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Billy Bishop Toronto City Airport (BBTCA)

Toronto, Ontario

Final Report

Air Quality Review

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SUBMITTED TO:

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EXECUTIVE SUMMARY

RWDI Air Inc. (RWDI) was retained by Bombardier to conduct an air quality study of the Billy Bishop Toronto City Airport (BBTCA). The purpose of the study is to assess the impact of the introduction of the CS100 aircraft on air quality in the region of BBTCA.

Summary of Key Findings

- A significant number of studies have been completed on air quality at airports. The studies generally show that the air quality at airports is typical of air quality at other urban environments and average contaminant concentrations at airports were generally found to be comparable or lower than the average pollutant concentrations at other urban sites.
- Estimated maximum levels of air pollutants in the Queens Quay/Bathurst Street area near BBTCA, with current operations at the airport, are similar in magnitude to those measured elsewhere in the downtown area (Bay Street at Wellesley Street).
- Emissions from road and rail traffic in the area are larger than those associated with aircraft operations at the BBTCA. This remains true with the introduction of CS100.
- The proposed aircraft, CS100, features the latest airframe and engine technology. The aircraft's significantly reduced emission levels are far below both the current and future proposed international emissions requirements.
- The annual emissions from BBTCA are expected to decrease with the introduction of the CS100 into the fleet, for most contaminants. Most notably, there is a reduction in particulate matter (soot) and total hydrocarbons (THCs), which play a role in the formation of smog and are also associated with adverse health effects. Emissions of nitrogen oxides (NO_x) are expected to increase; however, there will be very little impact on local air quality, given that the dominant local emissions source is the roads. The air quality levels in the vicinity of BBTCA are expected to remain similar to those elsewhere in the downtown area.
- From a regional perspective, the emissions from BBTCA account for an estimated 0.25% or less of total contaminant emissions from the City of Toronto both under future conditions and with the introduction of the CS100.
- The reduced average travel distance for ground transportation to BBTCA, compared to Pearson Airport, results in decreased contaminant emissions in the City of Toronto.
- The component of the aircraft emissions that have the potential to impact local air quality (i.e., emissions during takeoff, climb out, approach and idle) occur within about 1000 m of the surface. The flight paths within 1000 m of the surface are exclusively over water at BBTCA, thereby limiting the exposure to sensitive receptors.
- The Port Authority, Porter Airlines and Bombardier are taking steps to reduce emissions from BBTCA. Highlights of their emission reduction strategies include:
    - 100% of the electricity consumed at BBTCA is from renewable sources (i.e., Bullfrog Power).
    - Electric vehicles and ground support equipment are included in their fleet.
    - Successfully conducted the first biofuel-powered revenue flight in Canada as part of a test program. Porter flew one of the Q400 turboprops from BBTCA to Ottawa using a 50/50 blend of biofuel and Jet A1 fuel in one of its engines. The biofuel used was derived from oil seed crops.

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INTRODUCTION

RWDI AIR Inc. (RWDI) was retained by Bombardier to conduct an air quality study of the Billy Bishop Toronto City Airport (BBTCA). The purpose of the study is to assess the impact of the introduction of the CS100 aircraft on air quality through the answering the following key questions:

1. What are the key sources of air pollution or contaminant emissions in the vicinity of the airport?
2. What are the contaminants produced by aircraft today?
3. How is air quality assessed?
4. What studies have been conducted on airports and aircraft emissions? What is the impact of airports on cities?
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10. How will the air quality change with the introduction of CS100 at BBTCA?
11. What are the effects of change in vehicular traffic due to displacement of passenger traffic from Pearson to BBTCA on air emissions?
12. What are the flight paths at BBTCA and Toronto Pearson International Airport relative to residential areas?
13. How can the impacts of BBTCA on public health be reduced?
14. What is BBTCA's mandate to reduce pollution and be green?
15. What is Porter's experience with Bio-fuels with plan for the future/ environmental stewardship?

1. KEY SOURCES OF AIR POLLUTION

There are a number of key sources that affect air quality in the vicinity of BBTCA. These include:

- Transboundary air pollution. This is pollution that is emitted in upwind areas of Southern Ontario and in the United States and is transported into Toronto under certain weather conditions.
- Vehicle traffic on the Gardiner Expressway and Lakeshore Boulevard.
- Fuel combustion for space and water heating in individual residential buildings or in district plants to service the high population density, which is continuing to increase.
- Marine traffic.
- Ongoing construction activities in the surrounding area.
- Activities at BBTCA, including:
  - Aircraft operations (takeoff, climbout, approach and idle)
  - Ground support equipment (e.g., aircraft tugs, baggage tugs, cabin service vehicles etc.)
  - Storage tanks
  - Combustion equipment for heating of the terminal building
  - Emergency generators

2. CONTAMINANTS PRODUCED BY AIRCRAFT

Like most other forms of transportation, aircraft produce a variety of air contaminants as a result of fuel combustion (Table 1). The contaminants include those commonly referred to as criteria air contaminants, specifically:

- Nitrogen oxides (NO_X), which includes nitrogen dioxide (NO_2)
- sulphur dioxide (SO_2)
- carbon monoxide (CO)
- particulate matter (PM) including inhalable particulate (PM_{10}) and particulate ($PM_{2.5}$)
- Hydrocarbons (HCs), specifically volatile organic compounds (VOCs)

Although VOCs can include a wide range of compounds, specific compounds of interest relative to aircraft include (Illinois Environmental Protection Agency, 2002; McCulley et al, 1995; ENVIRON International Corporation, 2008):

- benzene
- acrolein
- acetaldehyde
- formaldehyde

Other air contaminants that have been identified through the literature review include (UCLA Medical Center, 2010; South Coast Air Quality Management District, 2010; ENVIRON, 2008):

- polycyclic aromatic hydrocarbons (PAHs; key representative is benzo(a)pyrene)
- lead
- ultra-fine particulate matter (UFP)
- greenhouse gases (i.e., carbon dioxide (CO_2))

Table 1: Relevant Air Contaminants

Contaminant	Aircraft Operations	Road Traffic	Rail Traffic	Marine Traffic
NO_X	√	√	√	√
SO_2	√	√	√	√
CO	√	√	√	√
PM, PM_{10}, $PM_{2.5}$	√	√	√	√
HC/VOC	√	√	√	√
PAH	√	√	√	√
UFP	√	√	√	√
CO_2	√	√	√	√

3. ASSESSMENT OF AIR QUALITY

As contaminants are emitted from a source, the emissions will drift downwind and disperse as they travel. The degree to which the contaminants disperse depends on the weather-related factors, such as wind speed and amount of turbulence.

There are a number of approaches to determine the downwind concentrations. The most direct approach is to measure specific air contaminant levels through an ambient monitoring program. This approach is useful when multiple ambient monitoring stations are set up both upwind and downwind of key sources such as an airport so that the influence of the sources can be established. Ambient monitoring, however, cannot be used where future air quality is of interest. In these situations, a computer simulation that predicts the dispersal of air contaminants as they drift away from the sources can be used. These simulations are referred to as dispersion models.

Once air contaminant concentrations are established through ambient monitoring or dispersion modelling, the levels are compared to air quality thresholds. These thresholds are set by either the Province of Ontario or the Federal Government and the Canadian Council of Ministers of the Environment. The World Health Organization (WHO) also sets their own air quality guidelines, which tend to be a key reference source for standards and criteria adopted in various jurisdictions. The thresholds are set over a variety of time-averaging periods (e.g., 1-hour, 24-hour, annual) to reflect the nature of the potential effect.

4. SUMMARY OF AIR QUALITY STUDIES ON AIRPORTS

Air quality in the local area surrounding airports has been studied extensively. A review of a number of more recent studies was undertaken. The results are presented below and summarized as general findings and on an air contaminant by air contaminant basis:

4.1 General Findings

- Average contaminant concentrations in areas adjacent to the airport were found to be comparable or lower than the average contaminant concentrations at other urban monitoring sites (Illinois Environmental Protection Agency, Bureau of Air, May 2002; ENVIRON International Corporation, February 2008).
- No significant differences between upwind and downwind measured air contaminant concentrations (McCulley et al, 1995).

4.2 Sulphur Dioxide (SO_2)

- Small amounts of SO_2 were attributed to airport sources on a local level relative to background sources (Institute for the Environment, 2011).

4.3 Carbon Monoxide (CO)

- In one study, long-term average CO concentrations at airports were reported to be similar to and often lower than those measured at other urban locations (South Coast Air Quality Management District, 2010)
- Other studies noted elevated CO levels close to the airports (Doncaster Health Authority, 2000; Institute for the Environment, 2011). In at least one study, however, the CO levels were attributed to nearby roadways and freeways and not the airport itself (South Coast Air Quality Management District, 2010).

- In one case the airport contribution to CO levels was quantified to be a maximum of 5% (Institute for the Environment, 2011).

4.4 Nitrogen Dioxide (NO_2)

- While airport activities have a measureable effect on NO_2 concentrations, long term NO_2 levels are comparable to other urban locations (Doncaster Health Authority, 2000; AEA Technology plc, 2012).
- For the Hong Kong airport, the airport activities have been estimated to account for less than 20% of total NO_2 levels at a location near the airport during periods of time when the contribution from other surrounding sources is low (Institute for the Environment, 2011).
- In the case of the Finningley Airport (U.K.), the study concluded that annual predicted levels of NO_2 were unlikely to cause adverse effects on public health (Doncaster Health Authority, 2000).

4.5 Particulate Matter (PM_{10}, $PM_{2.5}$ and UFP)

- The study of the Finningley Airport found that PM_{10} levels do not exceed their annual thresholds. The maximum 24-hour PM_{10} level may exceed its threshold, however the contribution of the airport sources is small (Doncaster Health Authority, 2000).
- In another study, long-term average concentrations of $PM_{2.5}$ were generally similar to and often lower than those measured at other locations in the city or district. Measured $PM_{2.5}$ levels could not be attributed to aircraft operations (South Coast Air Quality Management District, 2010).
- At Hong Kong, the impact of $PM_{2.5}$ from airport sources was considered negligible (Institute for the Environment, 2011). In another study, measured $PM_{2.5}$ levels were attributable to vehicle traffic (South Coast Air Quality Management District, 2010).
- Elevated black carbon levels were measured in the vicinity of the Teterboro Airport (New Jersey), but the levels were mostly attributable to local roadways (ENVIRON International Corporation, 2008).
- Aircraft idling generates large UFP concentrations over short time periods (South Coast Air Quality Management District, 2010). There are no established air quality thresholds for UFP in the Province of Ontario or in Canada. Another study of UFP near roadways indicates that the impacts are localized. This study involved conducting upwind and downwind monitoring near a road with 14,000 vehicles per hour. The results indicated that UFP levels beyond 300 m from the roadway were indistinguishable from upwind concentrations (Zhu et al, 2002). In the case of BBTCA, the buffer zone between the runways and any sensitive receptors is greater than 300m.

4.6 Volatile Organic Compounds (VOCs) and PolyAromatic Hydrocarbons (PAHs)

- A number of studies found long-term average concentrations of VOCs adjacent to airports were generally similar to and often lower than those measured at urban locations (South Coast Air Quality Management District, 2010; McCulley et al, 1995).
- These studies attributed the VOC levels to automobile exhaust (South Coast Air Quality Management District, 2010; McCulley et al, 1995).
- In one case, the airport contribution to VOC levels was quantified to be a maximum of 5% (Institute for the Environment, 2011).
- Acrolein levels at Chicago O'Hare were below the detection limit (Illinois Environmental Protection Agency, 2002).

- Measured downwind concentrations of acetaldehyde, formaldehyde, benzene and polycyclic hydrocarbons were higher than upwind concentrations at Chicago O'Hare. However, the concentrations measured downwind were considered to be "typical" of an urban area and in some cases lower than values measured in other cities (Illinois Environmental Protection Agency, 2002).
- No significant differences in upwind and downwind concentrations of formaldehyde, acetaldehyde and acrolein concentrations at Seattle-Tacoma. The concentrations were within the range of values for other urban areas (McCulley et al, 1995).
- For the Teterboro Airport, benzene and acetaldehyde concentrations were similar to other locations in New Jersey. Formaldehyde and toluene levels were higher than other locations in New Jersey; however the measurements were taken at the end of the runways, not in a surrounding neighbourhood (ENVIRON International Corporation, 2008).
- One study concluded that hazardous air contaminant concentrations in urban areas were 40% higher than the levels near airports, with the exception of formaldehyde, where the concentrations were 60% higher near the airport (Vennam et al, 2012). In the case of BBTCA, the overall hydrocarbon levels will decrease with the introduction of the CS100s (see Section 10).

4.7 Lead

- Lead emissions from airport are related to the use of piston driven aircraft and the leaded fuel they use (South Coast Air Quality Management District, 2010). The CS100s are jet aircraft, not piston driven. Therefore, there will be no lead emissions associated with their use.

5. AIR QUALITY IN THE STUDY AREA TODAY

Air quality in the broader area of downtown Toronto can be characterized with archived air quality monitoring data from the Ontario Ministry of Environment (Ontario Ministry of the Environment, 2000-2009). The closest monitoring station is at Bay and Wellesley.

Some contaminant data (i.e. volatile organic compounds) were not available from the Bay and Wellesly station and, instead, were obtained from the monitoring stations at Ruskin and Perth in West Toronto and at 223 College in Downtown Toronto, which are operated by Environment Canada as part of the National Air Pollution Surveillance (NAPS) program (Environment Canada, 1999-2006).

Table 2 shows the contaminants and the corresponding monitoring station where the measurement results were taken from.

Table 2: Ambient Station Information

Contaminant	Station Number	Station Name	Station Location	Years with Data Available
CO	MOE 31103	Toronto Downtown	Bay & Wellesley St.	2007-2011
NO_2	MOE 31103	Toronto Downtown	Bay & Wellesley St.	2007-2011
$PM_{2.5}$	MOE 31103	Toronto Downtown	Bay & Wellesley St.	2007-2011
PM_{10}	MOE 31103	Toronto Downtown	Bay & Wellesley St.	2007-2011
Acrolein	NAPS 60418	Toronto	Ruskin & Perth St.	1999-2003
Benzene	NAPS 60427	Toronto	223 College St.	2006-2010
Benzo(a)pyrene	NAPS 60427	Toronto	223 College St.	2006-2010

Contaminant	Station Number	Station Name	Station Location	Years with Data Available
1,3-Butadiene	NAPS 60427	Toronto	223 College St.	2002-2006
Formaldehyde	NAPS 60418	Toronto	Ruskin & Perth St.	1999-2003
Acetaldehyde	NAPS 60418	Toronto	Ruskin & Perth St.	1999-2003

Table 2 provides a summary of the data. The table shows that current air pollutant levels in the Downtown Toronto area are generally well within the desired thresholds. The exceptions are benzene and benzo(a)pyrene. However, the levels of these contaminants have been declining over the past decade and should continue to decline in the coming years, due to the ongoing effect of federal regulations and corresponding new technologies dealing with motor vehicle emissions. In the case of benzo(a)pyrene, the threshold established by the Ontario Ministry of the Environment is extremely ambitious, and this threshold is currently exceeded throughout all of Southern Ontario, in both urbanized and rural environments.

Table 3: Summary of Ambient Air Measurements (µg/m^3)

Contaminant	Averaging Period	90th Percentile	Maximum	Annual Mean	Desired Threshold
CO	1 hour	381	2,049	313	36200
NO_2	1 hour	59	148	36	400
$PM_{2.5}$	24 hour	14	41	7.3	30
PM_{10}	24 hour	27	76	14	50
Benzene	24 hour	1.49	2.79	0.98	2.3
	Annual	0.98	0.98	0.98	0.45
1,3-Butadiene	24 hour	0.24	0.4	0.2	10
	Annual	n/a	0.2	0.2	2
Formaldehyde	24 hour	4.63	11.10	2.79	65
Benzo(a)Pyrene	24 hour	0.00025	0.001	0.00013	0.00005
	Annual	0.00013	0.00013	0.00013	0.00001
Acetaldehyde	24 hour	2.70	5.10	1.78	500
Acrolein	24 hour	0.22	0.9	0.1	0.4

Notes:

[1] The threshold values are the ambient air quality criteria published by Ontario's Ministry of the Environment for all contaminants with the exception of $PM_{2.5}$, which is a Canada Wide Standard.

[2] MOE annual reports do not provide the 90th percentile 24-hour concentrations for $PM_{2.5}$. For simplicity, the 24-hour value was assumed to be equal to the 1-hour value.

[3] PM_{10} data were calculated from $PM_{2.5}$ data by using a published factor (Lall, et al., 2004)

6. BASELINE AIR QUALITY IMPACTS

Air quality levels in closer proximity to BBTCA were previously assessed in a study conducted by RWDI in 2010. The assessment was based on future operations at BBTCA for the year 2016, prior to the introduction of the CS100s. No projections were made for any time horizons further into the future than 2016. In this previous study, an emissions inventory, which is a detailed accounting of the air contaminants discharged into the atmosphere and their corresponding emission rates, was developed.

The following activities were included for the year 2016:

- aircraft traffic (i.e., takeoff, climb out, approach and idle)
- ground support equipment
- vehicle traffic at the airport
- roadway traffic, specifically:
  - Gardiner Expressway
  - Lakeshore Blvd.
  - Bathurst Street (north of Lakeshore Blvd.)
  - Streets south of Lakeshore (Queens Quay, Stadium Road, Bathurst Street, Spadina Avenue, and the fixed link).
- Ferry traffic

The air contaminants included were CO, NO_x, PM_{10} and $PM_{2.5}$. The results of the emissions inventory were applied to dispersion modelling techniques to predict the maximum air contaminant concentrations at the closest sensitive receptor locations (residences, schools etc.), as shown in Figure 1. Historical monitoring data were applied in order to characterize the contributions from other emission sources in the surrounding area (*i.e.,* background air quality) not explicitly included in the modelling.

The maximum predicted contributions of CO, NO_2, PM_{10} and $PM_{2.5}$ at select representative receptor locations, under worst-case weather conditions, are summarized in Table 4**,** along with applicable ambient air quality thresholds and a reasonable estimate of maximum contribution from background emission sources (based on the 90th percentile of historical monitoring data).

Table 4: Summary of Maximum Predicted Concentrations (without Background) in relation to Air Ambient Quality Criterion

	1-Hour CO (µg/m^3)	1-Hour NO_2 (µg/m^3)	24-Hour PM_{10} (µg/m^3) [1]	24-Hour $PM_{2.5}$ (µg/m^3) [1]
Maximum Concentration	1370	126	26	3.5
R1	1160	117	21	2.7
R5	819	116	17	2.5
R14	1180	124	24	.2
R18	718	112	6.0	2.8
R20	1370	109	24	3.3
Representative Maximum Background Concentration	381	59	27	14
Desired Threshold	36,200	400	50	30

Notes:
[1] PM emissions from aircraft were not included in the modelling assessment, as emissions factors were not available within the EDMS model applied in the 2010 study.

The maximum concentrations shown in the table, which represent baseline conditions (Q400 operations at the airport, with no CS100s), are similar in magnitude to those measured elsewhere in the downtown area (shown previously in Table 3) and are considered to be typical of the levels one would expect in an urban area in Toronto near a major highway. The predicted maximum concentrations of the contaminants shown in Table 4, in combination with background levels, are generally below their respective threshold values. As discussed later, in Section 9, the surface roadways in the area are the dominant local emission source for all of the contaminants shown in Table 4, with aircraft operations at BBTCA playing a lesser role.

7. RECENT ADVANCES IN AIRCRAFT EMISSIONS

Contaminant emissions from aircraft have been reduced over the last several decades through:

- Improvements in airframe resulting in improved aerodynamics and a corresponding reduction in fuel usage. Innovations in manufacturing including carbon fibre construction and fewer mechanical fasteners have resulted in reduced drag (ICAO, 2010; FAA, 2005).
- Reduction in aircraft weight through the use of advanced alloys/composite materials. Current aircraft entering the fleets, including the CS100, employ advanced materials including composite wings and parts of the fuselage resulting in weight savings. The reduction in aircraft weight allows for an increase in commercial payload (i.e., number of passenger seats or the amount of cargo) for the same amount of thrust and fuel usage (ICAO, 2010; FAA, 2005).
- Improved combustion technologies and fuel efficiency. The international Civil Aviation Organization (ICAO), a United Nations body, sets emission standards for aircraft. Standards currently exist for NO_x, HC, CO and smoke emissions. These standards have been in place since the early 1980s with the advent of the Committee on Aviation Environmental Protection (CAEP). The most recently adopted standard is CAEP/6 (2004). ICAO is currently working on developing standards for non-volatile particulate matter (PM) emissions and CO2 (ICAO, 2010).

ICAO has taken a balanced approach to jet engine development and has advocated less fuel consumption and hence less CO_2, coupled with less NO_x. Because of its role in global warming, CO_2 has become the greatest concern among regulators and this is where, given the high efficiency of the engine, the GTF (the engine used on the CS100) excels.

In 2004 CAEP/6 recommended, and ICAO's 35th Assembly subsequently adopted, three environmental goals: to limit or reduce noise exposure, local air quality emissions, and greenhouse gas emissions, setting a series of specific targets. CAEP/6 represents an approximate 12% reduction in NO_x emissions from previous standards, which were adopted by ICAO in 2001. None of the large commercial jet aircraft commonly flown in Canada today such as the A319, and 737-600/700/800 meet CAEP/6, however the Bombardier CS100 proposed by Porter will be the first commercial jet aircraft of its kind operating in the Toronto area to outperform the CAEP/6 targets with a 50% margin to the NO_x emission requirement and will outperform even more stringent CAEP/8 standards which go into effect at end of 2013.

CS100 margins to CAEP/6 are as follows:

- NO_x 50%
- Smoke 50%
- UHC (Unburned Hydrocarbons) 75%
- CO 50%

By comparison, the Boeing 737-700 emissions are higher than the CAEP/6 overall limits by 2%-12% depending on the engine variant, while the Airbus A319 emissions are higher than the CAEP/6 overall limits by 1.1%.

The GTF powering the CS100 will also be at least 35% below forthcoming CAEP 8 standards for NO_x.

The transition from piston engines to modern high-bypass turbofans has resulted in major advancements in energy efficiency and environmental performance (Federation Aviation Administration Office of Environment and Energy, January 2005). The geared turbofan (GTF) employed in the CS100 is an example of this technology. In the GTF a gear system separates the engine fan from the low pressure compressor and turbine, allowing each of the components to operate at their optimum speeds. This enables the fan to rotate slower while the low pressure compressor and turbine operate at a high speed, increasing engine efficiency and delivering significantly lower fuel consumption, noise and emissions (Pratt and Whitney, 2013). The CS100 employs this engine technology.

8. COMPARISON OF EMISSIONS FROM CS100 AND Q400

An LTO cycle, which is the basis for calculating emissions from aircraft, includes the following modes of operation:

- taxi out;
- take off (i.e., from the start of the ground roll until the aircraft reaches 305 metres above the surface);
- climb out (i.e., from 305 metres to the mixing height considered to be 914 metres for the purpose of air quality assessments);
- approach (i.e., from the mixing height to the surface);
- taxi in.

Emissions during these modes of operations have the potential to impact air quality at the surface. Contaminants emitted below the mixing height become well mixed in the turbulent layer and do not readily penetrate the layer above this height. Additionally contaminants released above the mixing height do not readily penetrate the mixed layer to return to ground levels due to minimal turbulence in this region.

Emissions for each contaminant on a gram per LTO and on a gram per seat basis for the Q400 and CS100 are shown in Table 5.

Table 5: Comparison of Q400 and CS100 Total Aircraft Emissions on a Per LTO and Per Seat Basis

Contaminant	Emissions (g/LTO)		Emissions (g/seat)	
	Q400	CS100	Q400	CS100
CO	1729	1894	25	17.7
HC	732	11	10	0.10
NO_x	2336	5917	32	55.3
PM	3.249	0.99	0.046	0.01

There are significant reductions in HC and PM emissions for the CS100 compared to the Q400s both on a g/LTO and on a per seat basis. CO emissions also decrease on a g/seat basis. NO_x emissions are approximately 2 times greater for the CS100 than for the Q400 on a g/seat basis.

9. COMPARISON OF AIRCRAFT EMISSIONS TO OTHER MODES OF TRANSPORTATION

Table 6 is an inventory of typical weekday emissions from a selection of major transportation sources in the local area near the BBTCA. The road and rail emissions in the table are based on a length of approximately 2km of road/rail corridor in the vicinity of the BBTCA (approximately from Exhibition Place to Union Station). The aircraft emissions shown in the table are those associated with landings, take-offs and taxiing (LTO).

The table shows that emissions from road and rail traffic in the area are significantly larger than those associated with LTO's at the airport. This remains true with the introduction of CS100 aircraft.

For areas in the Queens Quay / Bathurst Street area, impacts of the airport emissions would only be felt under winds from southerly directions, and impacts of the road and rail emissions would be felt under winds from northerly directions. The southerly directions are significantly less frequent than those from northerly directions, which further mitigates the potential impact of the airport emissions.

Table 6: Comparison of Q400 and CS100 Emissions with Other Transportation Sources near BBTCA

Mode of Transportation	Daily Emissions kg/day			
	THC	CO	NO_x	PM
Q400 LTOS	74	175	226	0.3
25% CS100/75% Q400 LTOs	**56**	**179**	**319**	**0.3**
GO Trains – 5.5 km Section	10.1	51	185	6.7
UPE Train- 5.5 km Section	2.7	29	25	1.9
Lakeshore Blvd. – 5.5 km Section	35	700	166	9.6
Gardiner Expressway – 5.5 km Section	126	2521	598	35
Total: Road and Rail	**174**	**3300**	**975**	**53**

Notes:

1. GO Train engine boiler horsepower is 5000 operating with 1 engine and a load factor of 0.6 and a speed of 48 km/h.
2. UPE engine boiler horsepower is 1000 per engine, operating with 2 engines and a load factor of 0.6 and a speed of 48 km/h.
3. Current GO Train fleet is compliant with Tier 2 locomotive emission standards. UPE will be Tier 4 compliant.
4. GO Transit & UPE the relevant section of the corridor is from Union Station to the Exhibition. Current volume is 98 GO trips/day and 140 UPE trips/day (GO Electrification Study, 2010).
5. Approx. Average Daily Traffic Volumes: Gardiner Expressway – 164,000; Lakeshore Blvd. – 45,000.
6. Road traffic emissions based on estimated average on-road fleet emissions for 2015, winter driving (MOBILE6.2C emission model).
7. Q400/CS100 emissions are based on the permitted maximum total number of movements per day (101 take-offs and 101 landings).
8. Emissions for road and rail were computed over a 5.5 km long section of corridor, corresponding to the typical horizontal travel distance of a Q400 or CS100 during climb-out to a height of 1000m.

10. HOW WILL THE IMPACTS CHANGE WITH INTRODUCTION OF CS100S

The annual emissions inventory for all aircraft at BBTCA and supporting GSE is provided in Table 7 for Scenarios 1 and 2.

Table 7: Comparison of Future Operating Scenarios at BBTCA

Contaminant	Annual Emissions (Metric Tonnes)		Change Relative to F1
	Future F1 Scenario	Future F2 Scenario	
CO	421	423	0%
HC	33	27	-18%
NO_x	106	136	28%
PM	0.5	0.48	-4%

Notes:

[1] Scenario 1: Emissions are based on 100% Q400 LTOs (total annual LTO of 65175)

[2] Scenario 2: Emissions based on a future scenario of 75% Q400 LTOs (48881 LTO) and 25% CS100 LTOs (16294 LTO)

As shown in the table, the annual emissions at BBTCA are predicted to decrease with the introduction of the CS100 into the fleet for all contaminants with the exception of NO_x, which is predicted to increase by 28%. This increase is expected to have very little impact on local air quality, given that the dominant local emissions source is the roads. At worst, if the NO_2 levels in the surrounding area were solely attributed to the airport, (which is not the case), the NO_2 concentrations could increase by 33%. The maximum values would remain well below their threshold levels. The reduction in HCs concentrations will have a positive impact on local air quality. A number of HCs have associated health effects and from a regional perspective, play a role in the formation of photochemical smog.

To provide an indication of the impact of the emissions from a broader regional perspective, annual emissions at BBTCA under the two future scenarios are compared to emissions in the City of Toronto in the Table 8.

Table 8: Future Emissions from BBTCA Relative to Total Emissions from the City of Toronto

Contaminant	City of Toronto All Sources (kilotonnes) [1]	Future Emissions as a Percent of Total Emissions from the City of Toronto	
		Future F1 Scenario	Future F2 Scenario
CO	408	0.1%	0.1%
HC	23	0.14%	0.12%
NO_x	54	0.2%	0.25%
PM	3	0.02%	0.02%

[1] City of Toronto Emissions based on the year 2004, from ICF, 2007.

From a regional perspective, BBTCA is a relatively small source in comparison to the total emissions from the City of Toronto. With the introduction of the CS100 in the F2 scenario, the largest contribution would be to total NO_x emissions, which only represent 0.25% of the total City emissions. Therefore, no air quality impacts are expected from a regional perspective as a result of the introduction of the CS100.

11. EMISSION IMPACTS OF THE CHANGE IN VEHICULAR TRAFFIC DUE TO DISPLACEMENT OF PASSENGER TRAFFIC FROM PEARSON TO BBTCA

A recent study conducted by Dillon Consulting quantified the effect BBTCA has had on local and regional vehicular traffic. The study found that BBTCA has had a net impact of approximately 18 million fewer kilometers driven within the GTA and approximately 39.7 million fewer kilometers driven on roadways outside of the GTA on an annual basis.

The study found the average travel distance to and from BBTCA was shorter than the distance needed to travel from TPIA. In addition to this, the modal split of access to BBTCA had more attractive public and private mass transportation options from the TTC, GO Transit, and the Porter Airlines shuttle operation.

The corresponding impact on emissions has been calculated and is provided in Table 9. Assuming that BBTCA travelers were diverted to TPIA, GTA would experience up to a 126% increase in ground transportation related emissions..

Table 9: Impacts of Ground Transportation Scenarios to BBTCA and TPIA on Air Emissions

		Emissions (tonnes) [Change in emissions relative to existing conditions (%)]			
Scenario	**Annual Travel Distance (vehicle-km)**	**CO**	**NO_X**	**PM_{10}**	**$PM_{2.5}$**
Existing Conditions (passengers flying out of BBTCA)	15,300,000	44	5.9	0.3	0.14
With additional shuttle service to BBTCA	14,400,000	42 [-6%]	5.6 [-6%]	0.29 [-6%]	0.13 [-6%]
All BBTCA traffic travels instead through TPIA	34,600,000	100 [126%]	13 [126%]	0.69 [126%]	0.32 126%]
85% of BBTCA traffic travels instead through TPIA; remainder makes alternative travel arrangements or does not travel	33,200,000 (GTA)	96 [117%]	13 [117%]	0.66 [117%]	0.31 [117%]
	39,700,000 (outside GTA)	115 [159%]	15 [159%]	0.79 [159%]	0.37 [159%]
All BBTCA traffic travels instead through TPIA; increase in transit use due to Union Pearson Express	29,700,000	86 [94%]	11 [94%]	0.59 [94%]	0.28 [94%]

12. FLIGHT PATHS AT BBTCA AND TPIA

The flight paths for BBTCA and Toronto Pearson International Airport (TPIA) are shown in Figures 2 and 3, respectively.

Aircraft emissions that have the potential to impact local air quality occur during takeoff, climb out, approach and idle. Only the component of these emissions that occurs within the well mixed turbulent layer of the atmosphere referred to as the mixing height is of interest. The mixing height varies with meteorological conditions, but typically does not exceed about 1000 m. Contaminants emitted below the mixing height become well mixed in this turbulent layer and do not readily penetrate the layer above this height. Contaminants emitted above the mixing height do not penetrate the mixed layer to return to ground level.

The flight paths for BBTCA for the zones where the aircraft would be within the turbulent layer (i.e., within 1000 m of the surface) are exclusively over water, thereby limiting the exposure of sensitive receptors to the emissions associated with the approach and climb-out components of the flight. Conversely, the flight paths for TPIA occur over densely populated areas that would be exposed to emissions from approach and climb-out components of the flights.

13. HOW CAN THE IMPACTS OF THE AIRPORT ON PUBLIC HEALTH BE REDUCED?

A summary of possible emission reduction initiatives is provided in the Table 10.

Table 10: Airport Emission Reduction Initiatives

Emission Source	Emission Reduction Strategy	Description
Auxiliary Power Units (APU)	Improve flight planning and scheduling	Reduce APU runtime, by decreasing holds prior to engine ignition (e.g. at gates)
Aircraft	Maximize use of pushback tractors	Minimize inefficient reverse thrusting and power backs by aircraft
	Improve flight planning and scheduling	Reduce aircraft engine idling by decreasing take-off queues
Ground Support Equipment (GSE)	Alternative fuel sources	Convert GSE to electric Switch to low sulphur diesel
	Improve combustion efficiency	Regular maintenance and tuning of combustion sources
	Improve combustion efficiency	Invest in exhaust abatement technology such as filter and catalytic converters
	Improve planning and scheduling	Minimize GES idling time
Stationary Sources	Improve combustion efficiency	Invest in low NO_x burners for stationary combustion equipment
	Improve combustion emissions	Invest in low NO_x burners for stationary combustion equipment
	Improve efficiency of on-site buildings	Implement principles of sustainable building design

14. BBTCA'S MANDATE TO REDUCE POLLUTION

BBTCA has taken steps to reduce air emissions from its activities. The initiatives include:

- 100% of the electricity consumed is from renewable sources (i.e., Bullfrog Power).
- Electric vehicles and ground support equipment are included in their fleet.

15. PORTER'S EXPERIENCE WITH BIOFUELS

In April 2012, Porter Airlines in along with its partners Bombardier, Pratt & Whitney Canada and Targeted Growth successfully conducted the first biofuel-powered revenue flight in Canada as part of a test program. Porter flew one of the Q400 turboprops from BBTCA to Ottawa using a 50/50 blend of biofuel and Jet A1 fuel in one of its engines. The biofuel used was derived from oil seed crops (Porter Airlines, 2013).

16. CONCLUSIONS

RWDI Air Inc. (RWDI) was retained by Bombardier to conduct an air quality study of the Billy Bishop Toronto City Airport (BBTCA). The purpose of the study is to assess the impact of the introduction of the CS100 aircraft on air quality in the region of BBTCA.

Summary of Key Findings

- A significant number of studies have been completed on air quality at airports. The studies generally show that the air quality at airports is typical of air quality at other urban environments and average contaminant concentrations at airports were generally found to be comparable or lower than the average pollutant concentrations at other urban sites.
- Estimated maximum levels of air pollutants in the Queens Quay/Bathurst Street area near BBTCA, with current operations at the airport, are similar in magnitude to those measured elsewhere in the downtown area (Bay Street at Wellesley Street).
- Emissions from road and rail traffic in the area are larger than those associated with aircraft operations at the BBTCA. This remains true with the introduction of CS100.
- The proposed aircraft, CS100, features the latest airframe and engine technology. The aircraft's significantly reduced emission levels are far below both the current and future proposed international emissions requirements.
- The annual emissions from BBTCA are expected to decrease with the introduction of the CS100 into the fleet, for most contaminants. Most notably, there is a reduction in particulate matter (soot) and total hydrocarbons (THCs), which play a role in the formation of smog and are also associated with adverse health effects. Emissions of nitrogen oxides (NO_x) are expected to increase; however, there will be very little impact on local air quality, given that the dominant local emissions source is the roads. The air quality levels in the vicinity of BBTCA are expected to remain similar to those elsewhere in the downtown area.
- From a regional perspective, the emissions from BBTCA account for an estimated 0.25% or less of total contaminant emissions from the City of Toronto both under future conditions and with the introduction of the CS100.
- The reduced average travel distance for ground transporation to BBTCA, compared to Pearson Airport, results in decreased contaminant emissions in the City of Toronto.

- The component of the aircraft emissions that have the potential to impact local air quality (i.e., emissions during takeoff, climb out, approach and idle) occur within about 1000 m of the surface. The flight paths within 1000 m of the surface are exclusively over water at BBTCA, thereby limiting the exposure to sensitive receptors.
- The Port Authority, Porter Airlines and Bombardier are taking steps to reduce emissions from BBTCA. Highlights of their emission reduction strategies include:
    - 100% of the electricity consumed at BBTCA is from renewable sources (i.e., Bullfrog Power).
    - Electric vehicles and ground support equipment are included in their fleet.
    - Successfully conducted the first biofuel-powered revenue flight in Canada as part of a test program. Porter flew one of the Q400 turboprops from BBTCA to Ottawa using a 50/50 blend of biofuel and Jet A1 fuel in one of its engines. The biofuel used was derived from oil seed crops.

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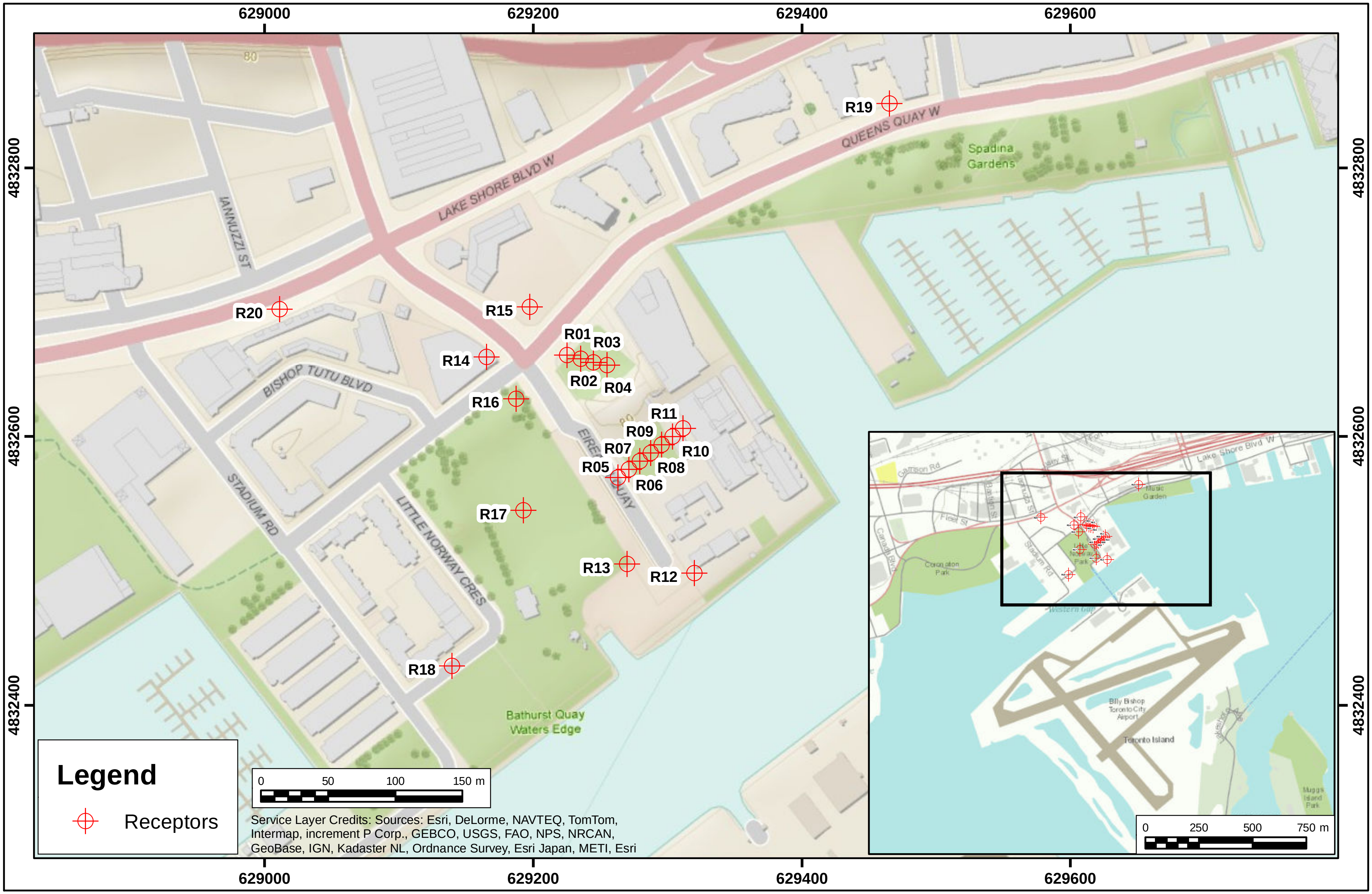
FIGURES



Receptor Locations

Map Projection: UTM NAD 83 17N.

Emissions Study for Billy Bishop Airport, Toronto, Ontario

True North

Project #1400311

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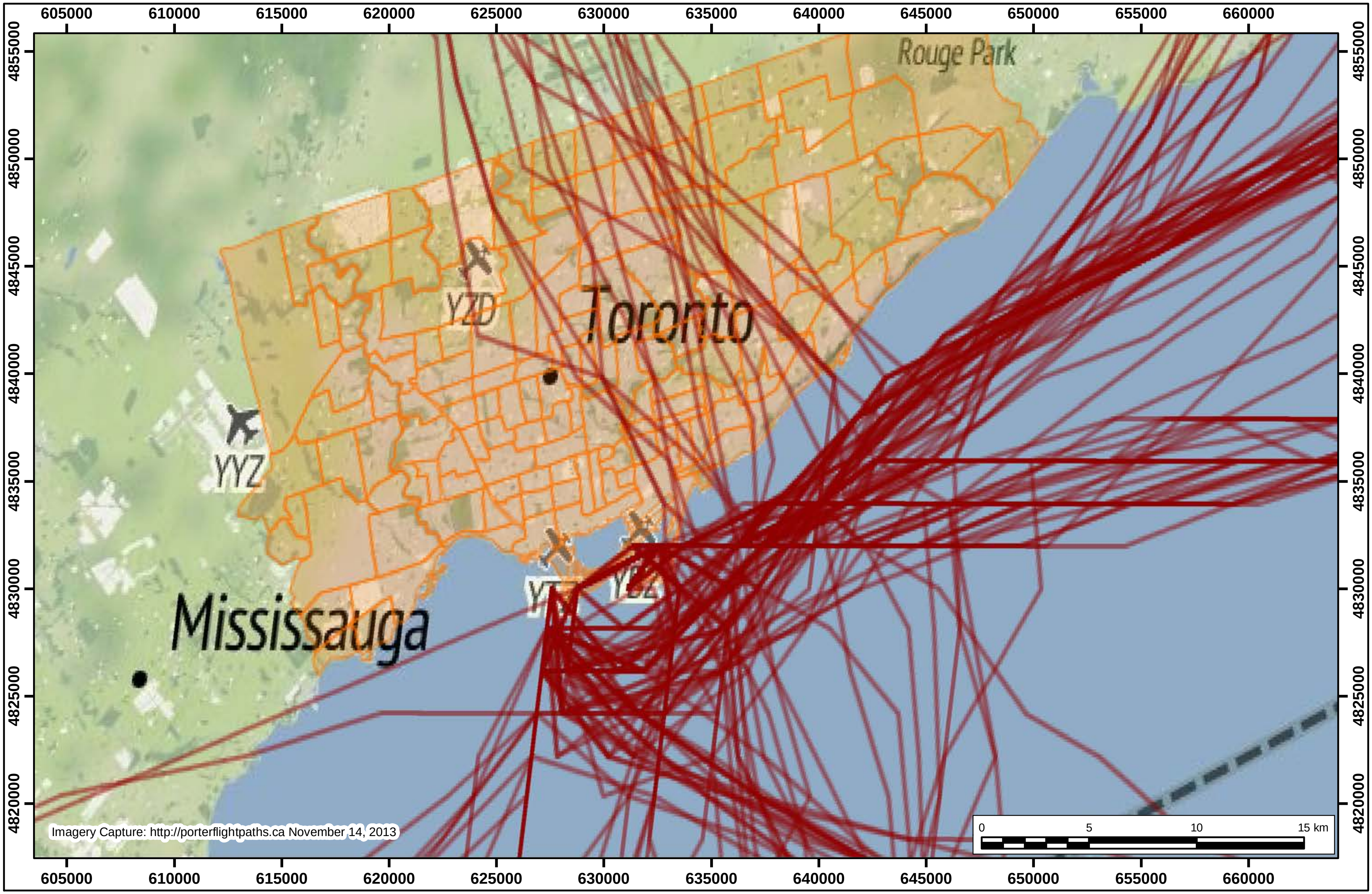
Date Revised:	Oct. 23, 2013		



Flight Paths at Billy Bishop Airport - Porter Airlines

Map Projection: UTM NAD 83 17N.

Emissions Study for Billy Bishop Airport, Toronto, Ontario

True North

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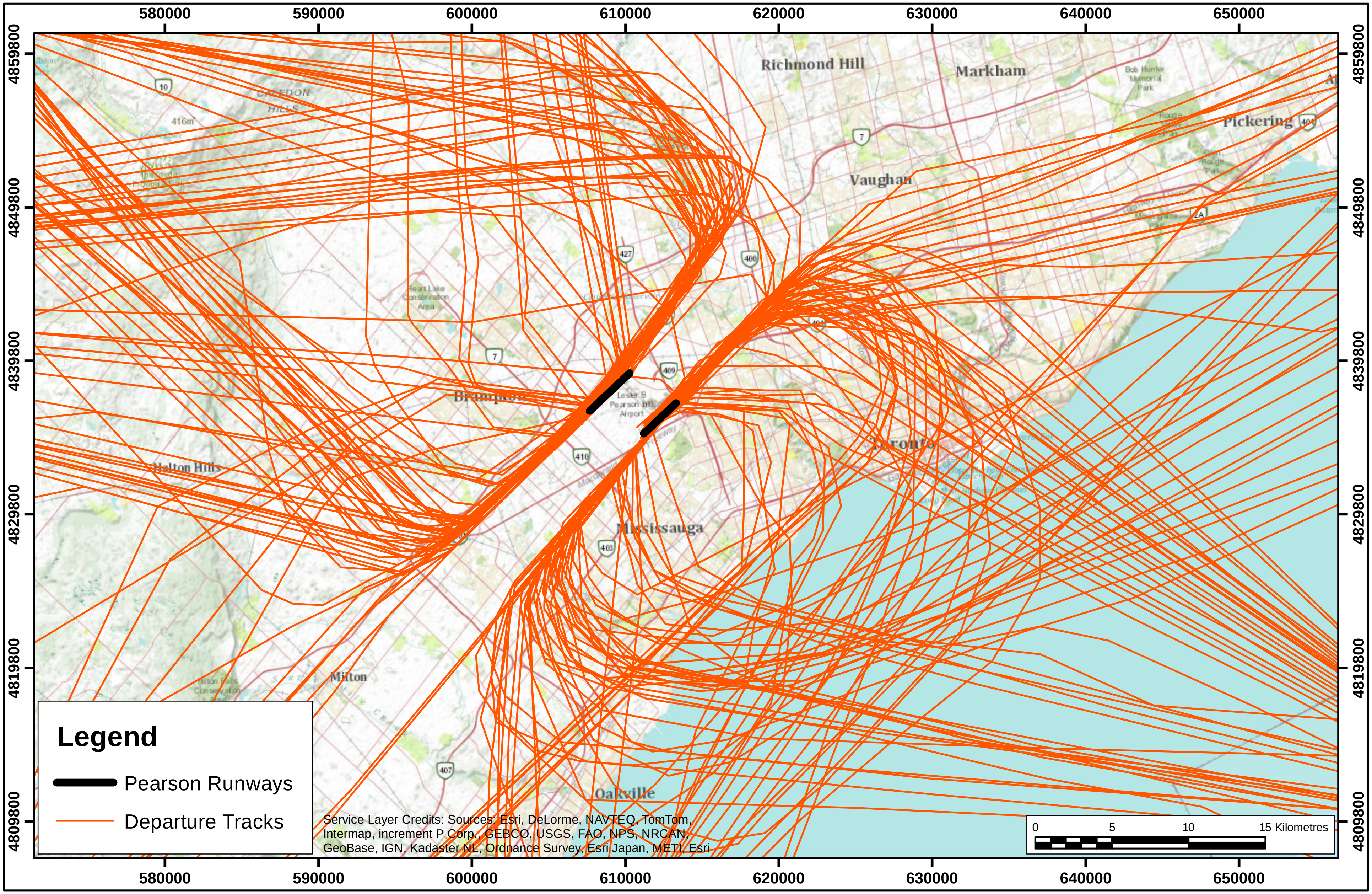
RWDI



Departure Tracks at Pearson International Airport

Map Projection: UTM NAD 83 17N.

Emissions Study for Billy Bishop Airport, Toronto, Ontario

True North

Project #1400311

Drawn by: CAM	Fig: 3
Approx. Scale:	1:350,000
Date Revised:	Nov. 5, 2013

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