8.0 SUMMARY AND CONCLUSIONS

The successful execution of the project has resulted in a number of new and interesting achievements, including:

- This is the first local neighbourhood or community cumulative air quality study to be completed at high resolution within Toronto.
- This is the first time that so many "Priority Air Contaminants" (including the standard 6 criteria air contaminants together with 24 air toxics) have been modelled to show their predicted spatial concentrations as distributions within a Toronto neighbourhood.
- This is the first time that transboundary sources (i.e. from USA and Ontario) have been modelled together with local sources (i.e. from Toronto, including the SRLB) to reveal the typical concentrations of 30 priority contaminants within a local neighbourhood or community airshed.
- This is the first time that the contaminant contribution from three different geographic source areas (i.e. USA, Ontario, and Toronto) to local air quality levels was assessed.
- This is the first time that the contaminant contribution from many different land use related activity areas (i.e. including industrial, commercial, transportation, and residential sources) were identified and incorporated in the local air quality modelling.
- This is the first time micro-emission inventories were developed at the neighbourhood level for addressing air quality issues in Toronto.

A key feature of the modelling project was to predict the cumulative concentration in the neighbourhood arising from multiple sources and geographies. This approach acknowledged that exposure to air pollution, and any related health impacts arises from a combination of emissions from multiple sources.

8.1 Summary

The objective of the study is to simulate and evaluate the cumulative impact of air pollution emissions that come from both local and transboundary sources that affect air quality in the South Riverdale- Leslieville-Beaches (SRLB) area of Toronto (i.e. Ward 30 and Ward 32). The study was originally requested by the Toronto Board of Health following a previous study of just the impacts of the Ashbridges Bay Treatment Plant on the health of people in South Riverdale-Leslieville-Beaches.

Three spatial emission inventories, based on anthropogenic activities as well as landuse, were developed for industrial, commercial, residential, transportation and agricultural categories. The contribution of each geographic source category was aggregated together to determine the origins of each specific contaminant that effects the SRLB airshed. The study was designed in this manner to understand where the air pollution comes from and which sources are the most prominent including nearby sources as well as distant sources (i.e., USA and south western Ontario). This allowed an assessment of the relative significance of the few larger sources (i.e., industrial) versus the many smaller sources (i.e., natural gas consumption) as well as the significance of the more local sources (i.e., transportation) versus the more distant sources (i.e., US).

The contribution to SRLB air quality of criteria air contaminants, persistent organic pollutants and other toxic substances was evaluated with the aid of a well established air quality modelling system on high spatial resolution over a one-year period (2006). The study was developed in close cooperation with staff of Toronto Environment Office and Toronto Public Health, as well as with input from local residents and stakeholders.

8.1.1 Approach

The study uses advanced air quality modelling techniques to assess the significance of 30 "priority air contaminants" as identified by Toronto Public Health and the Toronto Environment Office in SRLB. Annual average concentrations of these 30 contaminants, as well as their maximum 24- hour concentrations (midnight to midnight) experienced by residents were assessed, in keeping with established regulatory monitoring and applicable air quality standards and criteria.

Air quality monitoring remains the standard benchmark against which modelled concentrations at "virtual monitoring stations" (where a virtual monitoring station is an imaginary station that collects the equivalent of what a real monitoring station collects - and does so at each of the 550 "receptor" points in SRLB as modelled by this study) are judged. There are only four "full" (and "real") Ministry of Environment air quality index monitoring stations (MOE AQ stations) within Toronto and none of these are within the local study area. Environment Canada also maintains monitoring stations (EC NAPS AQ stations) equipment to measure local air quality. The air quality model created for the present study establishes some 550 “virtual monitoring stations” within the SRLB area as well as over a thousand beyond the local study area. The closest of these to MOE and EC AQ stations are used to "judge" the ability of the air quality model to properly represent the contaminant concentrations over Toronto and by inference within the SRLB local neighbourhood study area as well.

The advantage of airshed air quality modelling at the neighbourhood level is not only that it allows extrapolation to areas distant from air quality monitoring stations, but that unlike air quality monitoring it permits the identification of the sources which contribute to the community air quality. Modelling also allows the impact of future changes in the sources to be predicted and indeed also permits specified improvement solution scenarios to be tested. In addition, modelling can identify local issues that distant monitoring cannot, or even local monitoring in the study area may not - unless immediately adjacent to such issue sources.

The neighbourhood air quality modelling work for the SRLB study area includes a geographically diverse set of sources from as far as Indiana and Sudbury to as local as transportation and small autobody shops in Toronto. Three tiers of spatial resolution, covering the Great Lakes US states, southern Ontario and Toronto, were used in the comprehensive airshed study. The quantity of emission from sources were developed using well-established and detailed emission estimation techniques that rely on the level of human activity or landuse for an area. For all three tiers (US, southern Ontario and Toronto) emission sources were categorized as either

- Industrial;
- Residential/Commercial;
- Transportation (Road and Non-Road); and
- Biogenic & Agricultural.

US emissions around the Great Lakes were obtained from the US EPA on a state by state basis and processed on a 36 km grid resolution from southwest Indiana using the above categories. In addition, the emissions were allowed to vary according to time of day, day of week and month of year to more closely resemble expected variability of emissions.

Ontario and Toronto emissions were developed from a various databases including NPRI for industrial sources, MTO and Toronto traffic data sets, natural gas consumption data, population data, land use data and employment information (City of Toronto). The emission sources were geographically disaggregated based on landuse such as rail and roadway type, urban or rural residential area, industrial locations and marine/airports activity. For industrial, sources above a reporting threshold (tonnes/yr) must provide the amount of emissions released into the airshed (i.e., NPRI). In some cases, industries do report all emissions because they are below the threshold. To compensate for this lack of data, expected emissions were back-calculated from the NPRI data sets. For Toronto, surrogate-based emissions data for local auto body shops, drycleaners, and solvent users were calculated from employment data and emission developed emission factors from the US. The Toronto emission data were used to estimate emissions from other Ontario urban areas to provide a complete emission inventory for Ontario. Toronto emissions were geo-referenced on a 1 km resolution while Ontario emissions were geo-referenced to a 12 km grid resolution. In addition, all emissions were allowed to vary with time of day as the US emissions.

The advanced air quality modelling system requires a meteorological component to provide accurate weather data, a representative and well-founded emission database which covers a wide-range of anthropogenic and biogenic emissions and a well developed and reliable transport and dispersion model. The CALPUFF modelling system, coupled with the Penn State MM5 mesoscale meteorological model, was selected to simulate the transboundary and local source contributions to SRLB.

A full year (2006) of detailed hourly meteorological data was used to drive the model from a large scale to a small scale to ensure consistency between modelling domains and to portray synoptic and local patterns of pollutant transport and dispersion. It is the combination of meteorology, geophysical data and emissions that create the resultant air quality in nature and the model attempts to simulate this natural dynamic system.

Modelling was carried out for the thirty (30) "Priority Air Contaminants" which include the Toronto Public Health list of 25 substances and are presented below.

Acetaldehyde	1,2-Dichloroethane	$PM_{2.5}$ *
Acrolein	Dichloromethane	Tetrachloroethylene
Benzene	Ethylene dibromide	Toluene
1,3-Butadiene	Formaldehyde	Trichloroethylene
Cadmium	Lead	Vinyl Chloride
Carbon tetrachloride	Manganese	Carbon Monoxide
Chloroform	Mercury	PM_{10}
Chloromethane	Nickel Compounds	Sulphur dioxide
Chromium	Nitrogen oxides *	VOC (Anthropogenic/Biogenic)
1,4-Dichlorobenzene	PAHs (as B[a]Ps)	Ozone *

8.1.2 Findings

Airshed modelling of the SRLB was undertaken on three individual tiers (US only, Ontario [without Toronto] only and Toronto only) which allowed the contribution of each category within each tier to be assessed. The contribution of emission sources from the transboundary contributors, the US and Ontario, shows a much higher contribution than the sources from Toronto (including the SRLB area) sources. The US and Ontario sources contribute 39% and 25% by mass to the air pollution in SRLB, respectively but these regions are also responsible for over 99% of the total emissions or loading into the larger modelled domain and largely reflects the disparity of area included with in Tier I and Tier II compared to the area of the SRLB (see Figure 3.1 and Figure 3.10 and Figure 5.1).

Local emissions in Toronto (in percentage terms) are dominated by transportation sources and resultant concentrations reflect this. In Toronto, "on-road" transportation sources contribute 76% of the total emissions by weight released to the air in Toronto and as modelled in this study. "Off-road" transportation sources in Toronto including rail, marine and airports, contribute a further 10% - effectively 86% of air quality significant emissions released in Toronto (by weight) come from the transportation sector. By comparison, industry in Toronto contributes 6% and residential and commercial buildings contribute a further 8% combined in Toronto.

On average, the residential and commercial sources of Toronto, (including the SRLB area) contribute about 18% to the total ambient concentrations in SRLB while the Toronto mobile sources contribute about 13%. The influence of transportation emissions shows a strong spatial variation - within SRLB concentrations depend strongly on the geographic proximity to the Don Valley Parkway (DVP). Those residents closer to the transportation corridor (i.e., the DVP) are more greatly influenced by those sources than the others. Large industrial sources (i.e., NPRI sources) contribute about 4% to the total concentrations to the SRLB study area because there are a relatively smaller number of industrial sources in Toronto (16% of Ontario). The “on-road” mobile sources contribute strongly to Criteria Air Contaminants (CACs) (24%), mobile toxics (32%) and aromatics (14%), respectively. Non-road sources (i.e emissions from trains, airports, and marine activities etc) contribute primarily mobile toxics (13%) and CACs (6%) to the SRLB airshed.

Residential and commercial sources are the primary contributors to aromatics (40%) and halogens concentrations (33%) which are linked to dry cleaners, solvent users and auto-body shops. The presences of metals in the SRLB airshed are strongly connected with residential and commercial sources (18%) and mobile sources (13%) in Tier III. The residential and commercial sources also produce trace metals which come from natural gas consumption and other combustion sources.

The importance of transportation as a dominant source of emissions impacting the SRLB neighbourhood is reflected in the resultant modelled spatial distribution maps of concentrations across Toronto and Ontario. For the study area of SRLB, the intensely travelled transportation corridor of the Don Valley Parkway (DVP) is clearly a major source of contaminants and the resultant concentrations of those contaminants (i.e. those that emanate from the combustion of gasoline and diesel fuels) are very evident in those areas of SRLB that are in close proximity to the DVP. The transportation related contaminants that clearly come from the vehicles on the DVP are oxides of nitrogen, 1,3 butadiene, benzene, PAH, cadmium, carbon monoxide, chromium, and PM_{10} and to a lesser extent dichlorbenzene and dichlormethane. The contaminants that seem to emanate from the Billy Bishop Toronto City Airport (i.e., Island Airport) are acetaldehyde, acrolein, formaldehyde, and sulphur dioxide.

Although the number of major industrial sources has decreased in SRLB over the past years, emissions from the remaining plants can be significant on occasions. Annual average concentration maps represent what equates to a chronic background exposure level and the twenty four hour (24-hr) Ambient Air Quality Criteria (AAQC) "exceedances" represent what equates to an acute exposure level. Only the acute exceedances are regulated.

Of the 30 priority air contaminants modelled and compared with 24-hr AAQC standards, there are few contaminants that exceed their specific AAQC. There are only two contaminants that have been identified to exceed the AAQC at both the average and maximum cumulative measures, namely nitrogen dioxide and benzene. PM_{10} also exceeds as a maximum cumulative but not as an average cumulative. One industrial point source produces high local concentrations of benzene, $PM_{2.5}$ (which contributes directly to PM_{10} concentrations), toluene and tetrachloroethylene. The latter is also produced by a second industrial facility.

The meteorology that occurs during SMOG events is different from non-SMOG events such that air quality in the SRLB area is a consequence of both the greater significance of transported pollution from the upwind areas of the USA, Ontario and Toronto, as well as the more significant role being played by chemistry interactions between the major pollutants. At times of SMOG conditions and varying with the severity of the event, the concentrations predicted by the model did not correlate very well with the Environment Canada and Ministry of Ontario reported monitored data for the same events. The model over-predicted NOx levels and underpredicted $PM_{2.5}$ levels. This is likely because of the lack of chemistry in the model to convert NOx to atmospheric aerosols from long-range transport of emissions from well outside the City of Toronto. If this model had included atmospheric chemistry reactions, the NOx contribution from transboundary sources would be reduced while the particulate matter ($PM_{2.5}$) would be increased, but not proportionately.

8.2 Conclusions

1. The meteorological model (CALMET) component of the CALPUFF model system generated wind data which resembled measurements at the Toronto Pearson International Airport on a long-term basis. In addition, the wind flow during SMOG events showed the expected transport from the south-western quadrant to and across the GTA region. This provided a significant level of confidence that the modeling system simulated winds and the transport of emissions from the US and Ontario into the GTA very well.

2. The "annual average contaminant concentration" model results compare very well with long-term monitored data at a downtown Toronto monitoring station for various contaminants. Only three of eleven contaminants where monitoring data was available were either over or under predicted as compared to the standard level of acceptability (i.e. the "factor of two" ratio). The average ratio of monitoring to modeling was about 1.03 suggesting a highly satisfactorily overall performing model.

3. The results demonstrate that the air quality within the SRLB meets many of the AAQCs, with only two of 30 species above the annual AAQC and only four of 29 above the daily AAQC Most of the exceedences are near the major roadways with the exception of benzene and PM_{10} which are also associated with local industrial sources.

4. Sources within Toronto represented less than 1% of the total emissions into the large area domain used but represent 36% of the impact on the SRLB airshed, on average. This demonstrates that local emissions

have a large role on the local impact of the airshed but transboundary sources should not be ignored as they represent 64% of the background condition.

5. There was great variability in the sources responsible of for the concentrations of the 30 modelled species other than that the transportation sources are significant contributors to concentrations of criteria air contaminants, mobile toxics and aromatics. Industrial sources contribute strongly to the concentrations of metals and SO_2 in the SRLB neighbourhood.

6. Transportation is an obvious source of contaminants and close proximity to major highways is an obvious concern. This is also apparent across the City as a whole as TEO's city wide investigations of NOx and $PM_{2.5}$ reveal the significance of NOx and $PM_{2.5}$ as associated with the 421, 427, QEW and DVP to be significant near all of Toronto highways.

7. Industrial sources within the City are relatively minor sources of emissions but can still be significant locally.

8. Residential and commercial sources that utilize natural gas for home heating equipment also contribute significantly to local air pollution The estimated use of residential wood fired or oil-fired heating units also contribute to local $PM_{2.5}$ ambient air pollution.

9. Small commercial sources may be important sources of some Priority Air Contaminants such as dichloromethane and chloroform and cadmium.

10. The lack of chemistry in the modeling system is likely the cause of over-estimating NO_2 concentrations and under-estimating $PM_{2.5}$ levels, especial during SMOG events.

11. The annual ozone concentrations as predicted from chemical modelling, are considered to produce very good results when compared with monitored data. However, comparisons made between modelled and monitored shorter term concentrations (i.e., monthly) varied significantly.

8.3 Potential Modelling Improvements

The value opportunity of the modeling system provided to TEO could be improved in future as follows:.

1. The airshed modeling results should be incorporated into a cumulative health study which assesses the potential health impacts associated with predicted concentrations of the 30 Priority Air Contaminants by Toronto Public Health and the Toronto Environment Office.

2. The modelling was not adequate to simulate the atmospheric transformation of NOx and SO_2 to aerosols, so a simulation of the same data should be investigated with a fully capable atmospheric chemistry model.

3. The emissions inventory of the US was based on 2002 which can be upgraded to 2006 when the US database has finally been fully QA/QC'd.

4. The City of Toronto emission inventory could be revised when the newly emerging "ChemTrac" data is available. The ChemTRAC program will collect data about emissions of 25 substances from small businesses in Toronto. This will significantly improve on the limited dataset that was used to characterize commercial sources in the present study. All 25 ChemTRAC substances are on the PAC list. The local air quality model for SRLB has been specifically constructed so as to facilitate the incorporation of ChemTrac

data and to readily permit updating the resultant mapping of the 30 Priority Air Contaminants for the SRLB areas when it becomes available.

5. Transportation has a significant influence on the local air quality in SRLB and is very likely to have a similar significance for the rest of Toronto which could, and should, be investigated further. Future policies and strategies might beneficially consider the influence of citywide and regional transportation improvements on the City's air quality.

6. Commercial and residential sources also appear to have a significant influence on local air quality in SRLB. In future, our understanding of the extent of this influence would be improved by separating the commercial and residential categories, and upgrading the commercial emissions with a more complete dataset based on ChemTRAC data.

7. The community airshed modelling program could be repeated for other high priority air quality challenged neighbourhoods in Toronto such as:

   - Etobicoke – Lakeshore.
   - Etobicoke North.
   - Downtown Toronto.
   - North Scarborough. and
   - South Scarborough.

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