at the receptors. The Do Nothing 2011 data for each quadrant reflects the influence of these factors at both intersections. The Do Nothing levels decrease as more stringent emission regulations in the 2021 and 2031 lower the emission rates, but this effect is offset by increases in traffic volumes.

Examining the relative difference between the estimated concentrations at the receptors provides an indication of the changes induced by the different alternatives. Clearly, the alternatives which reduce

Figure 9 A.M. NOx Concentrations for Alternatives at Old School Healey and Airport Road

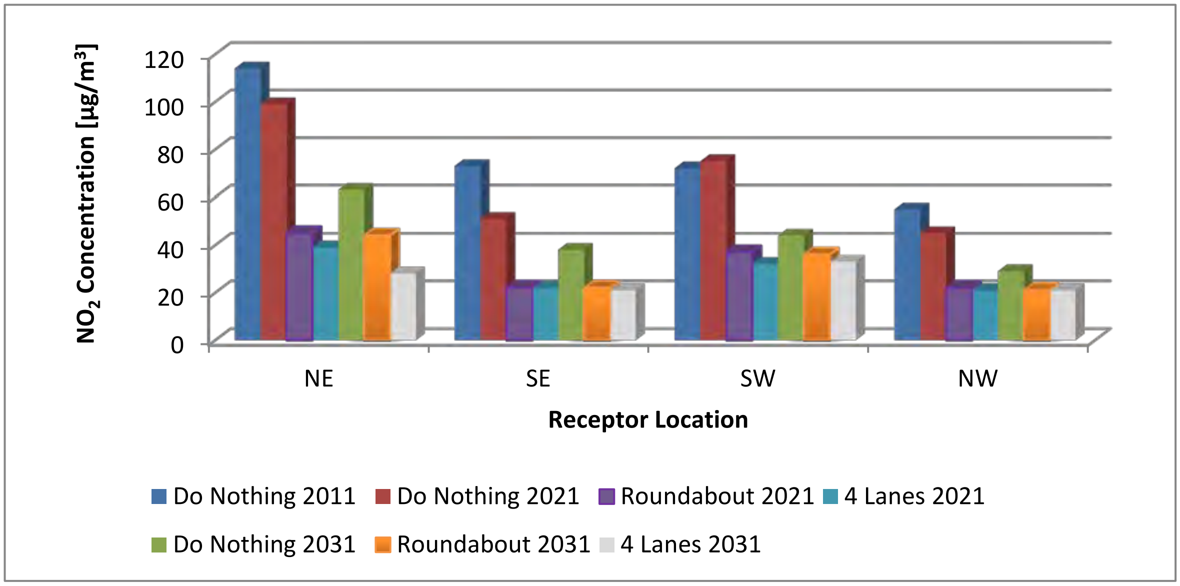
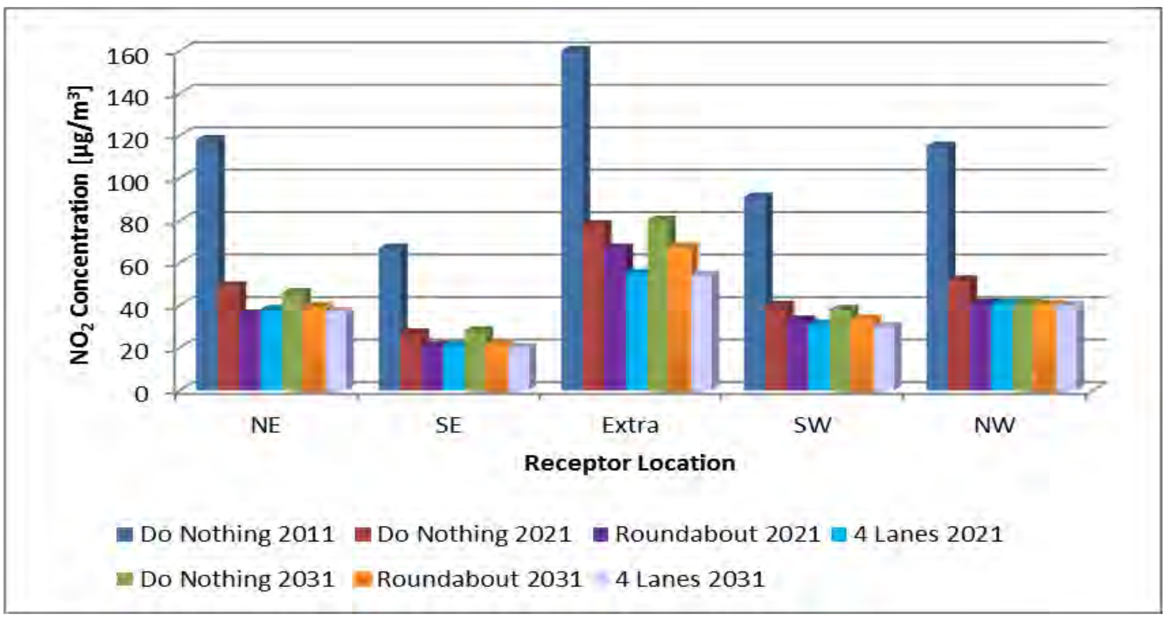


Figure 10 Alternatives Analysis A.M. NO_x Concentration Predictions around King and Airport Intersection



congestion in the intersections result in lower emissions and thus lower concentrations are predicted at the various receptors.

In Figure 9, the bars show that at the NE and SW receptors the roundabout alternative results in slightly higher concentrations. There is very little difference between alternatives based upon the predicted maximum concentrations at other two receptors.

Figure 10 shows the King and Airport Road data, but includes 5 receptor locations. The fifth location is a building close to Airport Road on the east side south of the intersection. Being closer to the road, this location has the highest concentrations for all the options.

As seen in Figure 9, the receptors at the King/Airport intersection show little difference between the effects of the alternatives at either the SE or NW receptor. The roundabout option results in slightly higher concentrations at the NE and SW receptors in both years. The extra receptor shows a higher differential between the alternatives in both years with the roundabout leading to higher predicted concentrations.

To reiterate, there are different assumptions about traffic movements incorporated into the TIM calculations for the intersections and the roundabouts. The roundabouts include a contribution from vehicles creeping through the intersection – that is, they do not come to a complete stop followed by acceleration but rather move up gradually until they can enter the roundabout and accelerate. This will generate slightly higher emissions and these are reflected in the predicted concentrations. In reality there will likely be some creep in the intersection case too, if nothing other than vehicles making turns at the intersections.

3.4 Predictions for the P.M. Peak Traffic Period

The discussion previously relates to the comparison of effects from the A.M. peak traffic volumes. As shown in Table 12 in Appendix A, the effective TIM in the intersections changes between the A.M. and P.M. peak hours. The ratio of A.M. to P.M. TIM for the 4 approaches at King and Airport Road is shown in Table 7. In all but the North Approach, the P.M. TIM values are greater than the A.M. values. Given this difference it was considered worthwhile running the model for the P.M. peak period to compare the impacts.

Table 7 Ratio of P.M. to A.M. TIM for Do Nothing Option King and Airport

Year	North Approach	East Approach	South Approach	West Approach
2011	0.74	1.27	1.40	1.27
2021	1.03	1.14	1.56	1.18
2031	1.15	1.12	1.52	1.26

From Table 12 the Do Nothing A.M. vs P.M. NO_x data has been compared as a percentage of the 2011 A.M. emission rate in Table 8 at all the intersections. Numbers less than 100 represent decreased emissions, and those greater than 100 increased emissions. At King and Airport the emissions on the NB approach decrease while the SB approach shows an increase as does the traffic on King Street. These reflect a change in traffic volume on the specific approaches. At Healey/Old School and Airport Road the SB approach at Healey and the EB and SB approach at Old School show increases whereas the NB approaches drop.

Table 8 PM NOx Emissions at a Percentage of AM Emissions

Intersection	NB Approach	EB Approach	SB Approach	WB Approach
Street A	104		75	109
Healey	41		140	89
Old School	57	155	105	
King	74	127	140	127

Since the meteorology changes between the morning and afternoon it should not be surprising that the predicted P.M. values do not scale directly with the changes in TIM as seen in Table 9. One might logically suspect that this will raise the ambient levels proportionately, however that does not appear to be the case.

Table 9 Comparison of 2011 Predicted NO_2 Concentrations at Receptors by Time of Day

Intersection	Quadrant	Predicted A.M.	Predicted P.M.	% Change
King and Airport	NE	118	132	+12
	SE	67	82	+22
	Special	160	135	-16
	NW	115	125	+9
	SW	91	91	0
Healey/Old School and Airport	NE	114	118	+4
	SE	73	72	-1
	NW	55	61	+11
	SW	72	74	+3

The percentages represent the change in concentration from the AM period to the PM period.

As noted earlier, winds typically are lower in the morning than in the afternoon because heating of the earth's surface created more convection currents thereby increasing dispersion. Winds can also shift during the day adding another perturbation to the situation. It should be remembered that the biggest component of the emissions in the acceleration time for vehicles leaving the intersection after stopping. The shift in emissions between the approaches depending upon the time of day reflects acceleration activity on the approaches.

While P.M. emissions on three approaches at King Street and Airport Road were estimated to increase by 1.27 to 1.40 times the changes induced an increase in the predicted P.M. value of 1.22 times at the SE receptor and no change at the SW receptor. Indeed near the road, the Special receptor had a 16% lower concentration in the afternoon. At the other two receptors the increase was 9% and 12% respectively. Overall the differences shown in Table 9 are in the ±12% range with the exception of 2 points.

In a comparison of monitored levels to levels predicted by AERMOD[12] the authors note that AERMOD results vary by ±46% from the measured results. Essentially this suggests that any results that are within ±50% of each other are not significantly different. The differences in the predicted NO_x values for 2011 at the various receptors are much closer than this.

The emission estimates are based upon traffic volumes that will vary, both by time of day, but also by season and day of the week. The mutual occurrence of the exact traffic emission condition with the exact dispersion conditions is hard to predict and to ascribe significance to these data by considering the differences between the morning and afternoon estimates is likely reading too much into the data.

The study was intended to address the trends in emissions that will occur as a result of improvements to the roadway, and to emission controls on vehicles over the various time horizons. The charts show these trends and illustrate that reducing congestion causes emissions to decrease with a consequent decrease in ambient air contamination in proximity of the road. It must be noted that residential properties closer to the road centerline have the potential to experience higher levels regardless of the traffic volumes or time of day. With that said, the maximum value anywhere in the modelled zone occurs on the centreline of Airport Road in the Old School Healey area. That value increases about 15% AM to PM, but is still less than 75% of the acceptable 1 hour average for NO_2, assuming all the NO_x is reported as NO_2.

3.5 Comparison to Existing Levels

While the preceding analyses suggest that measures to ease traffic congestion will reduce emissions and improve environmental conditions in the immediate vicinity of the intersections on Airport Road they also illustrate how sensitive the emissions are to potential congestion. It is important to note that congestion will be highest in the rush hour periods. If the roundabouts are the chosen alternative, during periods of lower vehicle flows the roundabout will result in decreased emissions since cars will not need to stop, idle and accelerate away from the stop line.

The highest levels in the quadrants can be compared to the Brampton data. The highest reported hourly average in Brampton was approximately 136 ug/m^3. This is well below the 400 ug/m^3 criteria level. The Do Nothing situation at the Old School/Healey and Airport Road intersections would appear to result in values that are below this level. Similar levels are predicted at the Airport Road and King Street intersection with the exception of the value at the receptor beside Airport Road. At the extra receptor the predicted level is just less than 160 ug/m^3. The combined effect of reducing vehicle emission rates and improving congestion at both intersections is to reduce the maximum concentrations expected around the intersections. The 2021 Do Nothing cases at King Street are generally less than half the levels seen in 2011. The same affect is not as pronounced for the Do Nothing situations at Old School/Healey and Airport Road. In all cases the alternatives to the Do Nothing situation produce lower estimated

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[12] Steven R. Hanna, Bruce A. Egan, John Purdum, and Jen Wagler. Evaluation of the ADMS, AERMOD, and ISC3 Dispersion Models with the OPTEX, DUKE FOREST, KINCAID, INDIANAPOLIS, and LOVETT FIELD Data Sets. A research project sponsored by the American Petroleum Institute. Available at: http://w3.ualg.pt/~lnunes/Textosdeapoio/9%20-%20ADMS%20Aermod%20and%20ISC%20evaluation.pdf

concentrations, indeed these are in the range of 20 to 40 ug/m^3 maximum. These levels are less than one third of the highest hourly value in Brampton suggesting that air quality at the receptors will be acceptable. In no case does the model predict that values in the quadrants will exceed the 400 ug/m^3 criteria level, although the results suggest that there might be higher levels nearer the road.

3.5 Construction Impacts

There exists a potential for air quality impacts related to construction activities for any road work required, widening, adding additional lanes, realignment or building a roundabout. The extent and duration of construction related emissions will vary depending upon what needs to be done at any given location in the study area. Road construction work requires excavation to lay a foundation and finished paving. At any point on the surface such operations should not be of long duration. This section addresses the types of emissions possible from these operations:

- dust emissions from non-combustion sources; and,
- exhaust emissions from construction vehicles and stationary combustion sources.

The latter emissions are similar to those arising from the vehicles operating on the existing routes only the quantities will vary depending upon the equipment. Gaseous contaminants have the potential to remain airborne and drift further away from where they are generated than do dust emissions from material handling operations. Each type of source is discussed below.

The design of the final configuration of the road in the study area is not complete at this time. The general approach has been defined. The discussion that follows defines the types of sources that could be present. Following the identification of the sources, there is a section that outlines best practices that can be employed to reduce local impacts due to construction activities.

Dust Emission Sources

Large transportation projects such as new highways generally have the potential to create significant dust emissions since they cover a large area and high levels of activity occur to grade, lay foundations and finally pave the new road. Sources of dust emissions for these activities include:

- pavement removal and earth excavation activities;
- vehicle travel on gravel or dusty roads;
- fugitive dust from material transfer operations; and,
- fugitive dust from dump trucks.

There is a potential for these emissions wherever activity occurs however the most likely points for long term dust emissions are in areas where major reconstruction/realignment is necessary.

Combustion Exhaust Emissions

Combustion emissions typically associated with construction activities include:

- diesel exhaust from earth moving equipment and trucks; and,
- exhaust from stationary combustion equipment including generators, heaters on site.

None of the diesel emissions can be estimated without detail knowledge of how the construction will be done and with what equipment. The important aspect of these emissions is that they are all temporary, and in many cases the duration of such operations will not extend for too long. In all cases the effects of these operations will be localized. It is unlikely that such activities will add to the regional air burden since the equipment would likely be used on other construction sites if it were not being used for road reconstruction.

There will be Greenhouse Gas emissions from the construction equipment similar to those expected from other construction projects of the same scale. The two major sources of GHG emissions are:

- direct emissions from fossil fuelled combustion equipment; and,
- indirect emissions from the production of cement used for construction.

The amount of GHG emissions from fossil fuelled combustion is directly linked to the amount of fuel used in the equipment. These are the only direct GHG emissions anticipated from the construction project. In a similar manner the amount of GHG emissions from cement production are directly proportional to the amount of cement used in every tonne of concrete produced. Typical GHG emission rates are 1 Mg eCO_2 per Mg of cement used in the mix. Since some types of concrete can be produced with fly ash and similar materials substituted for cement, there are ways to reduce the indirect GHG emissions for concrete use. Up to 50% of the cement can be substituted with flyash in some cases, but the use of flyash for cement would require careful consideration of the properties of the final product and this should be left to the designers to specify.

4.0 Mitigation of Air Quality Impacts and Greenhouse Gas Emissions

The analysis in the previous section indicates that over the long term the Airport Road reconstruction would result in a decrease in localized air quality impacts associated with improved traffic flow. The resulting emissions will not add significantly to local air quality conditions. There will be short term air quality impacts from construction related to a number of different operations and sources. However, there are measures that can reduce the impact of the project on air quality and GHG emissions. These are described in the following paragraphs.

4.1 During Operation

The major emissions in the study area will relate to vehicular traffic on Airport and adjoining roads. All measures that minimise traffic congestion on these routes will limit the overall emissions to the atmosphere. Furthermore, any measures that encourage the use of public transportation systems for commuter travel will also reduce the potential for emissions.

4.2 During Construction

Typically, public authorities include environmental controls practices in their construction contracts. With respect to air contamination these contract documents include measures that are aimed at limiting the amount of dust released during these activities. Contracts can include requirements to undertake air monitoring studies to address issue of particular concern with respect to worker health and safety. Any measures that will be applied during such contracts are to be addressed in an Environmental Controls and Methods Plan that must be developed by the contractor before any construction activities commence.

Typically, such plans would include dust control measures such as:

- watering to limit dust emissions from surfaces;
- covering of excavated materials or fill materials stored on site; and,
- street cleaning to limit tracking of materials.

They would also include guidelines to minimize the potential for minimizing impacts from diesel powered construction equipment such as:

- locating truck staging zone away from potential receptors; and,
- minimising the idling time for all diesel powered equipment operating on the site.

There are other of measures that can be applied by the contractors and site inspectors to ensure that the impacts of combustion source exhaust and fugitive dust emissions are controlled during construction.

For combustion related emissions and impacts the following measures can be employed:

- Selecting construction equipment to be used on site based upon low emission factors and high energy efficiency.
- Ensuring that all construction equipment is tuned and maintained in accordance with the manufacturer's specifications.
- Using only ultra-low sulphur fuel for diesel engines and ensuring that such equipment is equipped with diesel particulate matter traps to reduce particulate matter emissions.
- Utilizing electric or diesel powered equipment, in lieu of gasoline powered engines, where feasible.
- Ensuring that construction plans include a statement that work crews will shut off equipment when it is not in use.
- During smog alerts (May through October), measures should be taken to ensure that diesel equipment use is optimized to reduce the emissions of smog forming substances.
- Whenever possible, time the construction activities so as to not interfere with peak hour traffic and minimize obstruction of through traffic lanes adjacent to the site; if necessary, a flag person shall be retained to maintain safety adjacent to existing roadways.
- Support and encourage ride sharing and transit incentives for the construction crew.

There are a number of additional measures that can be employed to reduce the amount of fugitive dust released from construction activities. Generally the objective should be to employ the best available control measures to ensure that such dust does not remain visible in the atmosphere beyond the property line of the emission source. These measures include dust suppression techniques such as:

- Water active sites daily.
- All trucks hauling dirt, sand, soil, or other loose materials should be covered.
- All adjacent streets shall be cleaned by the contractor if visible soil materials are present due to his operations.
- Install wheel washers where vehicles enter and exit the work site onto public roads.

The following examples can be applied where appropriate to control dust generated by the construction activities:

- all haul roads can be designed with an appropriate road base to sustain heavy truck traffic.
- during clearing, grading, earth moving, excavation, or transportation of cut or fill materials, water trucks or sprinkler systems can be used to prevent dust from leaving the site and to create a crust after each day's activities cease.
- during construction, water trucks or sprinkler systems can be used to keep all areas of vehicle movement damp enough to prevent dust from leaving the site.
- immediately after clearing, grading, earthmoving, or excavation is completed, the entire area of disturbed soil can be treated until the area is seeded or otherwise developed so that dust generation will not occur.
- soil stockpiled for more than two days can be covered, kept moist, or treated with soil binders to prevent dust generation.

There is one caution that should be included in any specifications. The common practice of using nontoxic chemical soil stabilizers such as calcium chloride to minimize the need for watering uncovered soil surfaces should be kept to a minimum near more densely populated areas and public buildings, and its use should be severely restricted near watercourses. Typically this product is used in areas where graded areas are left inactive for ten days or more.

Regardless of the measures adopted, the Region and their contractors should establish a procedure for responding to complaints and documenting visual inspections, complaints and responses made.

5.0 Conclusions

The Traffic Needs Assessment suggests that measures are needed to improve traffic flow on Airport Road and the intersecting roads in the study area. Various measures have been proposed and the air quality impacts of these measures have been evaluated in this report. The report shows that measures that reduce congestion on the road will lower the total emissions along the route, and result in better air quality conditions than would be expected to exist in the two horizon years of 2021 and 2031 if no changes were made.

The study indicates that under most circumstances the quantities of contaminants released from the vehicles will result in maximum predicted concentrations that are below the criteria generally used for judging air quality.

There are likely to be construction induced emissions to the atmosphere, but these can be controlled through the application of good construction practices. Given the relatively short time frame for such activities they are unlikely to create major air quality impacts.

Appendix A Details of Emission Calculations

The Approach to Analysing Changes in Air Quality due to Traffic

1.0 Introduction

Air quality is affected by emissions to the atmosphere in the vicinity of the receptor of interest. A receptor can be any person, or building, or area. Generally the concern is the potential for exposure of humans to the contaminants released from the source. Contaminants include a wide range of substances from dust re-suspended into the atmosphere by wind blowing over open fields or ejected into the atmosphere by the reactions between the tires of vehicles and dust on the road surface. On particularly dusty surfaces even the air currents around a moving vehicle will serve to re-suspend the dust into the atmosphere. The most common contaminants in the atmosphere are the criteria contaminants such as particulate matter, carbon monoxide, sulphur dioxide, oxides of nitrogen and volatile organic compounds released from combustion processes. Combustion process include all sources that burn fuel of any type from the furnace in a building or the engine in a vehicle. It is the latter category that is of most interest when dealing with traffic impacts.

The amount of contaminants released from an internal combustion engine is a function of the amount of power being generated by the engine. As we drive a vehicle at a faster speed the amount of energy the engine needs to generate increases to counteract drag induced by moving the vehicle through the air. Going uphill takes more energy than going downhill because gravity works against or for the driver. High rates of acceleration consume more fuel because more energy is required. In recent years the US EPA has developed a new tool to estimate emissions from vehicles based upon the Vehicle Specific Power [VSP] being generated at any time in the driving cycle[13].

The VSP is estimated from the speed profile of the vehicle:

$$VSP = v \cdot [1.1 \cdot a + 9.81 \cdot \sin(arctan(grade)) + 0.132] + 0.000302 \cdot v^3$$

where VSP = the vehicle specific power [kW/tonne]
v = instantaneous velocity [m/s]
a = instantaneous acceleration/deceleration [m/s^2]
grade = gradient of the road [%]

To illustrate how VSP could vary consider the following. Drivers on an open stretch of road that is relatively uncongested will tend to drive at a speed close to the speed limit unless they experience some outside influence such as stopped traffic, or intersections. In the case of an intersection the operating modes of the vehicle change from cruising to deceleration as the driver slows to obey the traffic signals,

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[13] US EPA, 2012. Motor Vehicle Emissions Simulator MOVES. Users Guide for MOVES2010b. Assessment and Standards Division, Office of Transportation and Air Quality, U.S. Environmental Protection Agency EPA-420-B-12-049. August 2012. http://www.epa.gov/otaq/models/moves/documents/420b12049.pdf

idling while waiting for an appropriate gap in the traffic to proceed, and accelerating back to cruising speed when the way is safe. Each of these modes can be broadly associated with an emission level as noted by Papson et al.[14] who found that: acceleration results in 1.7 times the emissions generated at cruising speeds; deceleration results in 0.5 times the emissions generated at cruising speeds; and idling generates emissions that are 0.16 to 0.33 times those from cruising.

While emissions from any particular vehicle will follow the emissions versus VSP relationship the absolute emissions will vary depending upon the age of the vehicle, the maintenance level of the vehicle, and other factors including the weather and fuel being used. Most importantly, when considering long forward looking horizons, is the change in regulated emission levels. Over the last 10 years vehicle emissions have decreased as regulations have attempted to reduce the detrimental effects of automobile exhaust. The implication is that as the older vehicles are replaced with newer ones the generally level of emissions will decrease. Indeed, reductions are forecast to continue out to the two horizon years considered in this study, 2021 and 2031.

The effects of the regulatory changes can be seen in estimates of emissions determined with the UTEC calculator[15]. These estimates are based upon MOBILE6.2C a Mobile Source Emission Factor Model that employs fixed cycle emission measurements to estimate emissions for vehicles of different types and ages. The original US EPA version was modified by Environment Canada for application in the country and is calibrated for the mix of vehicles in a specific region of the country. To distinguish it from the US version, the C was added to the name. The UTEC calculator suggests that the average vehicle in Ontario will produce 67% less NO_x in 2021 than did the average in 2011 and this will drop a further 22% by 2031 meaning that in 2031 the average vehicle will be emitting NO_x at a rate that is only 29% of what it did in 2011.

The newer approach to estimating vehicle emissions is designated by the US EPA as MOVES but it has yet to be translated into the Canadian context. For the purposes of the comparisons undertaken in this study, the relative difference in emissions determined from the UTEC model was considered to sufficient for screening the impacts.

Cruising emissions can be assumed to be represented by the generalized emissions data for the three horizon years available in the UTEC calculator. The UTEC calculator generates emissions data in the form of g/vehicle kilometer travelled. These can be converted to g/s by assuming a cruising speed in the road segment. For this study the cruising speed associated with the emissions was assumed to be 70 km/h or 19.44 m/s. To maintain a cruising speed power must be generated to overcome the rolling resistance of the vehicle and the aerodynamic drag of the car moving through the air. The speed limit on Airport Road is 80 km/h north of Street A up to the approach to Sandhill where it is 60 km/h. King Street

[14] Papson, Andrew, Seth Hartley and Kai-Ling Kuo, 2012. Analysis of Emissions at Congested and Uncongested Intersections with Motor Vehicle Emission Simulation 2010. A paper in Transportation Research Report: Journal of the Transportation Research Board, No. 2270 pp 124-131.

[15] Transport Canada, 2008. USER GUIDE FOR URBAN TRANSPORTATION EMISSIONS CALCULATOR (UTEC). Available at http://wwwapps.tc.gc.ca/prog/2/UTEC-CETU/Calculator.aspx?lang=eng

in the Sandhill area is posted at 60 km/h whereas Old School Road and Healey Road are posted at 70 km/h. The difference in power required versus the selected 70 km/h average is ±30% at most.

The scaling factors noted in the Papson paper can be super-imposed on the cruise emissions to develop average emissions under different operating modes: cruising, acceleration, deceleration and idling. To determine emissions in this manner it is necessary to determine the time the vehicles will spend in each of the operating modes on particular stretches of the road. This is referred to as the Time in Mode [TIM] determination in this report.

2.0 Intersection Operating Conditions

Typical traffic movement at an intersection will consist of some combination of cruising, deceleration, idling, and acceleration as described earlier. Traffic flow will depend upon the nature of the traffic control measures. The driver of a vehicle would be required to stop if there is a red signal or a stop sign and wait for a suitable gap in the traffic or the signal to change before moving forward. The vehicle then accelerates back to cruising speed. Of course, if the intersection is only two way stop controlled, the main flow will move through the intersection unimpeded except when, on a two lane road, it is delayed by a driver making a left turn. Similarly a car making a right turn would also slow and possible impede traffic following it.

In evaluating the impacts of a traffic control alternative, the time that the vehicle spends in each mode of operation dictates the quantity of contaminants that it will release as it traverses a particular road section. This time is related to the level of congestion on the road segment. Clearly if there is a 6 km stretch of road posted at 80 km/h and there are no impediments, one might expect the vehicle to be the cruising speed over the full extent. The vehicle would be on that stretch of road for 270 seconds. If however, there was a traffic signal in the midst of the stretch, and the car needed to stop to obey the signal, it would need time to decelerate and accelerate after idling at the signal. To determine the exact time the vehicle would need to traverse the stretch under these circumstances one needs to make some assumptions about the behaviour of the vehicle.

For this study, the time spent decelerating was based upon an assumed maximum deceleration rate of 7.6 mph/s [3.3975 m/s/s] while acceleration was assumed to occur at 1.788 m/s/s. These values are the default values used by Claggett[16] in his comparison of MOBILE6.2 and MOVES emissions estimates and are suggested to be typical of traffic on arterial roads posted at 60 km/h. These rates were not applied as a constant rate of change, rather they represent the maximum rate of change for a sine function formulation of rate change[17]. Modelling vehicle performance in this manner reflects typical driver behaviour where more rapid rates of change become uncomfortable for the driver and any passengers. Effectively, this formulation for the rate of change of velocity suggests that as the vehicle approaches the

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16 Claggett, Michael, 2011. Implications of the MOVES2010 Model on Mobile Source Emission Estimates. A paper given at the 104th AWMA Annual Conference in Orlando Florida. Available at http://www.epa.gov/ttnchie1/conference/ei19/session6/claggett2.pdf

17 Akcelikk, R., and M. Besley, 2002. Acceleration and Deceleration Models. A paper presented at the 23rd conference of the Australian Institute of Transport Research, December 2001 and revised July 2002.

desired speed the rate of change decreases. During deceleration the formulation reflects an initial coasting period starting the decrease in speed followed by the application of the brakes to increase the rate of decreasing speed.

Since the most likely disruptions to speed on a road segment will be around intersections where there are traffic controls or turning movements, the intersections in the study area were considered to have an influence for 300 m either side of the centre of the intersection. Under these conditions the vehicle leaving the intersection will reach cruising speed approximately 275 m after leaving the stop line, before leaving the zone, and the decelerating vehicle will start to decrease speed approximately 150 m from the stop line. While both left and right turns can be executed from a rolling stop situation, thereby decreasing the amount of time needed for acceleration and deceleration, this study assumed that these movements were accompanied by a complete stop for the turning movements; that is the vehicle is decelerated into the turn, stopped and accelerated after turning. Of course such movements would involve very little idling time.

This approach allows the intersections to be isolated from the other portions of the stretch of road under study, somewhat simplifying the approach to modelling the impacts of road alterations. The study assumed that the number of vehicles moving in and out of driveways along the stretch of road would be incidental compared to the main traffic movements, and therefore any interference/delay they contributed was ignored.

Furthermore, while there are trucks on the route these were also ignored for the purposes of evaluating the effects of changes to the road.

3.0 Time in Mode Calculations

Traffic engineers have developed mathematical models to predict the level of congestion at intersections and on roadways based upon vehicle flow. These models were used for the Traffic Needs Assessment conducted for the Region of Peel[18]. That evaluation was based upon existing traffic and projections for traffic growth over the next 20 years. In the case of this study, the base year was 2011 with horizon years of 2021 and 2031.

The traffic model employed for much of the evaluation in the Traffic Needs report was Synchro 7. This computer program was developed for analysing and optimising traffic control systems. Based upon established traffic management practices, such as those presented in the Highway Capacity Manual[19], Synchro provides the user with a means to assess the cause and effect relationships for varying road configurations and signal timing. More importantly the model provides data related to the control delay at an intersection. Inputs to the model including intersection geometry and vehicle volumes along with signal timing which can be adjusted for optimal operation for a given volume of traffic. The outputs of

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18 Region of Peel, 2013. Traffic Needs Assessment, Airport Road EA, 1 km North of Mayfield Road to 0.6 km North of King Street.

19 Transportation Research Board National Research Council 2000. Highway Capacity Manual. Washington, D.C. ISBN 0-309-06746-4.

the model include the control delay for each movement in the intersection, vehicle queue distances for each movement, and the overall cycle time for the signals at the intersection. These values can be used to determine the aggregate time-in-mode [TIM] for the intersection by employing Webster's relationships for vehicles at signalized intersections as explained by Papson in the previously referenced paper.

The TIM for vehicles at a stop light controlled intersection depends upon the percentage of vehicles that are delayed in the intersection. Papson calculates the $\%_{delayed}$ by taking the number of vehicles in the queue and dividing it by the number of vehicles that approach the intersection within a cycle of the control system. In actual fact, the $\%_{delayed}$ is a proportion of the total traffic ranging from 0 to 1 in most cases. For the purposes of this study, very minor delays were entered as 0.001 and if queue lengths suggested that the vehicles were delayed for more than one cycle the delay was adjusted to 1.

The $TIM_{A,D}$, the time in mode for acceleration and deceleration, is a function of the number of vehicles that are delayed in the intersection. This value is calculated by multiplying the time for acceleration or deceleration by the vehicle flow and adjusting for the proportion delayed:

$$TIM_{A,D} = T_{A,D} \cdot q \cdot \%_d$$

where $T_{A,D}$ = the total time for acceleration and deceleration [seconds]
q = vehicle flow [vehicles/second]
$\%_d$ = portion of approach traffic that is delayed

The TIM_I, the time in mode for idling at the intersection, is a direct output from Synchro based upon the Control Delay. The total delay experienced is the sum of the idling time, the delay due to acceleration and the delay due to deceleration. Papson presents an equation for idling time:

$$TIM_I = q \cdot \%_d \left[\frac{C_d}{\%_d} + \frac{D_D + D_A}{V_{max}} - (T_A - T_D)\right]$$

where C_d = the control delay from Synchro [s]
V_{max} = posted cruising speed for approach and departure [m/s]
D_A = distance for acceleration [m]
D_D = distance for deceleration [m]
T_A = time for acceleration [s]
T_D = time for deceleration [s]

The last portion of the cycle is TIM_c, the time in mode for cruising in the segment. This is determined by back calculating from distance travelled while decelerating or cruising. Effectively, if the vehicle is not delayed this portion would be 100% or 27 seconds for our 600 m intersection length. If the vehicles are delayed the total for all the traffic can be calculated as:

$$TIM_C = \frac{q}{V_{max}} \left(L - \%_d(D_D + D_A)\right)$$

where L = the total distance in the intersection [m], assumed to be 600 m in this study.

By summing $TIM_{A,D}$, TIM_I, and TIM_C the total time that vehicles are in the intersection is determined in seconds.

For the purposes of calculating TIM the entry speed to and the exit speed from the intersections were assumed to be the posted limit for the particular road section being considered.

4.0 TIM for Two Way Stop Controlled Intersections

Essentially a stop controlled intersection generally involves a free flowing traffic direction and one that is controlled by stop signs. Under these circumstances the driver must come to a stop and proceed when there is sufficient space between cars in the through lanes to make a safe entry into or through the traffic. Presently both Old School Road and Healey Road tee into Airport Road with an offset of approximately 60 m so they behave as two individual one way stop controlled intersections with through traffic either eastbound or westbound entering Airport Road with a right turn and then making a left turn from Airport to proceed in the desired direction. Such a situation is not covered by Papson's approach for signalized intersections outlined earlier.

Furthermore, for stop controlled intersections there is no cycle time that can be applied to determine the percent delayed, vehicles move when there is an appropriate gap in the approaching traffic. Synchro provides an estimate of the probability that the approach will be queue free which can be used to infer the percentage delayed; however, since every vehicle must stop they will all have some delay. The Control Delay data from the Synchro runs was used to determine the TIM_I. Since there is only one lane in each direction on each of the side roads it was assumed that both left and right turn traffic would be delayed for a similar period.

The offset between these intersections complicates the situation as there are vehicles moving from eastbound Old School to eastbound Healey necessitating a right and left turn to exit the intersection. The opposite is true for westbound traffic. The traffic flow for the left turns was determined from the Synchro runs, but the intermediate acceleration/deceleration mode in the intersection was not specifically determined. All left turn vehicles were assumed to decelerate from 22.22 m/s including those move east west through the intersection. Since the east west vehicles will not have the same deceleration period the model likely over compensates for the delay and is conservative. Moreover, the through vehicles were assumed to accelerate at the specified rate for both movements. These assumptions will result in the TIM values at the stop controlled intersections being higher than might actually be experienced.

5.0 TIM for Roundabouts

The Traffic Needs report also considers the use of roundabouts at both the Healey/Old School/Airport intersection and the King/Airport intersection. It is Region policy to consider roundabouts for intersections that are indicated to require signal control. The Region considers that roundabouts have many benefits including the reduction of the severity of injury as a result of vehicle interactions due to reduced speeds, the reduction of speed in the area, the reduction of maintenance requirements, and the providing of easy u-turn movements. The Traffic Needs report contains discussions on the findings of a review of the use of roundabouts at both the Old School/Healey/Airport and the King/Airport intersections.

From an air quality perspective the literature suggests that there is a mixed benefit from roundabouts[20]. The authors collected on-road emissions at three intersections which had similar traffic volumes, but differing traffic control strategies. There was a roundabout, a 4 way stop controlled and a signal controlled intersection. They reported that, depending upon the pollutant and the driver, lower emissions were found in some cases at the roundabout and in other case either of the other two control strategies produced lower results. The authors also noted that Zuger and Porcher reported mixed results from on-board testing systems measuring emissions and fuel consumption at 4 intersections that were converted to roundabouts. Indeed, the paper concludes that roundabouts might not necessarily have lower emissions because a significant amount of time is spent with the engine operating in modes that emit more than those at idling. These results conflict with results reported by Mandavilli et al.[21]. These authors note that various publications, including one by the Insurance Institute for Highway Safety, suggest that roundabouts will reduce fuel consumption and emissions. It is suggested that vehicles at controlled intersections emit more CO_2 than they do at roundabouts because delays and queuing are reduced. The authors go as far as to suggest that congestion at the roundabout has to be significantly higher than at signal controlled intersections before the emissions equal those at the signalled intersections. Some of the lowered emissions conclusions are based upon the specific contaminant related emissions. For instance the authors quote a roundabout expert from the UK as noting that CO emissions are 7 times higher at idling than they are at 10 mph, and 4.5 times higher than at 5 mph suggesting that if the vehicle continues to move, albeit at a reduced speed, the CO emissions will be lower.

Much of the lower emissions data seems to have been generated by the application of computer models that simulate traffic behaviour. One oft quoted package that includes the ability to evaluate emissions from different situations is Akcelik and Associates software aaSIDRA (aaTraffic Signalised & unsignalised Intersection Design and Research Aid). This program was developed in Australia and is a popular intersection analysis software tool for evaluating alternative intersection designs in terms of capacity, level of service. It provides a wide range of performance measures including delay, queue length and stops for vehicles and pedestrians. While the software can provide a relative comparison between emissions for different intersection configurations using similar principles to the TIM approach discussed above, the TIM data is not directly extractable from the model output. Furthermore, the emission factors in the model cannot be easily changed to be comparable to the approach discussed in this report.

The Synchro software used to assess the signalised and stop controlled intersections currently does not handle roundabout evaluations. The Region used a software package called ARCADY to predict capacity, queues and delays at roundabouts. However, ARCADY does not provide the same level of information as Synchro when it comes to using the data for determining TIM values for roundabouts.

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[20] Hallmark, Shauna L. and Abhisek Mudgal, 2012. Comparison of VSP Profiles for Three Types of Intersection Control and Implications for Emissions. A paper from the 2012 15th International IEEE Conference on Intelligent Transportation Systems, Anchorage, Alaska. September.

[21] Mandavilli, Srinivas, Eugene R. Russell, and Margaret J. Rys, 2003. Impact of Modern Roundabouts on Vehicular Emissions. From the proceedings of the 2003 Mid-Continent Transportation Research Symposium, Ames Iowa. August.

Coelho et al.[22] recognized the limitations in the emission factors present in aaSIDRA when considering the effects of roundabouts on emissions. They proposed an alternative approach based upon the VSP approach inherent in the MOVES formulation, similar to that discussed by Papson et al. Coelho and her associates developed a speed profile for traffic moving through a roundabout and used that profile to develop TIM values for the traffic movement. The difference with the aaSIDRA approach appears to be the use of a binned approach that combines the TIM data with VSP for different operating conditions. The Coelho approach uses aaSIDRA data, or actual field data if available, to define the critical gap for integration of the arriving traffic into the circulating stream. They note that the size of the critical gap is influenced by the roundabout diameter and the ratio of Q_{in}/Q_{conf}. The average headway [$\bar{t}$] of the conflicting flow is given by:

$$\bar{t} = 3600/Q_{conf}$$

where Q_{conf} = conflicting traffic flow, essentially all the vehicles passing the particular entrance

From this it follows that the probability that an entering vehicle will encounter a gap bigger than the critical gap is defined by:

$$Prob(gap \geq \propto) = exp\left(\frac{-\propto}{\bar{t}}\right) = p$$

where α = the critical gap [s]

Using this probability, the expected number of gaps $E(n)$ that elapse before a vehicle can move is calculated as:

$$E(n) = (1-p)/p$$

and the idle time is then:

$$TIM_{IRA} = E(n) \cdot \bar{t}$$

This approach was combined with empirical measurements undertaken at typical single lane roundabouts. The measurements were used in a regression analyses to identify three representative speed profiles for a roundabout relative to the amount of congestion on the approach. The authors suggest that movements through a roundabout involve some vehicles not coming to a complete stop, while other vehicles stop once and a percentage stop more than once. Their regression equation is based upon the level of congestion at the approaches [$Q_{conf} + Q_{in}$] of two single lane roundabouts to define the percentage of the various operating modes. The range of data they fit to the equation extended to 1300 vehicles per hour. Time to travel through the roundabout was disregarded in their approach as they suggested that the time for the vehicles to move through the roundabout was quite small compared to the other operating modes.

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22 Coelho, Margarida C., Tiago L. Farias, and Nagui M. Rouphail, 2006. Effect of Roundabout Operations on Pollutant Emissions. A paper in Transportation Research, Part D Transport and Environment. Vol II, Issue 5 Sept 2006, pp 333-343

Their model suggests that the percentage of vehicles that do not stop is defined by:

$$\%_{no\ stop} = 100 - 0.0000611\ (Q_{conf} + \ Q_{in})^2$$

The percentage of vehicles that stop more than once is defined by:

$$\%_{stop\ more\ than\ once} = \exp[0.00123\ (Q_{conf} + \ Q_{in} - 300)^{1.2}] - 1$$

By difference the number of vehicles that stop once is simply 100% minus the sum of the two values calculated above. As the congestion level approaches the upper range of the data used for the regression, the no stop proportion goes to zero, or negative, and the more than one stop percentage exceeds 100%. This creates inconsistencies in the model output for roundabouts where the total traffic flow exceeds 1300 vph on an approach.

The Coelho et al. model goes on to identify the number of stop and go cycles for a specific queue length [TSG] based upon the following equation:

$$TSG = 1.997 \exp(0.1124\ QL) - 1$$
where QL = queue length in vehicles, assume 7 m per vehicle.

The queue length was taken from aaSIDRA. The total number of stop and go cycles was added to the movement profile for those situations where the vehicles stopped more than once. Using these formulae the authors suggest that total emissions in the roundabout can be derived by summing the product of the emission profile and the proportion of vehicles with that profile for the different movement regimes.

The limitations of the Coelho approach, the inconsistencies when the traffic flow exceeds the range of the data used for the regression equation and the use of single lane roundabouts limits its usefulness for the Airport Road study. Thus a combination approach was used for this study. Based upon the concepts discussed above, the aaSIDRA output, which includes 2 lane roundabouts, was used to define the terms needed for the Papson TIM approach.

The movement of vehicles through a roundabout as described by Coelho et al. is incorporated into aaSIDRA by adjusting the number of full stops by a factor that reflects vehicle movements up through the queue to the stop line. The total of these move-up and full stop events is listed as the effective stop rate in the output. This rate is thus analogous to the $\%_d$ used in the Papson approach. Note, with long queues or high traffic volumes aaSIDRA calculates the Effective Stop Rate as a value that is greater than one. This reflects the time it would take for the predicted queue length to clear the roundabout due to relatively slow move-up operations.

The aaSIDRA model also produces a control delay value for roundabout operations. It includes the time a vehicle spends at the stop line including the time needed to move up in the queue. Also included is the time is the geometric delay related to the time the vehicle would need to negotiate the roundabout if there was no other traffic. This is analogous to the control delay that Papson derives from the Synchro model.

The aaSIDRA model, Version 5, was run for the multi-lane roundabout with double entry lanes on King, Airport and Healey Roads and a single entry lane from Old School Road to provide the effective stop rate and control delay rates for the various approaches to the roundabouts.

The balance of the TIM values for acceleration, deceleration and cruise were calculated in the same manner as they were for the stop and signal controlled intersections. In this way the TIM values for each design alternative for the intersection can be compared with respect to the alternative's potential emissions.

6.0 Calculating the TIM for Alternatives

The time in each of the modes: decelerating, idling, accelerating and cruising were calculated for each intersection and each approach on that intersection to provide an estimate of how long vehicles will spend in each mode at the intersection. The approach to the intersection will involve the modes of cruising, deceleration and idling time, and the departure will involve acceleration and cruising time. On each of the legs of the intersection there will be arrivals and departures and the time in each mode for each leg was determined to define the emissions. The following operating conditions were assessed:

1. Do Nothing Alternatives at Street A; Old School Road; Healey Road; and King Street for 3 Horizon Years: 2011, 2021, 2031.
2. Widening Airport Road to 5 lanes and using different configurations in the two intersections:
    a. Realignment of the Old School Road, Healey Road, Airport Road intersection and introducing signals at the intersection. Evaluated for both 2021 and 2031.
    b. Adding auxiliary lanes at the King Street and Airport Road intersection to facilitate better traffic flow. Evaluated for both 2021 and 2031.
    c. Converting both the Old School Road, Healey Road and Airport Road intersection and the King Street and Airport Road intersection to dual lane roundabout operations. Evaluated for both 2021 and 2031.

Calculations to determine the TIM were completed for both the AM and PM hour using the Traffic Needs Assessment's Synchro data for the stop and signal controlled intersections. As discussed above aaSIDRA data was used to define control delay and average number of effective stops at the multi-lane roundabouts. The TIM results are summarized in Table 7. The values are in seconds for each mode. Zeros in the table indicate that there is no approach to the intersection from that direction, or the option was not evaluated for that particular year.

Table 10 Time in Mode [s] for Intersection Approaches

Alternative	Intersection	Horizon	Northbound Approach				Eastbound Approach				Southbound Approach				Westbound Approach			
			Decel	**Idle**	**Cruise**	**Accel**	**Decel**	**Idle**	**Cruise**	**Accel**	**Decel**	**Idle**	**Cruise**	**Accel**	**Decel**	**Idle**	**Cruise**	**Accel**
Do Nothing	Street A	2011 AM	311	1399	12597	278	0	0	0	0	584	3232	12775	1813	113	1944	881	117
		2011 PM	826	3190	11296	946	0	0	0	0	218	1009	10935	882	87	1568	980	205
		2021 AM	5418	21034	18564	398	0	0	0	0	1413	12106	15969	6627	630	10437	10205	2686
		2021 PM	3792	35466	18500	3497	0	0	0	0	934	12411	17286	13993	1709	21488	11620	1118
		2031 AM	5439	21403	21399	439	0	0	0	0	1758	15717	18990	7284	630	10437	10205	2686
		2031 PM	4175	41362	21046	4224	0	0	0	0	1105	14543	19711	14318	1709	23498	11620	1118
	Healey	2011 AM	289	274	2177	3079	0	0	0	0	3501	6742	13040	1720	1274	3847	1129	4821
		2011 PM	210	200	1172	1074	0	0	0	0	873	1663	17268	5318	3215	16095	1068	1776
		2021 AM	269	255	1124	13325	0	0	0	0	8893	26332	52479	1838	1325	5575	2100	4763
		2021 PM	287	272	1285	1949	0	0	0	0	1437	2987	31726	7162	4325	131655	1433	2381
		2031 AM	321	304	1188	5750	0	0	0	0	5307	15378	20896	2249	1623	21507	2549	5778
		2031 PM	350	332	1381	2703	0	0	0	0	1926	4336	36541	8726	5270	365061	1749	2908
	Old School	2011 AM	663	1372	10392	2845	1531	5501	1097	1093	49	47	11632	322	0	0	0	0
		2011 PM	3022	6147	3747	1311	801	2092	745	3670	74	70	8711	2424	0	0	0	0
		2021 AM	951	1972	15144	3827	2055	12324	1473	1464	62	60	16981	538	0	0	0	0
		2021 PM	4619	11261	6523	1764	1079	3593	1002	4919	96	91	16195	4325	0	0	0	0
		2031 AM	1278	2897	18194	4671	2517	51480	1804	1796	85	82	20243	905	0	0	0	0
		2031 PM	6256	18495	7622	2155	1315	8003	1222	6012	117	111	17859	6441	0	0	0	0
	King	2011 AM	847	2351	9025	7862	3095	9936	5654	7150	3847	12589	11002	1881	4522	16604	7982	6428
		2011 PM	3420	11449	9726	1734	3924	14512	5685	9665	1121	3589	10012	9140	6709	26700	8317	8103
		2021 AM	827	2284	10355	10547	2654	9203	5794	6958	5410	20778	13348	1606	4342	17737	8663	6024
		2021 PM	6043	25120	16252	2651	3613	17190	5813	7255	1549	5407	14098	12443	4927	23887	7449	8316
		2031 AM	986	2988	11939	13409	3339	13551	6722	8889	6796	35015	15872	1955	5594	30800	10251	7465
		2031 PM	8021	53456	17730	3707	4853	30266	7697	7322	2345	13769	14818	16671	5248	46266	8682	11271

Table 7 (cont'd) Time in Mode [s] for Intersection Approaches

Alternative	Intersection	Horizon	Northbound Approach				Eastbound Approach				Southbound Approach				Westbound Approach			
			Decel	**Idle**	**Cruise**	**Accel**	**Decel**	**Idle**	**Cruise**	**Accel**	**Decel**	**Idle**	**Cruise**	**Accel**	**Decel**	**Idle**	**Cruise**	**Accel**
4 Lanes + Aux	Healey	2011AM																
		2011PM																
		2021 AM	161	1365	15573	2735	1367	6686	2198	1014	1359	9972	16268	361	782	3917	2717	2860
		2021 PM	1373	10471	16253	1473	657	2582	2169	3506	455	3297	16702	3170	2503	11029	4892	1329
		2031 AM	198	1705	18508	3581	1677	8856	2707	1218	1769	13478	19480	441	934	5047	3347	3458
		2031 PM	1130	14694	19515	1025	385	2091	4243	2175	368	4111	19890	2980	1809	9889	7242	834
Roundabout	Healey	2011AM																
		2011PM																
		2021 AM	914	1820	12053	8953	1452	2872	2503	766	4555	9149	14209	1819	701	1525	2984	2946
		2021 PM	4028	7987	14907	4490	593	1216	2422	2454	1732	3476	12930	8010	2561	5329	6208	1982
		2031 AM	1149	2283	14038	11391	2173	4249	2788	949	5748	11591	16821	2299	869	1886	3203	4246
		2031 PM	4828	9562	16866	5667	743	1534	2763	3231	2146	4318	14691	9652	3321	6879	7328	2424
4 Lanes + Aux	King	2011AM																
		2011PM																
		2021 AM	211	1912	10960	3718	1827	6265	5761	5496	2001	12871	12107	570	3707	12334	7851	4934
		2021 PM	1621	12902	14809	1287	3062	10689	6367	4433	755	4504	14835	3683	2676	10076	8361	6013
		2031 AM	289	2616	12905	4784	2133	7701	7143	6582	2733	18307	14363	707	4399	15844	9571	6080
		2031 PM	1937	14845	17070	1492	3809	13717	7641	5418	969	5295	16800	5111	3540	11886	9791	7463
Roundabout	King	2011AM																
		2011PM																
		2021 AM	918	1869	6871	10536	2286	4627	6630	4521	5857	12359	9591	1769	2939	6253	8380	5974
		2021 PM	6200	12494	12579	4753	2558	5199	7076	5523	2076	4502	8378	9550	3211	6559	8624	6858
		2031 AM	1180	2405	6727	15057	3081	6223	7667	5804	8580	17789	10461	2288	3673	7834	9479	8227
		2031 PM	9080	17817	13152	6045	3243	6608	7949	7555	2547	5481	7902	13849	4385	8843	9477	9137

7.0 Average Emission Rates

As noted in the introduction the basis for emission estimates for this study were the average emission rate data derived from the UTEC calculator. By setting the parameters to the appropriate horizon year, with 100% passenger vehicles an emission rate in g/VKT were estimated. A comparison between arterial and local roads showed no difference for any contaminants except greenhouse gas emissions, so it was assumed that an average of the arterial and local roads would represent cruising conditions for comparison purposes.

Since the emissions from UTEC are in g/VKT but the dispersion modelling uses emissions in g/s it was necessary to convert the estimates to this basis By multiplying the emission rate by an assumed average cruising speed of 70 km/h, the emission rate is g/km can be converted to g/hr. Dividing the g/hr value by 3600 creates g/s emission values for the dispersion model.

Table 9 shows the estimated emissions in g/VKT for the three horizon years, and the various types of vehicles that can be estimated from the UTEC model. Table 10 provides the converted emission rate data in g/s. The data for passenger vehicles in Table 9 was used to describe cruising emissions. As noted earlier, acceleration emissions were estimated to be approximately 1.7 times the cruising emissions while deceleration emissions were assumed to be 0.5 times the cruising level and idling emission was assumed to be 0.25 times the cruising emissions. By taking the total seconds for each mode and multiplying by the appropriate factors to scale the emissions to cruise emissions relative emissions for each mode can be derived. Summing relative emissions over the four modes, and multiplying this value by the cruising emission rate provides an estimate of the total emissions for one hour. It was assumed that these emissions were evenly distributed over the hour thereby allowing the g/hr values to be coverted to g/s by dividing by the number of seconds in 1 hour.

The product of the time in mode, and the scaling factors multiplied by the emission rate for specific contaminants and horizon years are shown in Table 11 which covers two pages. Each section of the table pertains to a particular intersection and the operational configuration assessed for that intersection. The first four groups are the do nothing alternatives. On the second page of the table the results for the calculations for two different alternatives for the two intersections are presented. The Old School/Healey/Airport Road roundabout had two incoming and outgoing lanes for each approach except Old School Road which was single lane in and out of the roundabout. The King and Airport Road roundabout was considered with 2 approach lanes on each approach.

Table 11 Emissions by Horizon Year from UTEC Model [g/vkt]

Criteria Air Contaminant Emissions (g/vkt) 2011								
Vehicle Class	**CO**	**NOx**	**SO2**	**VOC**	**TPM**	**PM10**	**PM2.5**	**GHG**
Light-duty passenger vehicle	8.592262	0.396131	0.003735	0.43244	0.01611	0.015839	0.007423	327.0833
Light-duty commercial vehicle	0.065	0.074923	0.000915	0.036301	0.007439	0.007411	0.005837	503.8265
Medium-duty commercial vehicle	2.259694	1.957143	0.009367	0.251046	0.059031	0.058622	0.045561	716.0714
Heavy-duty commercial vehicle	1.158929	5.359694	0.01763	0.242883	0.129056	0.129056	0.100128	1106.378

Criteria Air Contaminant Emissions (g/vkt) 2021								
Vehicle Class	**CO**	**NOx**	**SO2**	**VOC**	**TPM**	**PM10**	**PM2.5**	**GHG**
Light-duty passenger vehicle	5.922619	0.147768	0.003563	0.211101	0.015405	0.015205	0.006824	308.631
Light-duty commercial vehicle	0.035612	0.024977	0.000896	0.015594	0.003214	0.003202	0.00196	478.8265
Medium-duty commercial vehicle	1.573469	0.475	0.009791	0.119898	0.026505	0.026224	0.016128	658.6735
Heavy-duty commercial vehicle	0.381378	1.152296	0.017028	0.165383	0.056122	0.055918	0.03273	1049.235

Criteria Air Contaminant Emissions (g/vkt) 2031								
Vehicle Class	**CO**	**NOx**	**SO2**	**VOC**	**TPM**	**PM10**	**PM2.5**	**GHG**
Light-duty passenger vehicle	5.407738	0.115595	0.003357	0.180744	0.015247	0.015048	0.006646	291.131
Light-duty commercial vehicle	0.026352	0.010834	0.00086	0.008168	0.002498	0.002484	0.001294	453.3163
Medium-duty commercial vehicle	1.315306	0.157423	0.010194	0.083214	0.020949	0.020722	0.011309	598.7245
Heavy-duty commercial vehicle	0.249311	0.409949	0.016429	0.146327	0.047092	0.046888	0.024408	994.1327

Table 12 Emissions [g/s] by Horizon Year assuming 70 km/h Average Speed

Criteria Air Contaminant Emissions (g/s at cruise) 2011								
Vehicle Class	**CO**	**NOx**	**SO2**	**VOC**	**TPM**	**PM10**	**PM2.5**	**GHG**
Light-duty passenger vehicle	0.16707	0.00770	0.00007	0.00841	0.00031	0.00031	0.00014	6.35995
Light-duty commercial vehicle	0.00126	0.00146	0.00002	0.00071	0.00014	0.00014	0.00011	9.79663
Medium-duty commercial vehicle	0.04394	0.03806	0.00018	0.00488	0.00115	0.00114	0.00089	13.92361
Heavy-duty commercial vehicle	0.02253	0.10422	0.00034	0.00472	0.00251	0.00251	0.00195	21.51290

Criteria Air Contaminant Emissions (g/s at cruise) 2021								
Vehicle Class	**CO**	**NOx**	**SO2**	**VOC**	**TPM**	**PM10**	**PM2.5**	**GHG**
Light-duty passenger vehicle	0.11516	0.00287	0.00007	0.00410	0.00030	0.00030	0.00013	6.00116
Light-duty commercial vehicle	0.00069	0.00049	0.00002	0.00030	0.00006	0.00006	0.00004	9.31052
Medium-duty commercial vehicle	0.03060	0.00924	0.00019	0.00233	0.00052	0.00051	0.00031	12.80754
Heavy-duty commercial vehicle	0.00742	0.02241	0.00033	0.00322	0.00109	0.00109	0.00064	20.40179

Criteria Air Contaminant Emissions (g/s at cruise) 2031								
Vehicle Class	**CO**	**NOx**	**SO2**	**VOC**	**TPM**	**PM10**	**PM2.5**	**GHG**
Light-duty passenger vehicle	0.10515	0.00225	0.00007	0.00351	0.00030	0.00029	0.00013	5.66088
Light-duty commercial vehicle	0.00051	0.00021	0.00002	0.00016	0.00005	0.00005	0.00003	8.81448
Medium-duty commercial vehicle	0.02558	0.00306	0.00020	0.00162	0.00041	0.00040	0.00022	11.64187
Heavy-duty commercial vehicle	0.00485	0.00797	0.00032	0.00285	0.00092	0.00091	0.00047	19.33036

Table 13 Emission Rate for Approaches by Alternative [g/s]

Do Nothing at Existing Intersections

Location	Period	Northbound Approach Wt. Time [s/hr]	Northbound NOx [g/s]	Northbound CO [g/s]	Northbound PM2.5 [g/s]	Eastbound Approach Wt. Time [s/hr]	Eastbound NOx [g/s]	Eastbound CO [g/s]	Eastbound PM2.5 [g/s]	Southbound Approach Wt. Time [s/hr]	Southbound NOx [g/s]	Southbound CO [g/s]	Southbound PM2.5 [g/s]	Westbound Approach Wt. Time [s/hr]	Westbound NOx [g/s]	Westbound CO [g/s]	Westbound PM2.5 [g/s]	Greenhouse Gases [tonne/h]
Street A	2011 AM	13575	0.029	0.630	0.001	0	0.000	0.000	0.000	16957	0.036	0.787	0.001	1623	0.003	0.075	0.000	736
	2011 PM	14115	0.030	0.655	0.001	0	0.000	0.000	0.000	12795	0.027	0.594	0.001	1764	0.004	0.082	0.000	657
	2021 AM	27207	0.022	0.870	0.001	0	0.000	0.000	0.000	30967	0.025	0.991	0.001	17696	0.014	0.566	0.001	1639
	2021 PM	35206	0.028	1.126	0.001	0	0.000	0.000	0.000	44643	0.036	1.428	0.002	19748	0.016	0.632	0.001	2152
	2031 AM	30215	0.019	0.883	0.001	0	0.000	0.000	0.000	36181	0.023	1.057	0.001	17696	0.011	0.517	0.001	1714
	2031 PM	40655	0.025	1.187	0.001	0	0.000	0.000	0.000	48240	0.030	1.409	0.002	20250	0.013	0.591	0.001	2224
Healey	2011 AM	7625	0.016	0.354	0.000	0	0.000	0.000	0.000	19400	0.042	0.900	0.001	10923	0.023	0.507	0.000	869
	2011 PM	3152	0.007	0.146	0.000	0	0.000	0.000	0.000	27162	0.058	1.261	0.001	9719	0.021	0.451	0.000	917
	2021 AM	23975	0.019	0.767	0.001	0	0.000	0.000	0.000	66634	0.053	2.132	0.002	12253	0.010	0.392	0.000	2222
	2021 PM	4810	0.004	0.154	0.000	0	0.000	0.000	0.000	45366	0.036	1.451	0.002	40558	0.032	1.297	0.001	1960
	2031 AM	11200	0.007	0.327	0.000	0	0.000	0.000	0.000	31217	0.019	0.912	0.001	18559	0.012	0.542	0.001	1243
	2031 PM	6234	0.004	0.182	0.000	0	0.000	0.000	0.000	53422	0.033	1.560	0.002	100594	0.063	2.938	0.004	3266
Old School	2011 AM	15902	0.034	0.738	0.001	5096	0.011	0.237	0.000	12215	0.026	0.567	0.000	0	0.000	0.000	0.000	760
	2011 PM	9024	0.019	0.419	0.000	7907	0.017	0.367	0.000	12887	0.028	0.598	0.001	0	0.000	0.000	0.000	683
	2021 AM	22618	0.018	0.724	0.001	8070	0.006	0.258	0.000	17941	0.014	0.574	0.001	0	0.000	0.000	0.000	1051
	2021 PM	14646	0.012	0.469	0.001	10801	0.009	0.346	0.000	23619	0.019	0.756	0.001	0	0.000	0.000	0.000	1060
	2031 AM	27497	0.017	0.803	0.001	18986	0.012	0.555	0.001	21844	0.014	0.638	0.001	0	0.000	0.000	0.000	1392
	2031 PM	19037	0.012	0.556	0.001	14100	0.009	0.412	0.001	28896	0.018	0.844	0.001	0	0.000	0.000	0.000	1264
King	2011 AM	23402	0.050	1.086	0.001	21840	0.047	1.014	0.001	19270	0.041	0.894	0.001	25322	0.054	1.175	0.001	2057
	2011 PM	17245	0.037	0.800	0.001	27706	0.059	1.286	0.001	27009	0.058	1.253	0.001	32122	0.069	1.491	0.001	2383
	2021 AM	29269	0.023	0.936	0.001	21251	0.017	0.680	0.001	23979	0.019	0.767	0.001	25509	0.020	0.816	0.001	2161
	2021 PM	30060	0.024	0.962	0.001	24250	0.019	0.776	0.001	37377	0.030	1.196	0.001	30021	0.024	0.960	0.001	2629
	2031 AM	35974	0.022	1.051	0.001	26890	0.017	0.785	0.001	31347	0.020	0.916	0.001	33439	0.021	0.977	0.001	2601
	2031 PM	41407	0.026	1.209	0.001	30137	0.019	0.880	0.001	47774	0.030	1.395	0.002	42032	0.026	1.228	0.002	3288

Table 11 (cont'd) Emission Rate for Approaches by Alternative [g/s]

Alternatives for Do Nothing at Intersections
(assumes Airport Road is widened and intersections are either signalised or multi lanes roundabouts).

Location	Period	Northbound Approach				Eastbound Approach				Southbound Approach				Westbound Approach				Greenhouse Gases
		Wt. Time [s/hr]	NOx [g/s]	CO [g/s]	PM2.5 [g/s]	Wt. Time [s/hr]	NOx [g/s]	CO [g/s]	PM2.5 [g/s]	Wt. Time [s/hr]	NOx [g/s]	CO [g/s]	PM2.5 [g/s]	Wt. Time [s/hr]	NOx [g/s]	CO [g/s]	PM2.5 [g/s]	[tonne/h]
4 Lanes	2011AM	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0
Healey	2011PM	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0
	2021AM	20645	0.0165	0.660	0.001	6275	0.0050	0.201	0.000	20054	0.0160	0.642	0.001	8950	0.0071	0.286	0.000	1208
	2021PM	22061	0.0176	0.706	0.001	9104	0.0073	0.291	0.000	23143	0.0185	0.740	0.001	11160	0.0089	0.357	0.000	1414
	2031AM	25121	0.0157	0.734	0.001	7830	0.0049	0.229	0.000	24483	0.0153	0.715	0.001	10955	0.0068	0.320	0.000	1394
	2031PM	25496	0.0159	0.745	0.001	8655	0.0054	0.253	0.000	26167	0.0163	0.764	0.001	12036	0.0075	0.352	0.000	1475
Roundabout	2011AM	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0
Healey	2011PM	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0
	2021AM	28185	0.0225	0.902	0.001	5250	0.0042	0.168	0.000	21866	0.0175	0.699	0.001	8724	0.0070	0.279	0.000	1383
	2021PM	26550	0.0212	0.849	0.001	7194	0.0057	0.230	0.000	28282	0.0226	0.905	0.001	12191	0.0097	0.390	0.000	1603
	2031AM	34548	0.0216	1.009	0.001	6550	0.0041	0.191	0.000	26501	0.0165	0.774	0.001	11326	0.0071	0.331	0.000	1608
	2031PM	31304	0.0195	0.914	0.001	9010	0.0056	0.263	0.000	33252	0.0208	0.971	0.001	14828	0.0093	0.433	0.001	1801
4 Lanes	2011AM	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0
King	2011PM	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0
	2021AM	17863	0.0143	0.571	0.001	17584	0.0140	0.562	0.001	17295	0.0138	0.553	0.001	21177	0.0169	0.677	0.001	1597
	2021PM	21034	0.0168	0.673	0.001	18106	0.0145	0.579	0.001	22599	0.0180	0.723	0.001	22441	0.0179	0.718	0.001	1819
	2031AM	21835	0.0136	0.638	0.001	21325	0.0133	0.623	0.001	21508	0.0134	0.628	0.001	26067	0.0163	0.761	0.001	1849
	2031PM	24287	0.0152	0.709	0.001	22185	0.0139	0.648	0.001	27297	0.0170	0.797	0.001	27219	0.0170	0.795	0.001	2058
Roundabout	2011AM	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0
King	2011PM	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0	0.0000	0.000	0.000	0
	2021AM	25709	0.0205	0.822	0.001	16615	0.0133	0.532	0.001	18617	0.0149	0.596	0.001	21570	0.0172	0.690	0.001	1783
	2021PM	26882	0.0215	0.860	0.001	19044	0.0152	0.609	0.001	26776	0.0214	0.857	0.001	23527	0.0188	0.753	0.001	2079
	2031AM	33515	0.0209	0.979	0.001	20630	0.0129	0.603	0.001	23088	0.0144	0.674	0.001	27259	0.0170	0.796	0.001	2129
	2031PM	32423	0.0161	0.751	0.001	24067	0.0150	0.703	0.001	34090	0.0213	0.996	0.001	29413	0.0184	0.859	0.001	2309

Appendix B Air Modelling Procedures

1.0 Introduction

Any time fuel is burned, contaminants are released to the atmosphere. These releases add to the amount of materials that is present in the environment. The contaminants disperse as they move downwind and eventually the settle to the ground.

If you observe the plume from a stack, you will see it move downwind and spread both vertically and horizontally along the plume centerline. Much of what we see is water vapour which eventually evaporates into the atmosphere and is no longer visible. If the plume contains a great deal of particulate matter, the plume will persist for much longer but will appear to get less dense as the plume spreads. The degree of spread depends upon the speed of the wind which stretches the plume in the downwind direction. A highly turbulent atmosphere will cause the plume to be mixed with the surrounding air in the vertical and across plume direction. The spreading reduces the concentration of contaminants in the plume and the plume becomes invisible. The speed of the wind and the amount of mixing are a function of atmospheric conditions, wind speed, wind direction, the amount of solar energy hitting the earth's surface, and the amount of turbulence present in the atmosphere.

Other factors limit the plume's spread. The vertical spread can be limited by a layer of stable air above the ground surface which has little of the inherent turbulence needed to promote mixing. While the plume continues to be stretched in the downwind direction, vertical spread is limited and the contaminants have a higher concentration than would occur if the vertical mixing were stronger. Most of the time though, there is little practical limit to the vertical mixing, particularly with relative low stacks.

Low stacks also bring other factors into play and these affect the plume's behaviour. As the wind moves over a building, areas of recirculation can be set up downwind of the building, and materials can be trapped in this recirculation zone and increase in concentration. If the stack is not high enough, the plume can get trapped in this recirculation zone. Eventually, the materials in this downwind zone settle on the ground as, for the most part, they are influenced by gravity.

Based upon detailed study of the behaviour of plumes, scientists have developed mathematical models that predict the distribution of contaminants released for a source. These models use historic weather data for the area where the study is located to define the downwind, cross-wind and vertical mixing that dilute the concentrations in the plume.

Typically the models are used to estimate the ambient concentrations of contaminants associated with new sources. These are generally referred to as point of impingement [POI] values. In Ontario, the MoE has developed a set of standards for different contaminants based upon these POI values. These are listed in various tables in O.Reg. 419/05, sub-titled Air Pollution - Local Air Quality. If the model predicts values that exceed the POI values, the proponent has to take measures to reduce the rate at which contaminants are released from the stack. Values lower than the standards are generally judged to be acceptable, provided the emission estimates are conservative, or unlikely to be exceeded for any substantial period of time. POI estimates that are very low compared to the standards are assumed to indicate that there is little possibility of effects from the contaminant.

As part of the studies being conducted for the Airport Road EA, the emissions from the sources identified for the road system were modelled with an advanced algorithm approved by the MoE. The objective of the modelling was to determine point of impingement estimates for comparison to the O.Reg. 419/05 criteria and the ambient air quality standards applied in the province. The modelling requires consideration of the local terrain and meteorological conditions as well as characterisation of the emissions. Modelling was completed using the US EPA approved AERMOD model.

2.0 AERMOD Algorithm Overview

Simulating the mixing and dispersion of exhaust gases released to the atmosphere involves describing these processes by way of parameters developed from laboratory and field experiments. The majority of dispersion occurs in the Planetary Boundary Layer of the atmosphere. This is the zone of turbulent air next to the earth's surface that is influenced by surface heating and the nature of the surface. This layer is also affected by the presence of stable air masses above it. Motion in this region is governed by surface roughness which creates friction in the lower layer and increases atmospheric turbulence. This turbulence increases the mixing of the plume with the atmosphere thereby reducing the concentrations of contaminants as the plume moves downwind. Increased turbulence can cause materials to remain suspended in the atmosphere for longer periods of time but in some circumstances the nature of the surface can deplete the materials at a faster rate.

The height of the planetary boundary layer varies depending upon the time of day, 1 to 2 km during the day and a few hundred meters at night. The movement in the atmosphere can be described in terms of a convective boundary layer and a stable boundary layer. The convective layer has a vertical structure and turbulence scales that were defined through experiments earlier than were the factors that describe the stable boundary layer. Both conditions are incorporated into the latest dispersion modelling algorithms.

The algorithms use eddy-diffusion techniques to describe surface releases, statistical theory and planetary boundary layer scaling for dispersion parameter estimation, and a probability density function to describe motion in the convective boundary layer. These factors are related to meteorological variables (e.g., surface heat flux) that govern turbulence parameters and simple techniques have been developed to describe these factors.

As the general level of knowledge advanced there were opportunities to improve the dispersion model and the AERMOD algorithm represents current state of the art for such models. It was developed under the direction of the American Meteorological Society and the United States Environmental Protection Agency [US EPA]. It contains improvements in the description of the planetary boundary layer turbulence, plume interaction with the terrain, building downwash and dispersion over urban areas. The AERMOD model addresses short-range dispersion for industrial sources. It replaces the older Industrial Source Complex [ISC] model that had been used as the regulatory standard model for many years.

Relative to the older ISC3 model, AERMOD contains new or improved algorithms for:

1. dispersion in both the convective and stable boundary layers;
2. plume rise and buoyancy;
3. plume penetration into elevated inversions;
4. computation of vertical profiles of wind, turbulence, and temperature;
5. the urban night time boundary layer;
6. the treatment of receptors on all types of terrain from the surface up to and above the plume height;
7. the treatment of building wake effects;
8. an improved approach for characterizing the fundamental boundary layer parameters; and,
9. the treatment of plume meander.

AERMOD is a modelling system that consists of two pre-processors and the dispersion model. A pre-processor for the meteorological data (AERMET) generates the data necessary to characterise the planetary boundary layer while the terrain pre-processor (AERMAP) is used to provide the surface characteristics that the model requires and to develop the receptor grids used by the model.

AERMET uses meteorological data and surface characteristics to calculate boundary layer parameters (e.g. mixing height, friction velocity, etc.) needed by AERMOD. This data, whether measured off-site or on-site, must be representative of the meteorology in the area being considered.

AERMAP uses gridded terrain data for the modeling area to calculate a representative terrain-influence height associated with each receptor location. While for most locations in the United States, this data can be derived from the Digital Elevation Model (DEM) data produced by the United States Geological Survey (USGS 1994), or similar data for Canada. These parameters were defined as part of this project, as described later in this report. The terrain pre-processor computes elevations for both discrete receptors and receptor grids.

AERMOD requires certain data to describe the system that needs to be modelled. Inputs include:

- Emission characteristics;
- Meteorological data;
- Terrain characteristics; and,
- Receptor locations.

Each of these aspects is addressed in the following sections with specific reference to this project.

2.1 Emissions

AERMOD allows the user to specify the type of sources that apply to the study. Sources are generally characterized as: point; area; or volume type.

2.1.1 Point Sources

Point sources are generally related to fixed stacks that exhaust to the atmosphere. Point sources are defined in terms of the size of the stack (diameter, height); the stack gas characteristics (volumetric flow, and temperature); and, the rate of release of different contaminants in grams per second. For this study there were no point sources since all vehicles were assumed to be moving, or stationary only for the period of the traffic control system.

2.1.2 Vehicular Sources

The sources for this study are associated with exhaust emissions from vehicles. Such sources can be addressed through the use of area, volume sources, or a modified volume source used to describe line sources for the traffic on the roads.

Volume Sources – sometimes referred to as a virtual source, the volume source approach employs an imaginary point source located a certain distance upwind from the center of the source to account for the initial size of the source. The AERMOD algorithm then treats this source as a stack with the ability to address meandering plume, however the volume source has no initial momentum or buoyancy factors applied to the plume, but the modeller assigns a release height for the source. The emissions are entered into the model as gram per second [g/s] emission rates. The modeller must specify the initial lateral and vertical dimensions for the source. The guidance documents suggest that the initial lateral dimension is the shorter of the two measurements that would describe the width and length of the source area divided by 4.3. The initial vertical dimension is the vertical dimension of the source divided by 2.15 if the source is surface based.

Area Sources –Area sources explicitly simulate a uniform emission density across an area, which may be more realistic in some respects than other approaches[23]. In particular the area source approach allows concentrations to be calculated within the area of the source, or at least close to the source area. The emission rate for the area source is the g/s emission rate divided by the area of the source [$g/s/m^2$]. The volume source approach excludes receptors within the source area defined by the side dimension and a 1 m exclusion zone outside that area. If this area is considered important, the area source approach should be used. Essentially this approach uses a numerical integration in the upwind and crosswind direction of the point source plume. Area sources can be irregularly shaped whereas volume sources are square. Recommendations suggest that area sources with a length to width ratio of 100:1 can be used.

Line Sources – are a modified version of the volume source. Employing this approach generates a series of equally spaced volume sources along a road with the size of the each being defined by the 8characteristics of the vehicles and the type of road. The emissions rate for the line source is the g/s emission rate for that particular section of road but it is equally divided between all the individual volume sources making up the line. The line source can be used to represent various locations on a road where the emissions are anticipated to be different by defining different links for each operating condition.

2.2 Meteorological Data

For the Airport Road EA study the MoE provided the AERMET processed data that can be used for the study. For this study the meteorological data was developed from historical data collected at Toronto's Pearson International Airport located south of the study zone. The data used is in the form of hourly values for the various parameters: wind speed, wind direction, temperature etc. reflecting local historical data. AERMOD was run for a 5 year period using this hourly data. The model calculates concentrations at all the receptors for each hour of the period and retains the maximum hourly values at each receptor. It can also generate maximum 24 hour average values, and annual averages.

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[23] Robinson and Daye, 2011. December 6, 2011 memorandum with Haul Roads Workgroup Final Report . Included in a March 2, 2012 memo from Tyler Fox, US EPA to Regional Office Modelling Contacts. http://www.epa.gov/scram001/reports/Haul_Road_Workgroup-Final_Report_Package-20120302.pdf

2.2.1 Terrain Characteristics

AERMET requires that Surface Parameters be specified for the area around the sources. These are specified in terms of appropriate values for three surface characteristics: surface roughness length [*zo*], albedo [*r*], and Bowen ratio [*Bo*]. The values for the study were developed by the MoE as part of preparing the meteorological data noted earlier.

The surface roughness length is related to the height of obstacles to the wind flow and represents the height at which the mean horizontal wind speed is zero based on a logarithmic profile. The surface roughness length influences the surface shear stress and influences the magnitude of mechanical turbulence and the stability of the boundary layer. The albedo is the fraction of total incident solar radiation reflected by the surface back to space without absorption. The daytime Bowen ratio, an indicator of surface moisture, is the ratio of sensible heat flux to latent heat flux and is used for determining planetary boundary layer parameters for convective conditions driven by the surface sensible heat flux.

2.3 Receptors Used for Modelling

The model was set up with a uniform 60 m x 60 m receptor spacing covering an area measuring approximately 2500 m in both directions. This receptor grid was centered on the intersections and for some model runs was extended to include additional receptors along the cruising sections. As discussed in the text, for ease of comparing the various alternatives discrete receptor points were defined at 5 residential properties around the King Street and Airport Road intersection and 4 points around the Old School/Healey/Airport intersection. Using the AERMAP module in the program, and terrain elevations downloaded from the WEBGis site, the elevation of all the receptors and sources were determined before the model was run in the elevated terrain mode.

2.4 Chemical Conversion

AERMOD can address the effect of ozone in the atmosphere in the conversion of oxides of nitrogen emissions to NO_2 although it was not used for this modelling exercise. Engine exhaust from vehicular traffic is responsible for a large portion of the NO_x released into the atmosphere. Oxides of nitrogen, NO_x, are the collective term used to describe emissions of combustion related nitrogen compounds to the atmosphere. These emissions are defined as 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 the 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. Hourly values show that ozone levels start to decrease after the sun sets. In areas with lower vehicular related emissions one might expect to see higher ozone levels, particularly if it originates from areas upwind of the monitoring station.

AERMOD accounts for the effect of the ozone using a procedure referred to as the ozone limiting method that is when all the ozone in the atmosphere is consumed the amount of NO_2 generated is determined. The default for the NO_2 emission rate from facilities is 10% of the total NO_x released according to the model. The ambient ozone levels can then be converted from NO_x in the atmosphere to NO_2 based upon an assumed ozone level. A more conservative approach is to assume that all NO_x released is NO_2 and compare the results of the model to the NO_2 criteria level. That approach was followed for this study.

6	<u>**Roundabout Design**</u> - Urbanized cross section. - Paved shoulder will merge in to roundabout sidewalk (3m+sidewalk+splash pad.) - Design has minimized property and access impacts. - 55m diameter will accommodate farm vehicles. - Centre of roundabout could be considered for LID and provide space for a feature if Airport Road designated as Veteran's Way – improvements or other signage features will be determined in detailed design. - Question asked if long combination vehicles can be accommodated in roundabout? IBI will run model to make sure it works. - Question asked about possible interchange location for GTA West on Airport Road – how will it impact function of roundabouts. - MTO will consider all possibilities as it reviews interchange locations. <u>**Roundabout Property Impacts**</u> - full property buyouts are those that are generally closer than 6m from the proposed new impact area - At the NW corner of King there are 2 properties located next to a development application which are shown as full buy-outs. - Developer at the NW corner of King/Airport may have interest in the 1st adjacent property marked for full buyout. Will know more after the information is made public on November 27th. - Sally and Joe will be approaching property owners who have major impacts in advance of the PIC. <u>**Education Programs and Services**</u> Imre will be contact at the PIC to answer questions and provide attendees with a handout that directs them to the Peel website: www.peelregion.ca/roundabouts	***Info*** ***Allan Ortlieb*** ***Info***
7	<u>**Carpool Lot**</u> - Transportation Planning conducted a carpool lot study that showed proposed locations in close proximity and within the study area - A question was asked if GTA West is planning for car pool lots and should a lot be included in the study? Natalie confirmed that carpool lots within the GTA West corridor are within the scope of the study. - Natalie responded that Ministry will not be obtaining property for a long time since it has no funding commitment yet. GTA West is not warranted until 2031. - MTO will work with Peel and the Town of Caledon to investigate potential partnership for a carpool lot in relation to the GTA West.	***Info***
8	<u>**MTO**</u> - Ministry will have a long list of possible interchange locations at upcoming meeting with Peel on November 7th. - long list is not intended to determine final locations but provide possible locations that will be taken forward for further review. - The preferred route will be presented late 2015/early 2016 with a preliminary design. - Natalie will give Peel an advanced update before Ministry's PIC so we are	***Natalie/Tina***

	able to answer questions at our PIC. - The first of the next round of PIC's for GTA West is scheduled November 27th in Halton.	
9	**<u>Review of PIC#2 Boards</u>** Suggested changes were noted and updates will be made to the boards.	***Info***

Notes from meeting with MNR re Structures on Airport Rd

September 9, 2014

Attendees: LGL, Shari Faulkenham, - Parish, Mark Heaton - MNR, Liz Brock, Sally Rook – Region of Peel, Allan Ortlieb, Rakesh Pandey - IBI

1. **Background**

- Study area is approx. 6kms – Airport Rd (1km north of Mayfield Rd to 500m north of King St
- Salt creek crosses at 12 locations throughout the study area (3 major, 9 minor)
- LGL has conducted aquatic resource mapping of Norris', Dean's and Salt Creek structures (3 major crossings)
- Meander belt plus 30M MNR's preference
- Entire watercourse recovery habitat for Redside Dace
- Salt Creek overtops road at Norris' Bridge

Propose replacement of 3 major structures:

a) Norris' Bridge – replace with a 14.46m X3.66m conspan
b) Dean's Culvert – replace with a 10.67m X2.13m/2.44m precast culvert
c) Salt Creek Culvert – replace with a 10.67m X2.13m/2.44m precast culvert

There is not much cover for Salt Creek and Dean's culverts. IBI feels a larger conspan bridge at these locations is not 'preferred' for the following reasons:

- Watercourses are so close to each other that the catchment area is not changing
- If larger structures are used the road profile would need to be raised +2ft creating much greater expense and impacts to nearby properties
- Would require a lot of fill in the valley to accommodate

Norris' will be replaced with conspan bridge. The catchment area at this structure is almost double what it is at the others.

Mark asked to ensure that the ESR includes documentation of options that were considered and why the precast culverts were selected. Cost comparison to include the cost of raising profile of Airport Rd.

2. There are 9 smaller crossing culverts for tributaries along the study area that will all be replaced and upsized to 800mm culverts

Urban Area (500m north of King St to south limits of Sandhill Settlement Area)
Within the Sandhill Settlement Area (approx. 800-900m) the road cross section will be urban with a treatment train that includes curb & gutter, storm sewers with oil & grit separators and bioswales
Treatment train approach for all SWM throughout the study area
Enhanced infiltration techniques will provide water quality improvements and thermal mitigation

Rural Area (South limits of Sandhill Settlement Area to Street 'A')
In rural areas, to upgrade all existing 'V' ditches to flat bottom bioswales

3. Permit Process

Document structure size alternatives re: species at risk – explain thinking for alternatives as MNR sees ultimate as best for the species i.e. meanderbelt + 30m. Create Cost and benefit review.

- Look at recovery habitat
- Removal of in-stream barriers, e.g. beaver dam
- Water quality improvements
- Private land stewardship
- Channel naturalization

MNR uses a point system to rate plans

- i.e. sq/m of impact
- catalogue of projects
- look at what's achievable
- create an overall benefit catalogue
- incorporate LID wherever possible

This information will be used in later stages of the project (60% detailed design) to complete the Avoidance of Alternatives Form (AAF)

4. Roundabouts

LID proposed for roundabouts for rainfall storage
Urban cross section to use LID bioswales – for enhanced retention
Provide examples to MNR where will be designed

5. Smaller tributaries

Proposed site visit (October/early November) to confirm 9 smaller water course crossing to determine how they contribute to habitat
Will check out pools for water at Dean's culvert to see what fish species are present
Look for Barnswallow nests on structures

6. Overall Benefit

Create wildlife passage through Conspan structure(s) – benching + riverstone + granular B
so mammals can move under structure. Mammals that would use include coyote, fox, skunk raccoon - and may accommodate deer on larger structures.

Bankful width at Norris Bridge is 2m to 6 m along reach + low flow channel
Create sinuosity as part of overall benefit

Self-regulating registry process for Barnswallow. Example of benefit – nesting cups in new structure.
Document in ESR the requirement of a Barnswallow study before starting structure replacements.

Make sure screening is complete for all species at risk. Obtain final letter from MNR that it concurs with proposed mitigation and gives approval in principle.

Look at Region's road kill data to see what animals are turning up – see if there is anything out of the usual.

Look at use of wildlife fences in meander belt to funnel wildlife to crossings e.g. Sandalwood Parkway and Creditview at Mississauga Road projects