BOWMANVILLE/SOPER CREEK WATERSHED EXISTING CONDITIONS REPORT CHAPTER 7 – AIR QUALITY

FINAL – December 2011

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Air pollution is an on-going concern for people living in Ontario. Airborne pollutants come from a variety of sources including fixed sources such as factories and power plants, mobile sources such as planes, trains, and automobiles, and natural sources such as fires, dust, and biogenic emissions (Ministry of the Environment, 2006). Smog, primarily ground-level ozone (O_3) and fine particulate matter (PM), is a form of air pollution that, while not always visible, often appears as a yellow-brown haze over cities and worsens during periods of warmer, sunnier weather.

2.0 STUDY AREA AND SCOPE

The Bowmanville/Soper Creek watershed is situated entirely within the Regional Municipality of Durham and covers an area of approximately 170 km^2 (Figure 1). The watershed drains southerly towards Lake Ontario from its headwaters in the South Slope Till Plain of the Oak Ridges Moraine. The Bowmanville/Soper Creek watershed consists of 2 primary subwatersheds: Bowmanville Creek and Soper Creek, whose tributaries join together prior to outletting to Lake Ontario.

Poor air quality is known to affect human health, the environment and the economy. As such, this chapter provides insight as to the state of the ambient air quality including the potential impacts on human health and the environment. Air pollutants are generated locally, regionally, nationally and internationally, can travel extensive distances from their source, and can remain in the atmosphere for long periods of time. As a result, affected areas may be far removed from the source of contaminants. Much of Ontario's smog problems are caused by a combination of local emissions and pollutants carried by the wind from sources in the United States. It is estimated that during periods of elevated smog more than half of the ozone and fine particulate matter (smog) in Ontario originates south of the border (MOE, 2009).

The impacts caused by poor air quality do not exist in isolation; they are linked through interactions between humans, the environment and economics. For instance, acid rain may reduce soil productivity and lead to increased economic stresses. Alternatively, providing pollution reduction incentives may in turn improve human and environmental health.

Considering that the delineation of 'airshed' boundaries and patterns are complex, this study is scoped to a general understanding of the major pollution issues, types of pollutants and their sources and potential impacts at a regional level. Climate change and its effects on the environment, though noted in this study, are not explicitly discussed, but are however discussed in Chapter 8 - Climate.

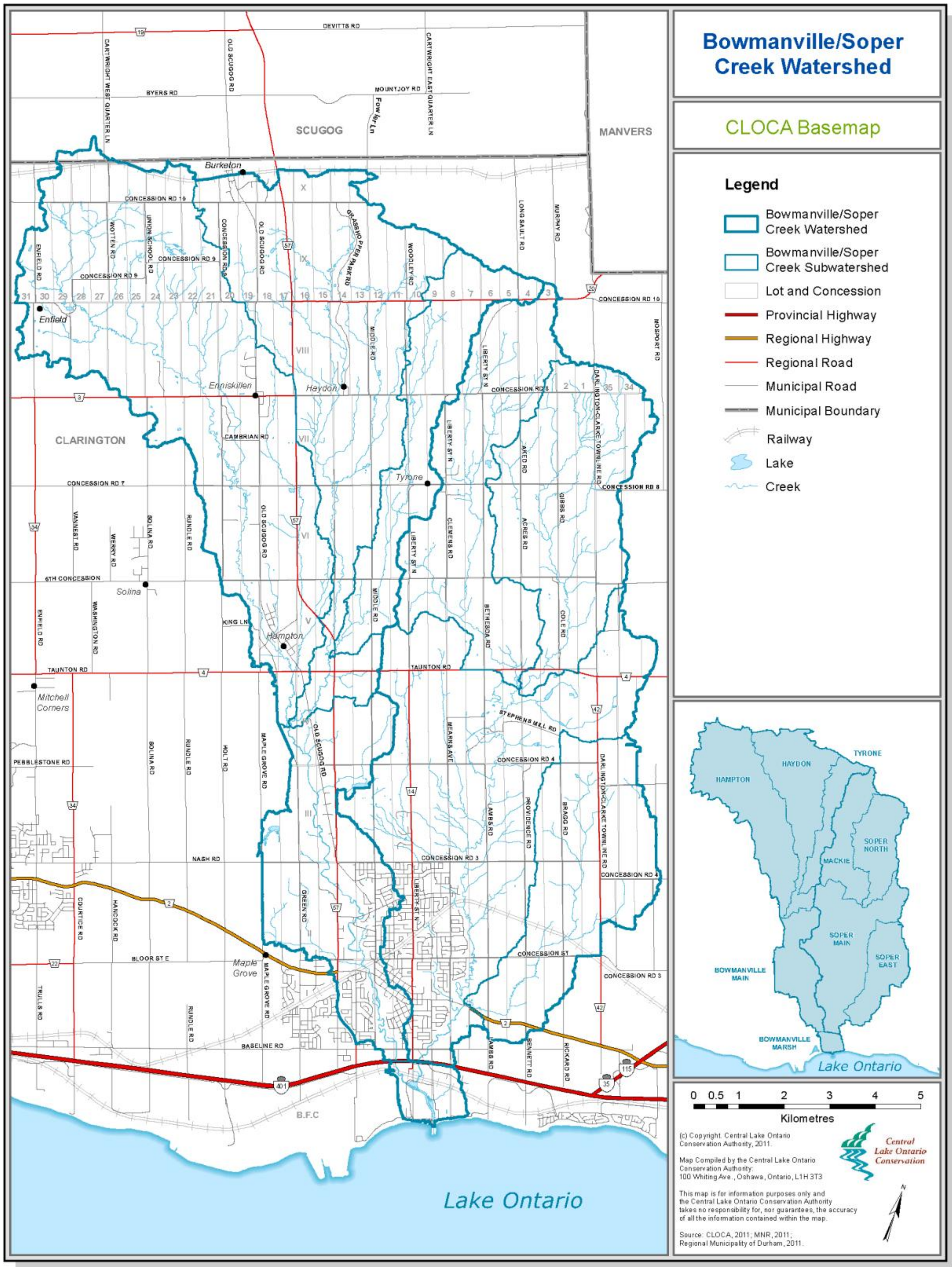

Figure 1: Bowmanville/Soper Creek watershed.

3.0 METHODOLOGY

Relevant information for this report was gathered primarily from Environment Canada (www.ec.gc.ca) and the Ontario Ministry of the Environment (www.ene.gov.on.ca) air quality monitoring programs, technical publications and reports. Air quality standards referenced in this study are either from Ontario's ambient air quality criteria (AAQC), or the Canada-wide Standard (CWS) guidelines developed by the Canadian Council of Ministers of the Environment (CCME).

The identification of trends in ozone levels was undertaken using publicly available data from the Ministry of the Environment's (MOE) ambient air quality monitoring network. The network consists of 40 Air Quality Index (AQI) stations across Ontario. The Oshawa station (ID# 45026) provides data that is useful in providing a local context considering its proximity to the Bowmanville/Soper Creek watershed. This station replaced the station (ID# 45025) located on Ritson Road in 2005. Potential impacts of poor air quality on the environment were also researched from various sources.

Soper North Subwatershed Cane Track

4.0 FINDINGS

The following section describes key air pollutants of concern, including current pollution issues, pollution sources and their potential impact on human health and the environment.

4.1 Pollutants

The term “pollutants”, in this chapter, refers to airborne substances that are undesirable because of their impact on human health, the environment and the economy. Pollutants can be grouped into the following four general categories.

1. Criteria Air Contaminants such as sulphur dioxide (SO_2), nitrogen oxides (NO_x), and volatile organic compounds (VOC) contribute to smog and acid rain and are produced from a number of sources including the burning of fossil fuels.
2. Persistent Organic Pollutants (POPs) such as, dioxins and furans, last in the environment for long periods of time and can travel long distances. POPs enter the food supply, bio-accumulate and can impact on human health and the environment.
3. Heavy Metals such as, mercury and lead, also bio-accumulate. These metals can also be transported by air and enter the food and water supply, posing a threat to humans and the environment when above threshold levels.
4. Toxic Pollutants include many of the above-mentioned pollutants in addition to others, such as benzene, which are toxic to human health and the environment.

Some air pollutants are naturally occurring, and come from sources such as conifer forests, forest fires, soil erosion and dust. However, the addition of air pollutants from human sources can significantly impact the environment.

The Canadian Environmental Protection Act, 1999 (CEPA 1999; Schedule 1) provides a list of pollutants that are subject to legislative controls. CEPA 1999 has also legislated that these pollutants be reported to the publicly accessible National Pollutant Release Inventory (NPRI).

Considerable information is available on the effects of degraded air quality and human health; local information can be found at: http://www.airqualityontario.com/.

4.2 Pollution Issues

Table 1 identifies several key pollutants and their linkage to various pollution issues at elevated levels.

Table 1: Linkages Between Air Pollutants and Current Issues (modified from: Ministry of the Environment, 2006).

Pollutant	Smog	Global Warming	Acid Deposition	Odour	Visibility/ Soiling
Ozone	Yes	Yes	Yes	No	No
Sulphur Dioxide	Yes	Yes	Yes	No	Yes
Carbon Monoxide	Yes	Yes	Yes	No	No
Nitrogen Oxides	Yes	Yes	Yes	No	Yes
Volatile Organic Compounds	Yes	Yes	No	Yes	No
Particulate Matter	Yes	Yes	Yes	Yes	Yes
Total Reduced Sulphur Compounds	No	No	No	Yes	No

Several key issues regarding pollutants as documented by Environment Canada (EC) and Ontario Ministry of the Environment (MOE) are briefly described in the following sections.

4.2.1 Smog

Smog is a commonly used term that refers to a mixture of gases and particles and has been linked to a number of adverse effects on health and the environment. Most public 'smog advisories' or 'alerts' issued by the MOE are triggered by elevated levels of either ground-level ozone or particulate matter levels exceeding a provincial threshold for air quality.

Ground-level ozone (O_3) and particulate matter (PM) are the primary constituents making up smog. Up to two-thirds of fine particulate matter and almost all ground-level ozone, a secondary pollutant, are formed in the atmosphere from gaseous compounds. Therefore, in order to address particulate matter and ozone, it is also necessary to address the primary pollutants (EC, 2005).

4.2.1.1 Ground-Level Ozone (O_3)

The ozone layer that exists in the atmosphere is formed naturally and helps protects the earth's surface from ultraviolet rays. Ground-level ozone, which is formed at the earth's surface, is different and is considered an air pollutant that is harmful to humans, man-made materials, animals and plants (MOE, 2006). Ground-level ozone is a colourless, odourless gas at ambient concentrations and contributes significantly to smog. It is a secondary pollutant meaning that it is formed when gases, primarily nitrogen oxides (NO_x: the term nitrogen oxide typically refers to any binary compound of oxygen and nitrogen) and volatile organic compounds (VOCs) are emitted directly to the atmosphere and then react with sunlight and heat. This explains why smog becomes a problem on hot summer days.

Nitrogen Oxides (NO_x) Characteristics and Sources

Nitrogen oxides are produced by burning fossil fuels such as coal, oil, gas, and diesel in motor vehicles, industries, power plants and homes (Figure 2). In Ontario, in 2006, transportation accounted for approximately 68% of NO_x emissions (MOE, 2008). Other industrial processes are the second largest source and accounted for approximately 11%. All combustion in air produces oxides of nitrogen (NO_x), of which nitrogen dioxide (NO_2) is a major product, along with nitric oxide (NO). While natural sources of NO_x include lightning and the aerobic activity of soil bacteria, these sources are, however, small compared to emissions caused by human activity.

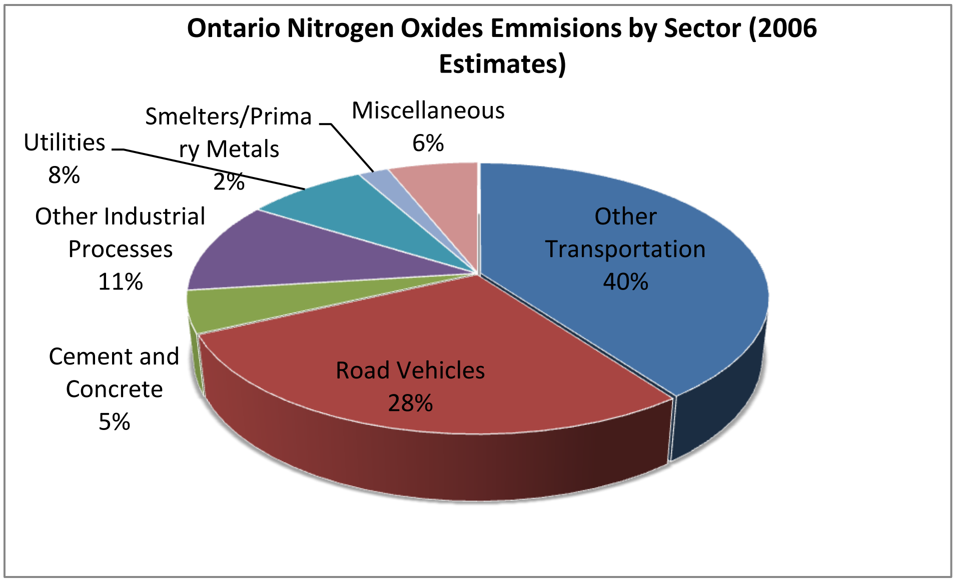

Figure 2: Sources of Nitrogen Oxides by Sector in Ontario, 2006 estimates (modified from: Ministry of the Environment, 2008).

Nitrogen dioxide is a reddish-brown gas with a strong and irritating odour and is the most common smog-causing air pollutant. It transforms in the air by combining with water molecules to form gaseous nitric acid, which contributes to the formation of acid rain, acid snow, acid fog, and toxic organic nitrates (MOE, 2006). As mentioned previously, NO_2 plays a major role in atmospheric reactions that produce ground-level ozone, the major component of smog. In addition, NO_2 is a precursor to nitrates, which leads to more particles in the atmosphere.

Hourly data from the AQI network indicates concentrations of NO_x tend to increase during a typical morning rush-hour in urban areas, ultimately resulting in higher ambient ozone levels later in the day. Ozone levels typically peak by mid-afternoon and then begin to decline at dusk. In addition, transport of ozone is highly dependent on weather patterns.

Volatile Organic Compounds Characteristics and Sources

Volatile organic compounds (VOC) include carbon-containing gases that are emitted by a wide array of products including when gasoline and solvents are burned. While human generated sources in populated and industrialized areas are the main contributors to air quality problems, there are natural sources of VOCs that include vegetation, forest fires, and animals (EC, 2005). Provincially, transportation accounts for approximately 38% of VOC emissions (MOE, 2008). Printing/surface coating and general solvent use accounts for approximately 19% and 18% respectively, being the second and third largest sources of VOC emissions (Figure 3).

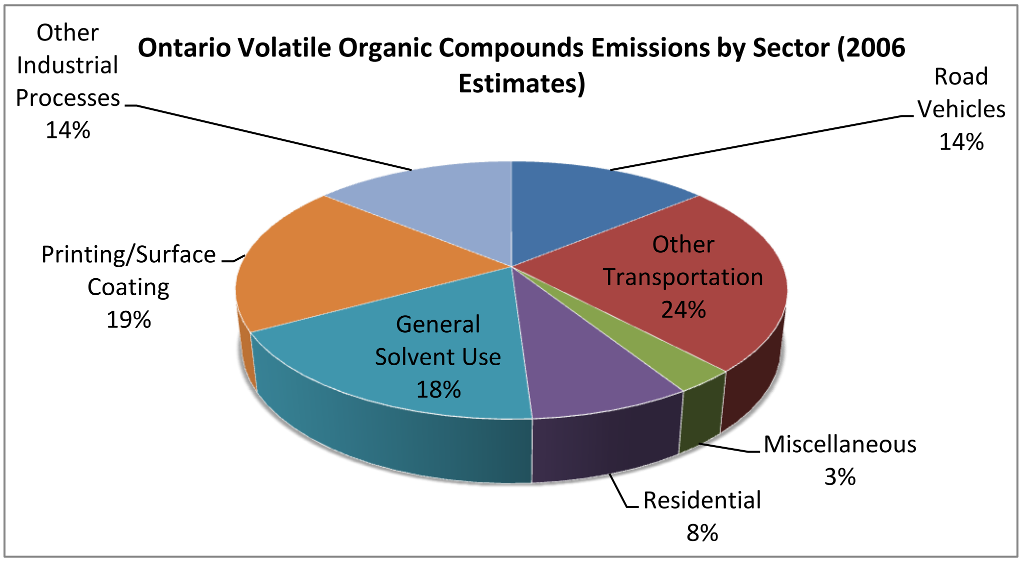

Figure 3: Sources of VOCs by Sector in Ontario, 2006 estimates (modified from: Ministry of the Environment, 2008).

Many VOCs in the presence of sunlight react with NO_x to produce ground-level ozone and particulate matter. Some VOCs are also known to be carcinogenic (e.g., benzene).

Trends in Ground-Level Ozone Levels

Consistent with provincial trends, Figure 4 shows there has been an increasing trend in annual average ozone levels during the 10-year period from data recorded at the Oshawa station. High air temperatures recorded in 2005 correspond to the increased levels of ozone measured. Provincially, summer ozone averages have increased by approximately 30% and the winter averages by 60% over the period from 1980 to 2007 (MOE, 2008). The increase in winter ozone average concentrations is being attributed largely to rising global background ozone concentrations throughout Ontario. Summer average increases may be related to meteorological conditions and drift from the U.S.

The Ontario one-hour ambient air quality criteria (AAQC) for ozone is 80 ppb. A Canada-wide standard (CWS) was developed for ozone in 2000 by the Canadian Council of Ministers of the Environment (CCME) being 65 parts per billion (ppb). In 2007 Of the 20 designated CWS reporting sites across Ontario, 19 exceeded the standard for ozone for the years 2005 to 2007. Ontario's effort towards achieving this standard is to work towards a 45% reduction in NO_x and VOC emissions from 1990 levels by 2010 or earlier; remaining ambient ozone levels above the CWS in the province will be considered attributable to the transboundary flow from the U.S where the federal government is responsible for addressing the transboundary flow (MOE, 2004).

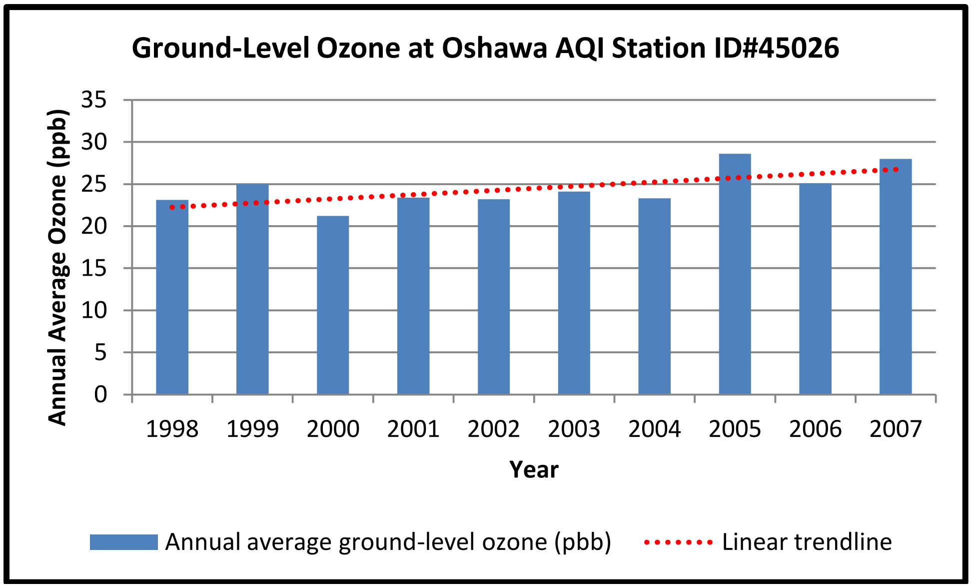

Figure 4: 10-Year Trend for Ground-Level Ozone Recorded at Oshawa Station ID#45026 (compiled from: Ministry of the Environment, 2008).

Effects of Ground-Level Ozone

Ozone is known to have significant effects on human health. Exposure to ozone has been linked to premature mortality and asthma symptoms. The Ozone Annex was added to the Canada-United States Air Quality Agreement (December 2000) to address transboundary air pollution leading to high levels of ground-level ozone.

4.2.1.2 Fine Particulate Matter (PM)

Particulate matter (PM) consists of airborne particles in solid or liquid form. PM may be classified as primary or secondary, depending on the compounds and processes involved during its formation. Primary PM is emitted at the emissions source in particle form, for example, a recently tilled field subject to wind erosion. Secondary PM is created from a series of chemical and physical reactions involving gases, such as sulphur, nitrogen oxides, and ammonia reacting to form sulphate, nitrate and ammonium particulate matter.

Particulate matter is categorized by its size mainly because of the different health effects associated with the different sizes. $PM_{2.5}$ are particles equal to or less than 2.5 microns in diameter or approximately 30 times smaller than the width of a human hair.

Sources

Aerosols, smoke, fumes, fly ash and pollen may result in particulate matter. $PM_{2.5}$ is also emitted from fuel combustion such as from vehicles, smelters, power plants, industrial facilities, residential fireplaces, woodstoves, agricultural burning and forest fires (MOE, 2006). It can also be formed indirectly through a series of complex chemical reactions in the atmosphere. Significant amounts of $PM_{2.5}$ are carried into Ontario from the U.S. During periods of widespread elevated levels of fine particulate matter, it is estimated that more than 50% of Ontario's $PM_{2.5}$ comes from the U.S. (MOE, 2009) In Ontario, transportation and the residential sector account for approximately 24% and 34% of primary $PM_{2.5}$ emissions, respectively, during 2006 (MOE, 2008). Other industrial processes accounted for 21%.

Effects of Fine Particulate Matter

Numerous studies have linked PM to aggravated cardiac and respiratory diseases such as various forms of heart disease, asthma, bronchitis and emphysema. PM can also have adverse effects on vegetation, buildings and structures, and contributes to haze.

4.2.2 Acid Rain and Acid Deposition

Acid rain or wet acid deposition is primarily caused by the release of sulphur dioxide (SO_2) and nitrogen oxides (NO_x) into the atmosphere. These primary pollutants are subsequently transformed in the atmosphere into secondary pollutants such as sulphuric acid (H_2SO_4), ammonium nitrate (NH_4NO_3) and nitric acid (HNO_3). The acids are then removed from the atmosphere in rain, snow, sleet or hail. Dry acid deposition is primarily caused when fly ash, sulphates, nitrates, and gases (such as SO_2 and NO_x), are deposited on surfaces and are converted into acids when they contact water.

Acid deposition affects lakes, rivers, forest, soils, fish and wildlife populations and buildings. While many areas of Ontario cannot effectively neutralize the effects of acid deposition, there are some areas that have alkaline soils, such as found in the Bowmanville/Soper Creek watershed, which provide some natural buffering.

4.2.3 Transboundary Air

Prevailing winds can carry air pollution long distances through the atmosphere. Recognizing that many pollutants are transported from other jurisdictions is important in addressing air pollution concerns. Several key initiatives have been implemented between Canada and the U.S to address the following:

- transboundary air pollution leading to acid rain;
- high concentrations of ground-level ozone; and
- particulate matter (PM) levels in the air.

Also, Canada and the United States have completed a joint transboundary PM science assessment report in support of the Canada-U.S. Air Quality Agreement. Internationally, both countries participate in the Commission for Environmental Cooperation (CEC) North American Air Working Group and the United Nations Economic Commission for Europe where acid rain, smog and other transboundary air issues are a focus.

4.2.4 Land Use

As noted previously, transportation is a key element in the creation and persistence of smog. Low density development not only requires the construction of more roads, but typically increases the distance one must travel to work, to shopping, and to other activities. Urban sprawl increases reliance on personal motor vehicles, hence increasing congestion, lowering fuel efficiency and increasing harmful emissions.

4.3 Air Quality Indices

4.3.1 Air Quality Index (AQI)

Ontario's current Smog Alert program, a joint effort between MOE and Environment Canada, relies on ambient air quality data collected from the Air Quality Index (AQI) network. In 2007, the AQI network relied on 40 monitoring sites situated across the province to provide data on ozone, fine particulate matter, NO_2, SO_2, and total reduced sulphur compounds. These pollutants were selected as they all have adverse effects on health of humans and the environment at elevated levels. Hourly readings for each pollutant at stations are assigned an AQI value from zero upwards using a common scale. The highest hourly AQI value for any pollutant becomes the AQI value for the station (0-15 is very good; 16-31 is good; 32-49 is moderate; 50-99 is poor; >100 is very poor). AQI values above 50 may have adverse effects on human and animal populations, and may cause significant damage to vegetation and property (MOE, 2006). Air quality or smog advisories are issued by MOE to the public and news media when AQI values are greater than 49 and persistent smog (ground-level ozone and fine particulate matter) are forecasted. AQI values and air quality forecasts can be found at www.airqualityontario.com.

In 2007, air quality levels recorded at the Oshawa station measured very good and good (AQI values of 0-31) approximately 91% of the time and moderate to poor about 9% of the time (MOE, 2008). As a reference, very good air quality levels were achieved during 84% of the year in Sarnia and 98% in Thunder Bay. The 2007 provincial average for AQI values was in the good to very good range approximately 90% of the time and was moderate to poor about 10% for the remainder of the year. Across the province in 2007, poor air quality values were generally the result of fine particulate matter (32%) and ozone (68%).

4.3.2 Air Quality Health Index (AQHI)

The Air Quality Health Index (AQHI) is a health based air pollution risk communication tool, developed by Environment Canada and Health Canada, which assesses the cumulative health impact of ground-level ozone (Os), particulate matter (PM2.5) and nitrogen dioxide (NOs) and provides specific health advice to those at increased risk (EC, 2010). The AQHI assessment numbers ranges from low to high risk being 1 to 10+, respectively, In 2008, Region of Durham participated in the AQHI pilot project for expansion of this program to the area. To date, AQHI readings are provided by Ontario Ministry of Environment (in collaboration with Environment Canada) for parts of Durham, Halton, Peel, Ottawa, Toronto, and York. In 2010, an electronic toolkit was developed by Toronto Public Health, Durham, Halton, Peel, York health units and the Clean Air Partnership – to provide information on the AQHI and how to plan activities considering the local air quality readings (OPHA, 2010). The toolkit is available at www.toronto.ca/health/airquality/aqhi/toolkit.htm.

4.4 Other Pollutants

4.4.1 Sulphur Dioxide (SO_2)

SO_2 is a colourless gas that can combine with water molecules to form sulphuric acid. Like nitric acid, sulphur dioxide contributes to the formation of acid rain, acid snow and acid fog. SO_2 when mixed with water creates sulphates, which are one of the main ingredients of airborne fine particulate matter.

Approximately 69% of the SO_2 emissions in Ontario in 2006 came from smelters and utilities (MOE, 2008). SO_2 is emitted from the combustion of fossil fuels that contain sulphur, such as coal and oil (e.g. coal used for electricity generation or fuel used in diesel-powered vehicles). Other sources include iron and steel mills, petroleum refineries, and pulp and paper mills. Small sources include residential, commercial and industrial space heating.

SO_2 is known to damage trees and crops. SO_2 and NO_x are the main contributors to acid rain. Elevated levels of acidity in precipitation contribute to the acidification of lakes and streams, accelerated corrosion of buildings and reduced visibility. SO_2 can also form acid aerosols, which have serious health implications and contribute to climate change.

4.4.2 Total Reduced Sulphur Compounds (TRS)

Total reduced sulphur compounds (TRS) produce offensive odours similar to rotten eggs or cooked cabbage. TRS is a gaseous mixture of compounds consisting mainly of hydrogen sulphide (H_2S), methyl mercaptan (CH_3S-H), dimethyl sulphide (CH_3-S-CH_3) and dimethyl disulphide (CH_3-S-S-CH_3).

Industrial sources of TRS include the steel industry, pulp and paper mills, refineries and sewage treatment facilities. Natural sources include swamps, bogs and marshes.
Once released into the atmosphere, oxidation products of TRS compounds, such as sulphuric acid, contribute to the acidity of the environment.

4.5 National Pollutant Release Inventory

The National Pollutant Release Inventory (NPRI) is a Canada-wide, publicly-accessible inventory of annual releases to air, water, land and disposal or recycling from industrial, government, commercial and other sources. The Ontario Ministry of the Environment (MOE) also requires Ontario-based facilities that emit certain quantities of substances to the air to report these releases, and these are also included in the NPRI database.

A search of the 2007 release inventory for Oshawa and surrounding areas, resulted in a list of 40 emitters, 27 of which reported emitted tracked substances into the air (Environment Canada, 2008). Many releases were of particulate matter, while others were of heavy metals, nitrous oxides, volatile organic compounds and other chemicals. Although these emitters are located in Oshawa and surrounding nearby areas, the Bowmanville/Soper Creek watershed will also be impacted by releases from areas further to the west and south, due to prevailing wind conditions in this region.

4.6 Effects on the Environment

Impacts of air pollutants on humans and the environment may be small or unknown and remain relatively hidden in day to day life. However, over time, the cumulative impact of air pollutants will take its toll on the environment. Humans, wildlife and vegetation have varied levels of resistance to pollutants, though in some cases, this resistance can be overwhelmed particularly amongst sensitive groups within a species such as the young, rapidly growing, sick or elderly.

4.6.1 Soil and Water Resources

Airborne pollutants can pollute the precipitation that falls on soils and water bodies. As soils become more acidic, nutrients, minerals and elements such as calcium, magnesium and potassium are removed from the soils more rapidly, making them less available. Mobilization of heavy metals such as aluminum into wetlands and creeks is also increased. Many of the heavy metals are poisonous to fish and other wildlife at elevated levels. Soils within the Bowmanville/Soper Creek watershed are more resistant to acidification due to higher concentrations of calcium carbonate which help neutralize acids. The long-term impacts of on-going exposure are unknown.

NO_2 chemically transforms into nitric acid in the atmosphere where it becomes available for deposition in the watershed. This deposition contributes to lake and soil acidification. Nitric acid can corrode metals, fade fabrics and degrade rubber. It can damage trees and crops, resulting in substantial losses.

Creeks and wetlands may be polluted directly by acid precipitation from rain, snow and particulate matter, or indirectly by nutrients, elements and heavy metals leached from soils and suspended in the water. Water bodies have been known to experience 'acid shock' where the acidified snow pack that is released during spring melt creates potential lethal conditions for aquatic species.

4.6.2 Vegetation

Ground-level ozone at elevated levels is toxic to many plants and damage has been identified in the province including leaf damage in various crops, garden plants and trees. Ozone can affect photosynthesis and plant respiration, reduce growth rates and affect reproduction (MOE, 2006). Ozone injury was observed on foliage in elderberry, yellow poplar, sycamore, walnut and milkweed at a site near Port Stanley (Figure 5, MOE, 2006). Ozone damage on plant foliage typically appears as stippling on the upper leaf surface. On species such as potato and tomato plants, leaf damage appears as shiny grey or bronze spots on the under surface. Ozone is also a powerful greenhouse gas and is known to contribute to climate change. Refer to Chapter 8 - Climate for more information on climate change.

Notes:

- *i. Bean leaf with upper surface ozone stippling and coalescent injury on intervienal tissue.*
- *ii. Elderberry foliage with ozone injury on upper surface.*
- *iii. White bean plant with distinctive ozone stippling and bronzing on upper surface of several leaves.*

Figure 5: Ozone injury on upper leaf surface of sensitive vegetation (Ministry of the Environment, 2006).

4.7 Using Lichens to Monitor Air Quality

Lichens have been used to map areas of poor air quality in the Montreal area, as early as the 1970s, (Leblanc and DeSloover, 1970) and more recently, in Hamilton and its surrounding area (McCarthy, 2005). This technique has been used as an early-warning system for poor environmental quality in many countries (McCarthy, 2005).
Lichens are suitable biomonitors for air pollution for a number of reasons (Hutchinson et al., 1996):

- Many species have large geographical ranges, allowing the determination of pollution gradients over long distances;
- They can accumulate pollutants throughout the year;
- Lichens are usually very long lived;
- Lichens are sensitive to pollution, because water and gas are exchanged over the entire surface and since they do not have roots must depend on deposition, water seeping over substrate surfaces, and atmospheric sources of nutrients;
- Some species are more tolerant of air pollution than others; and
- Monitoring their presence/absence can be done fairly rapidly and is therefore cost effective.

The Environmental Monitoring and Assessment Network (EMAN) Coordinating Office, in conjunction with lichen experts, developed a reference manual highlighting 20 common lichens (Brodo and Craig, 2003), with a range of pollution-tolerance levels, which can be monitored in urban and surrounding areas. EMAN recommends three different monitoring protocols, depending on the goals of the study:

1. Lichen Mapping: Mapping the relative abundance and distribution of arboreal lichens using a visual survey of the trunk for a select suite of indicator species.
2. Mapping Lichen Diversity: Recording changes in arboreal species diversity in fixed plots over time, either through the use of grid or transects samples, using a standardized method developed by European lichenologists.
3. Metal analysis: Determining the elemental content of lichen tissue in relation to differing pollutant concentrations.

5.0 CONCLUSIONS

The information gathered suggests that the main pollution issues identified are relevant to the residents and to the environment within in the Bowmanville/Soper Creek watershed. These issues include smog, acid rain, transboundary air and land use. It is important to note that road vehicles and other transportation activities as noted in the chapter contribute significantly to primary and secondary pollutant issues.

While considerable information is available on the subject of air quality, the effects of air-borne pollutants on the natural environment within the watershed remain difficult to assess, based on limited local information. Further investigation, from agencies specializing in air quality issues, is required to advance this understanding locally.

6.0 REFERENCES

Brodo, I.M. and B. Craig. 2003. Identifying Mixed Hardwood Forest Lichens: A Reference Notebook, Version 4.1. Retrieved October 2007 from http://www.eman-rese.ca/eman/ecotools/protocols/terrestrial/lichens/hardwood/... Identifying%20Mixed%20Hardwood%20Forest%20Lichens%20%20Ver%204.1.pdf

Canadian Environmental Protection Act. 1999. (CEPA 1999; Schedule 1). Government of Canada. http://www.ec.gc.ca/CEPARegistry/the_act/Contents.cfm.

Environment Canada, 2005. Volatile Organic Compounds in Consumer and Commercial Products. Last modified February 28, 2005. Retrieved October 2007 from http://www.ec.gc.ca/nopp/voc/en/bkg.cfm.

Environment Canada, 2008. National Pollutant Release Inventory. Last modified October 7, 2008. Retrieved April 30, 2009 from http :www.ec.gc.ca/pdb/websol/… querysite/query_e.cfm

Environment Canada. 2010. Air Quality Health Index. Last modified June 3, 2010. Retrieved March 2011 from http://www.ec.gc.ca/cas-aqhi/default.asp

Hutchinson, J., D. Maynard, and L. Geiser. 1996. Air Quality and Lichens - A Literature Review Emphasizing the Pacific Northwest, USA. USDA Forest Service, Pacific Northwest Region Air Resource Management Program http://www.fs.fed.us/r6/aq/lichen/almanac.htm

Leblanc, F. and J. DeSloover. 1970. Relation between industrialization and the distribution and growth of epiphytic lichens and mosses in Montreal. Canadian Journal of Botany 48: 1485-1496.

McCarthy, D. 2005. The Hamilton Lichen Survey 2004. For the Environmental Monitoring and Assessment Network (EMAN), Februrary 2005. Retrieved October 2007 from http://www.eman-rese.ca/eman/ecotools/protocols/terrestrial/lichens/... The%20Hamilton%20Lichen%20Survey%202004.pdf.

Ontario Ministry of the Environment. 2004. Ontario's Clean Air Action Plan: Protecting Environmental and Human Health in Ontario. Retrieved October 2007 from http://www.ene.gov.on.ca/programs/4708e.htm.

Ontario Ministry of the Environment. 2006. Air *Quality in Ontario 2005 Report*. Environmental Monitoring and Reporting Branch, 2006. pp. 61.

Ontario Ministry of the Environment. 2008. Air *Quality in Ontario 2007 Report*. Environmental Monitoring and Reporting Branch, 2008. pp. 55.

Ontario Ministry of the Environment, 2009. Air Quality Ontario. Various home page links. Website last modified August 12, 2009 (individual pages, unknown). Retrieved October 2007 from http://www.airqualityontario.com

Ontario Public Health Association. 2010. OPHA Resolution: Provincial Expansion and Promotion of the Air Quality Health Index (AQHI). Retrieved March 2011 from http://www.opha.on.ca/our_voice/ppres/papers/2010-04_res.pdf

WHAT WE DO ON THE LAND IS MIRRORED IN THE WATER