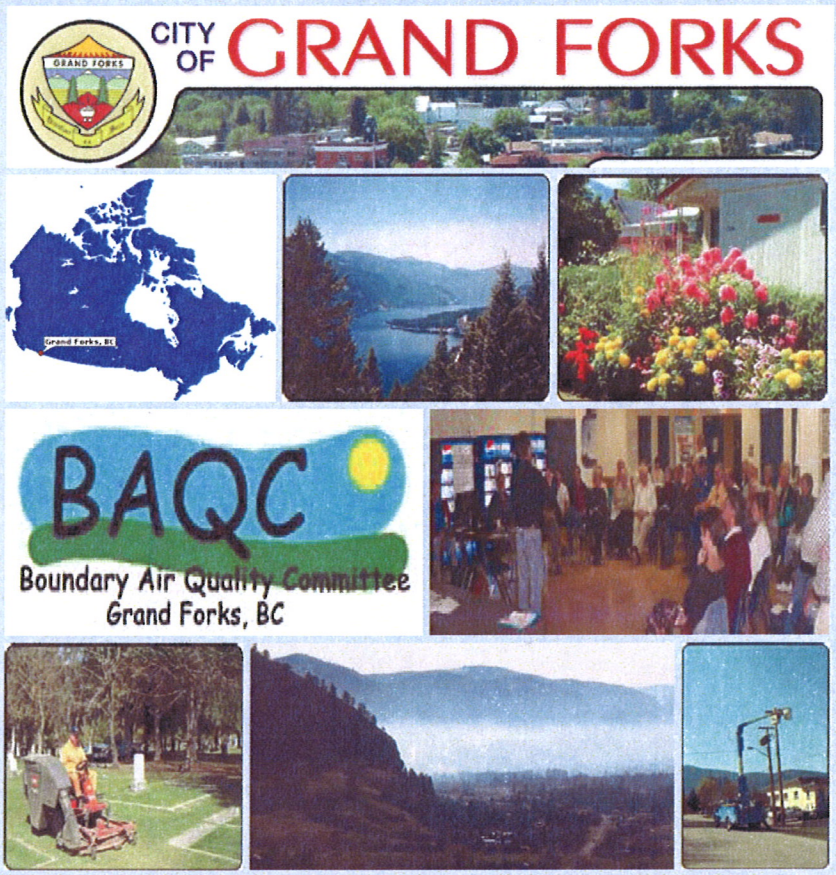
Draft Report:

City of Grand Forks and Surrounding Area Emissions Inventory



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November, 2007

Acknowledgments

The authors would like to thank the following people and organizations for their help in collecting data to support emissions estimates:

Chris Moslin, Joy Davies from the Boundary Air Quality Committee
Michael Rensing from B.C. Ministry of Environment
Paul Willis and Peter Jarman from B.C. Ministry of Environment
Carl Withler from B.C. Ministry of Agriculture
Dan Zabinsky, Victor Kumar from City of Grand Forks
Hans Mertins from Terasen Gas
Blair Weston from Fortis BC
Alan Wilkie from Pope & Talbot
Peter Metcalf from CanPar Industries
Peter Regenberg from Roxul
John Ketrenos from Pacific Abrasives
Tim Ripper from Selkirk Paving
Rick Hammond from Grand Forks Railway
Alan Stanley from the Regional District of Kootenay Boundary
Karen Chow from Insurance Corporation of British Columbia
Derek Adams from Statistics Canada
JACM for residential survey data entry

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GLOSSARY OF ACRONYMS

AP-42	U.S. EPA Compilation of Emission Factors for various sources
CAC	Common Air Contaminants
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
EC	Environment Canada
GHG	Greenhouse gases
GloBEIS	Biogenic emissions model to estimate hydrocarbon emissions
HC	Hydrocarbons
LFV	Lower Fraser Valley in British Columbia
NH_3	Ammonia
NO_x	Nitrogen oxides
N_2O	Nitric oxide
PM	Same as TSP
PM_{10}	Inhalable particulate matter (mean aerodynamic diameter less than 10 μm)
$PM_{2.5}$	Respirable particulate matter (mean aerodynamic diameter less than 2.5 μm)
SOA	Secondary organic aerosols (secondary particulate matter)
SO_x	Sulphur oxides
THC	Total hydrocarbons
TOG	Total organic gases
TSP	Total suspended particulate matter (mean aerodynamic diameter less than 30μm)
U.S. EPA	United States Environmental Protection Agency
VOC	Volatile organic compounds

EXECUTIVE SUMMARY

SENES Consultants Limited (SENES) was commissioned by the City of Grand Forks to complete a comprehensive emissions inventory of all significant emission sources in and surrounding the City in 2006. The inventory work was managed on behalf of the City by the Boundary Air Quality Committee (BAQC), which is made up of representatives from the City, the public, industry and the B.C. Ministry of Environment (MoE). The emissions inventory corresponds to an 'airshed' that was defined as approximately 240 square kilometres, which fully contains the City and surrounding area known as Area D of the Kootenay Boundary Regional District.

Following the usual convention, the Grand Forks Emission Inventory (GFEI) is organized to three main source-groups:

1) *Point sources* refer to fixed-location large industrial sources that operate under a discharge permit from the Province. There are five point sources in the GFEI.
2) *Mobile sources* include all modes of motorized transportation, including motor vehicles, aircraft, rail, and non-road engines (lawnmowers, chainsaws, tractors etc).
3) *Area sources* include all remaining emission sources, which in many cases tend to be widely distributed throughout a community. An example of an area source is space heating due to combustion of natural gas.

Annual point source emissions were available from past emissions monitoring data or emission estimates managed by the MoE. The many individual mobile and area sources were characterized by a survey of residential activities, a highway traffic study, information requests sent to industry, the City and the Regional District, information from Statistics Canada and on-site observations made during a visit to the City during August 1-3, 2007. Activity data collection was very successful, thanks in large part to volunteers from the BAQC, industry representatives and many other individuals and groups named in the *Acknowledgements*.

The requirements for generating the GFEI included estimation of nitrogen oxides (NO_x), sulphur oxides (SO_x), suspended particulate matter (PM, as total suspended particulate matter – TSP, PM of diameter 10 microns or less – PM_{10} and PM of diameter 2.5 microns or less – $PM_{2.5}$), carbon monoxide (CO), volatile organic compounds (VOC) and ammonia (NH_3). This group of pollutants is collectively referred to as 'Common Air Contaminants' (CACs). The requirements also included estimation of Greenhouse Gases (GHGs), including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

In addition to the emissions directly released from emission sources (which can be referred to as 'primary' emissions), the GFEI contains estimates of organic and inorganic secondary particulate

matter. Secondary PM results from chemical reactions in the atmosphere involving primary gaseous emissions (NO_x, SO_x, NH_3, VOC). Although secondary PM estimates have been included in the GFEI, there is a much higher degree of uncertainty associated with their calculation methods when compared to the primary emissions estimates. The majority of secondary particulate matter accounted for in the GFEI results from biogenic emissions from coniferous forest species.

Fugitive TSP and PM_{10} emissions (dust emissions resulting from wind erosion, actions of vehicle tires on roadway surfaces or material handling) were estimated as 'suspendable' and 'transportable' amounts. A significant proportion of suspendable TSP and PM_{10} emissions (75% and 60%, respectively) were considered to be deposited very near the point(s) of release, and were therefore not included in the airshed summary totals. In effect, this approach distinguishes between the amount of dust that stays within 2 metres of the ground (and is deposited near the source of emission) and the amount that influences air quality over a significant area. All fugitive $PM_{2.5}$ emissions were considered to be transportable.

Table ES-1 provides the common air contaminant and greenhouse gas emissions inventory for 2006. This inventory summary does not include secondary particulate matter or the diesel sub-fractions of particulate matter estimates (amount of PM that is associated with diesel combustion).

Table ES-2 provides the diesel and secondary particulate matter emissions inventory for 2006. This inventory includes secondary organic aerosol (SOA) and inorganic (nitrates and sulphates) compounds, as well as fine particulate matter caused by diesel combustion (PM_{10}_D and $PM_{2.5}$_D). Secondary PM should be considered to be entirely within the smallest PM size fraction ($PM_{2.5}$). As a general rule, estimates for the secondary particulates are accurate within an order of magnitude. Also worth noting, secondary particulate matter formation occurs throughout the airshed and at various heights above the ground. For these reasons, it is considered to be inappropriate to add primary and secondary particulate matter emissions as total PM emissions for the airshed.

Table ES-1
CAC and GHG Emissions Inventory for Grand Forks*

Source Type	Category	CACs (tonnes)								GHGs (tonnes)		
		CO	NOx	SOx	VOC	NH3	TSP	PM10	PM25	CO2	CH4	N2O
AREA	Area_Agriculture	39.79	1.37	0.00	16.51	8.22	17.94	13.52	8.50	0.00	53.11	0.99
	Area_Dust	0.00	0.00	0.00	0.00	0.00	615.10	309.24	74.94	0.00	0.00	0.00
	Area_Energy	179.47	12.66	0.61	39.51	0.70	28.03	26.46	26.46	34,092.93	28.39	1.01
	Area_Other	32.91	31.39	0.24	1,973.70	0.19	5.38	5.04	4.94	1,214.10	446.34	7.78
	AREA TOTAL	**252.2**	**45.4**	**0.9**	**2,029.7**	**9.1**	**666.5**	**354.3**	**114.8**	**35,307.0**	**527.8**	**9.8**
MOBILE	Mobile_Highway	1,031.96	98.71	0.88	90.10	3.24	2.48	2.48	1.74	20,586.35	4.47	5.42
	Mobile_Local	614.64	49.95	0.38	52.74	2.07	1.28	1.28	0.89	10,591.60	2.75	2.83
	NonRoad_AG	7.50	0.51	0.01	0.62	0.00	0.01	0.01	0.01	44.44	0.04	0.00
	NonRoad_Agriculture	68.55	12.98	1.04	4.84	0.05	0.84	0.84	0.81	1,261.49	0.41	0.40
	NonRoad_COM	7.37	0.03	0.00	0.16	0.00	0.00	0.00	0.00	24.20	0.02	0.00
	NonRoad_Commercial	156.95	13.43	0.40	19.77	0.01	1.29	1.29	1.21	1,041.43	0.57	0.24
	NonRoad_CON	1.43	0.85	0.10	0.23	0.00	0.15	0.15	0.15	81.26	0.01	0.03
	NonRoad_Construction	25.85	4.49	0.46	1.66	0.01	0.38	0.38	0.37	445.75	0.11	0.15
	NonRoad_IND	4.12	3.86	0.42	0.36	0.01	0.25	0.25	0.24	351.22	0.03	0.13
	NonRoad_Industry	43.44	18.43	1.75	3.13	0.03	0.98	0.98	0.95	1,786.97	0.29	0.56
	NonRoad_Recreational	67.92	0.27	0.01	31.63	0.01	0.87	0.87	0.80	380.73	0.44	0.01
	NonRoad_Residential	412.67	2.51	0.02	41.90	0.01	1.18	1.18	1.09	770.12	0.88	0.02
	MOBILE TOTAL	**2,422.0**	**200.8**	**4.9**	**245.8**	**5.4**	**9.3**	**9.3**	**7.8**	**36,864.5**	**9.9**	**9.6**
POINT	CanPar	116.40	81.66	1.14	269.13	0.50	420.00	87.00	66.00	0.00	0.00	0.00
	Pacific Abrasives	0.00	0.00	0.00	0.00	0.00	17.00	3.60	3.60	0.00	0.00	0.00
	Pope & Talbot	14.50	72.68	0.43	50.00	0.00	62.00	54.00	34.00	0.00	0.00	0.00
	Roxul	0.00	0.00	0.00	26.04	3.31	84.20	78.20	74.20	0.00	0.00	0.00
	Selkirk Paving	1.00	0.20	0.03	0.25	0.00	0.25	0.18	0.17	0.00	0.00	0.00
	POINT TOTAL	**131.9**	**154.5**	**1.6**	**345.4**	**3.8**	**583.5**	**223.0**	**178.0**	**0.0**	**0.0**	**0.0**
Grand Total		***2,806.0***	***400.7***	***7.4***	***2,620.9***	***18.4***	***1,259.2***	***586.6***	***300.7***	***72,171.5***	***537.7***	***19.4***

*Includes transportable fugitive dust emissions only. GHG emissions for point sources (industry) are captured within Area_Energy sources.

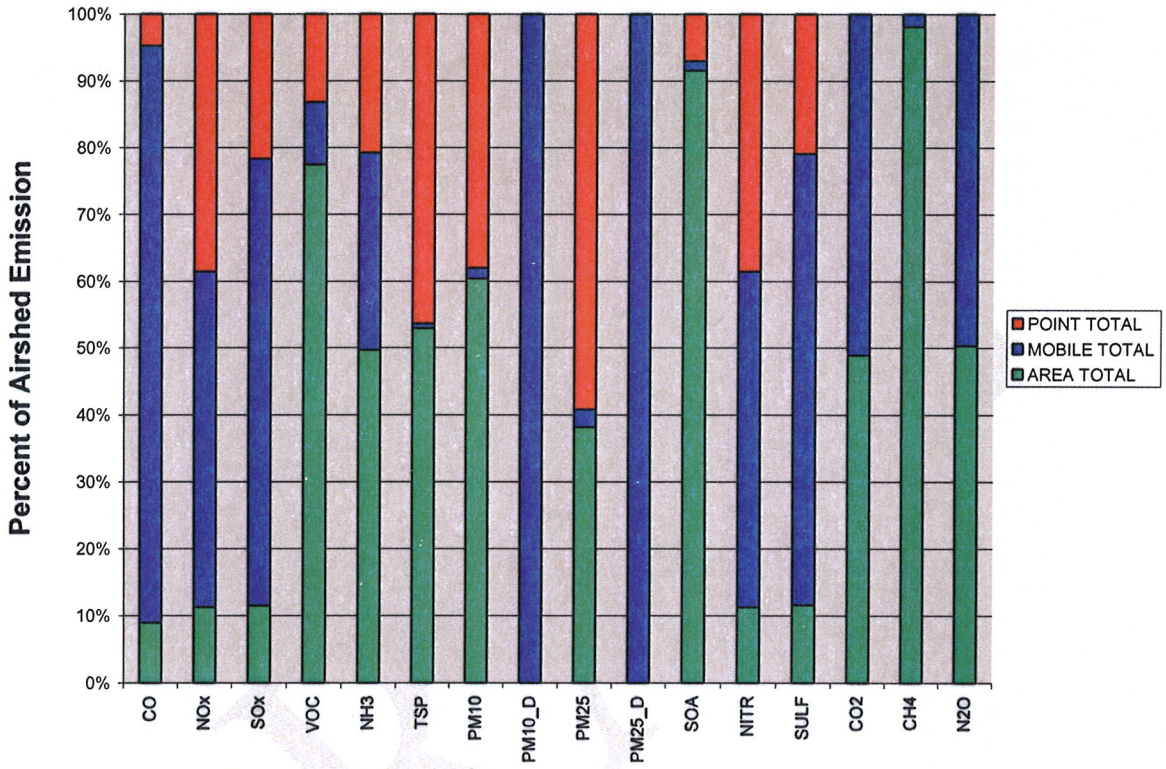
Table ES-2
Diesel and Secondary Particulate Matter Emissions Inventory for Grand Forks*

Source Type	Category	CACs (tonnes)		Secondary PM (tonnes)		
		PM10_D	PM25_D	SOA	NITR	SULF
AREA	Area_Agriculture	0.00	0.00	0.01	0.06	0.00
	Area_Dust	0.00	0.00	0.00	0.00	0.00
	Area_Energy	0.00	0.00	0.00	0.58	0.01
	Area_Other	0.00	0.00	192.86	1.44	0.00
	AREA TOTAL	**0.0**	**0.0**	**192.9**	**2.1**	**0.0**
MOBILE	Mobile_Highway	1.26	1.17	1.06	4.52	0.02
	Mobile_Local	0.65	0.60	0.63	2.29	0.01
	NonRoad_AG	0.01	0.01	0.00	0.02	0.00
	NonRoad_Agriculture	0.81	0.78	0.02	0.59	0.02
	NonRoad_COM	0.00	0.00	0.00	0.00	0.00
	NonRoad_Commercial	0.17	0.16	0.25	0.61	0.01
	NonRoad_CON	0.15	0.15	0.00	0.04	0.00
	NonRoad_Construction	0.35	0.34	0.01	0.21	0.01
	NonRoad_IND	0.25	0.24	0.00	0.18	0.01
	NonRoad_Industry	0.91	0.88	0.03	0.84	0.04
	NonRoad_Recreational	0.00	0.00	0.42	0.01	0.00
	NonRoad_Residential	0.00	0.00	0.57	0.11	0.00
	MOBILE TOTAL	**4.1**	**3.9**	**3.0**	**9.2**	**0.1**
POINT	CanPar	0.00	0.00	1.70	3.74	0.02
	Pacific Abrasives	0.00	0.00	0.00	0.00	0.00
	Pope & Talbot	0.00	0.00	13.07	3.33	0.01
	Roxul	0.00	0.00	0.00	0.00	0.00
	Selkirk Paving	0.00	0.00	0.00	0.01	0.00
	POINT TOTAL	**0.0**	**0.0**	**14.8**	**7.1**	**0.0**
Grand Total		***4.1***	***3.9***	***210.6***	***18.4***	***0.1***

Notes: PM10_D is the fraction of PM_{10} caused by diesel combustion PM25_D is the fraction of $PM_{2.5}$ caused by diesel combustion
SOA is the total amount of secondary organic aerosol formed within the airshed
NITR is total nitrate aerosols formed within the airshed SULF is total sulphate aerosols formed within the airshed

Figure ES-1 provides a bar chart of the GFEI, showing the relative contribution of each of the three general source types (point, area and mobile), for each air contaminant inventoried.

Figure ES-1
GFEI by Emission Source Group*



* PM10_D, = diesel fraction of PM_{10}, PM25_D = diesel fraction of $PM_{2.5}$, SOA = secondary organic aerosols, NITR = nitrates, SULF = sulphates

Figures ES-2 to ES-5 provide further breakdown of the relative source contributions for annual NO_x, TSP, $PM_{2.5}$ and CO_2. Secondary PM is not included in the $PM_{2.5}$ and TSP diagrams.

Figure ES-2: NO_x Emissions by Source Type

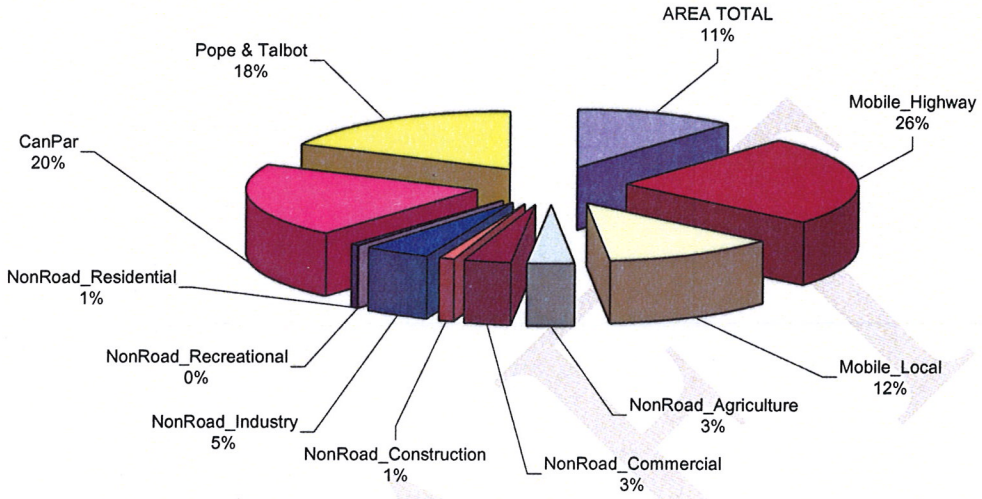
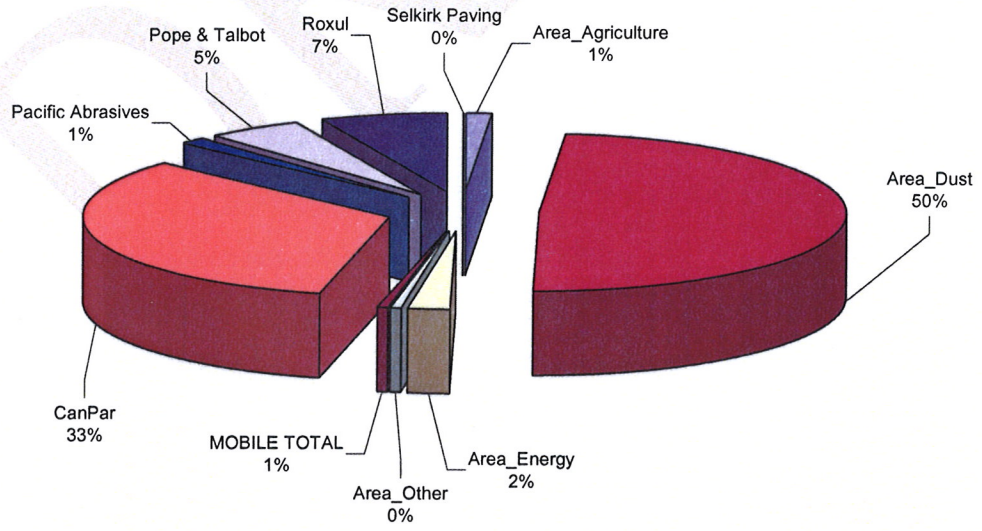
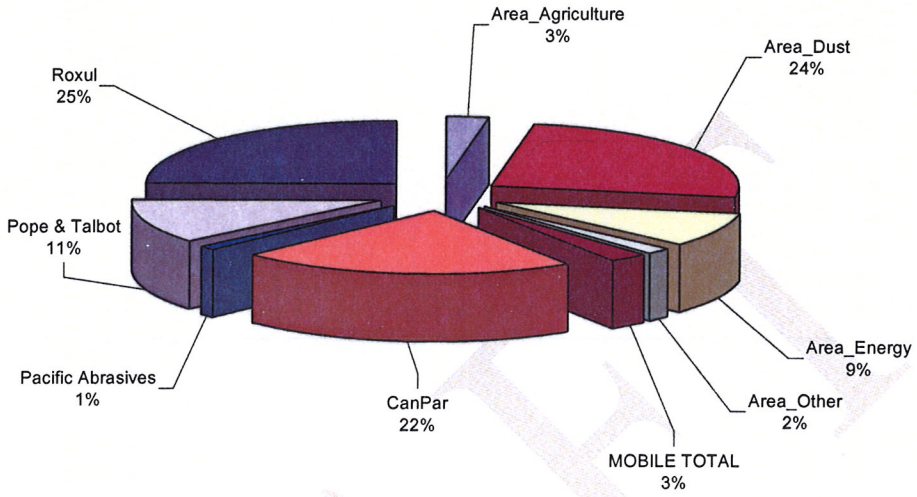


Figure ES-3: TSP Emissions by Source Type*



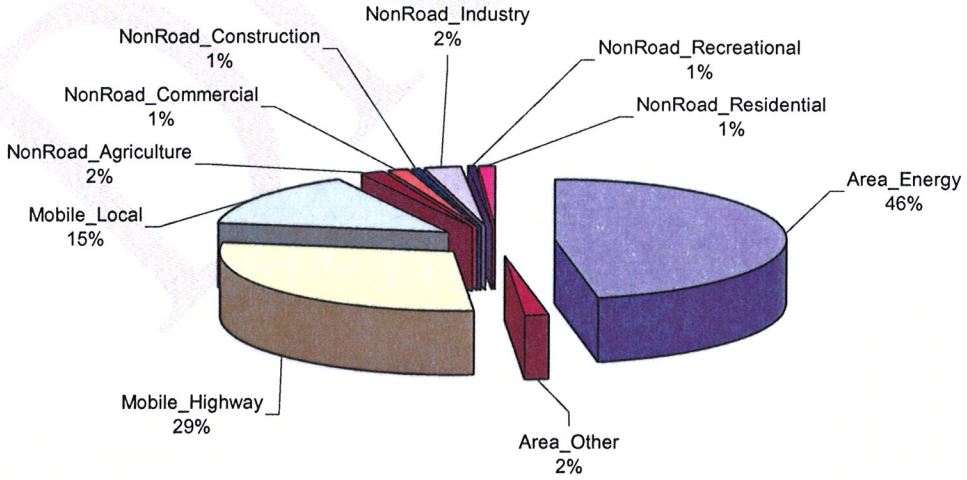
*Includes transportable dust emissions only

Figure ES-4: $PM_{2.5}$ Emissions by Source Type*



*Does not include secondary particulate matter

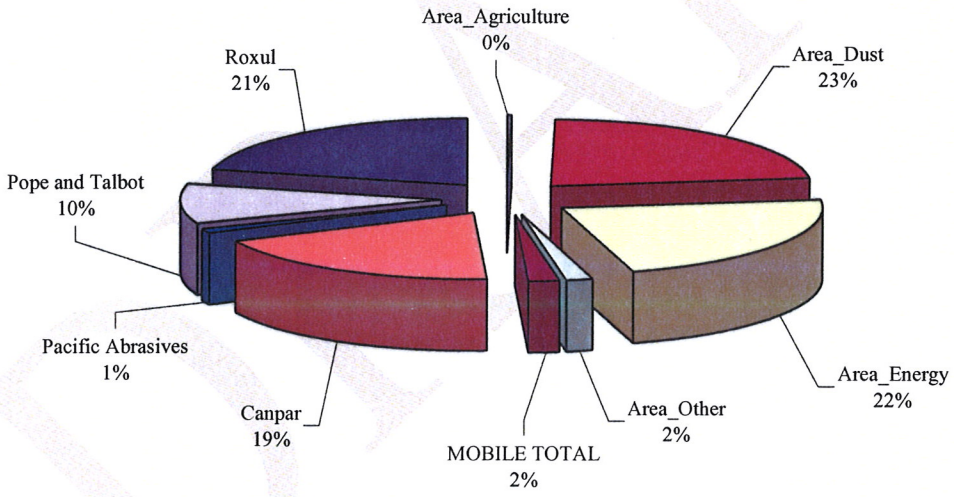
Figure ES-5: CO_2 Emissions by Source Type*



*Point Source (Industry) CO_2 emissions are included with the 'Area_Energy' source group.

The GFEI was developed within an emissions inventory database. The database allows the user control over both activity rates (such as kms of vehicle travel, cords of wood use etc) and seasonal adjustment rates. The database can be used by the BAQC to accomplish many other types of relative comparisons of interest. For example, selecting 'winter' in the database shows that winter-time emissions of VOC and PM differ substantially from emissions in other seasons (VOC lower and PM higher). Figure ES-6 provides the relative source contributions to total winter $PM_{2.5}$ emissions in the airshed. It can be seen that Area_Energy emissions, which primarily relate to woodstove use, are much more significant to the inventory total during this season.

Figure ES-6
$PM_{2.5}$ Emissions by Source Type in Winter



Over time, the BAQC may in fact develop improved or adjusted activity estimates for some of the emission sources. For example, the database will support testing of different 'scenarios', such as the replacement of older wood stoves with more advanced stoves.

However, the following cautions are necessary to consider when using or adjusting the database:

- Each source has an associated uncertainty. For those sources with relatively high uncertainty (for example, wind erosion from the slag piles), scenario testing has limited relevance. The uncertainties should always be considered before making adjustments to the activity rates.
- Some sources require an associated activity assumption such as average engine size. These assumptions are visible in the activity entry form. Such parameters may not be intuitive and should not be changed based on 'common sense'. The parameters are based on emissions modelling and represent harmonized conditions (for example, average hp inherently relies on typical usage patterns including idling periods).
- The upper and lower bounds shown in the reporting should not be added linearly to estimate an upper or lower bound for the entire inventory. Instead, they may be considered on an individual source basis (for example, 'what are the maximum possible annual emissions from highway road dust within the methodology used?'). The individual estimates in the inventory are based on professional judgment of the authors, and the total inventory uncertainty levels are estimated (and presented) using a non-linear approach described in Appendix A.
- Should the inventory be used for future dispersion modelling, the issue of suspendable versus transportable fugitive dust must be revisited. In effect, a dispersion model may or may not be able to reasonably account for the fraction of fugitive dust that is able to travel beyond the immediate vicinity of the source.

The GFEI is based on the current understanding of feasible air emissions estimation methodologies. For some sources, improved methodologies may become available in the future. The GFEI was constructed in such a way that updates can be achieved relatively easily.

1.0 INTRODUCTION

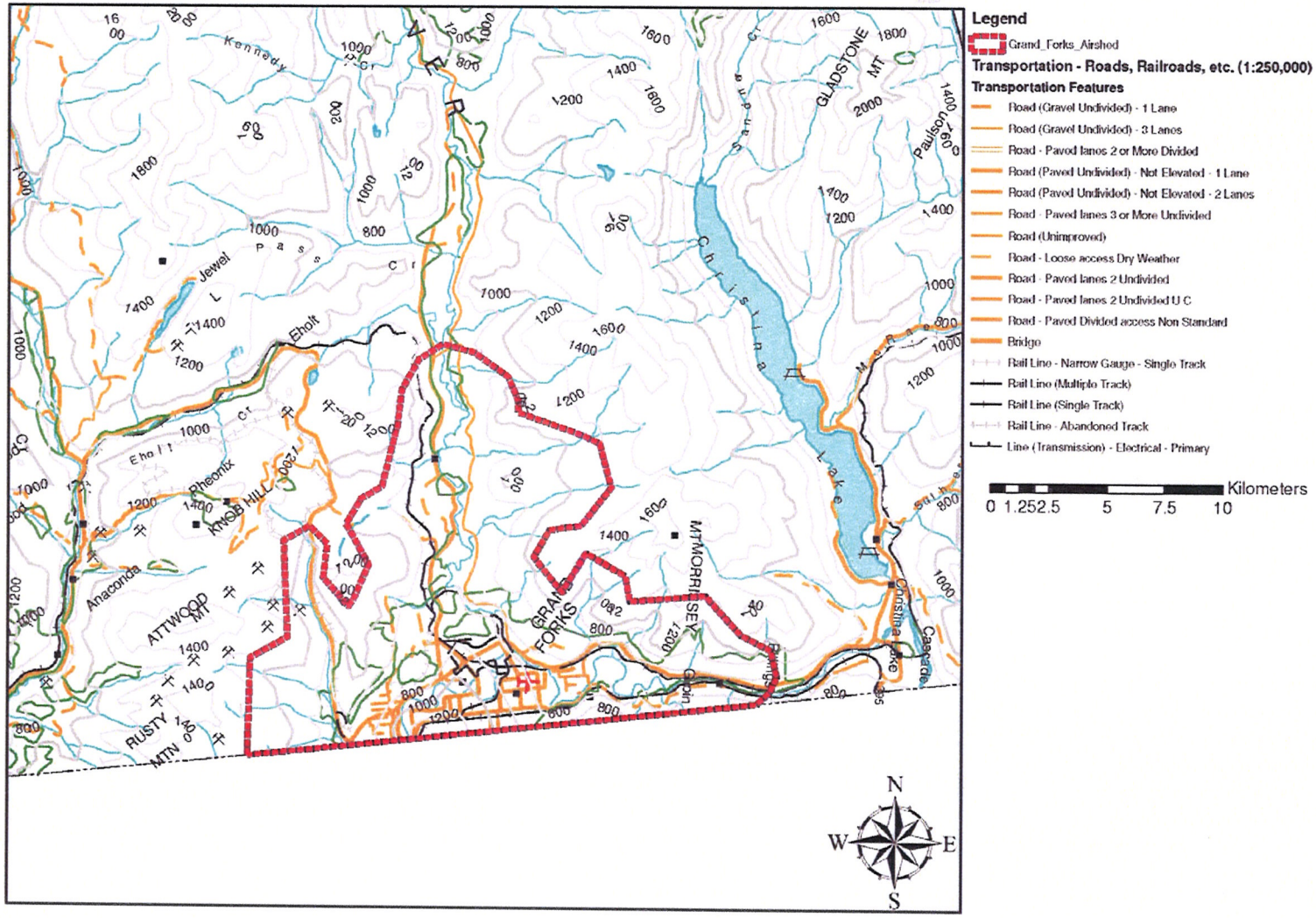
SENES Consultants Limited (SENES) was commissioned by the City of Grand Forks British Columbia (City) to complete an air emissions inventory of all significant natural, residential, commercial and industrial sources within a predefined airshed as shown in Figure 1.1. The airshed includes Grand Forks and additional rural areas adjacent to the city within Area D of the Regional District of Kootenay Boundary. This rather small mountain valley makes up a natural 'bowl' area that can limit the movement of air and pollutants within its boundaries. The year 2006 was chosen for the annual inventory baseline, with a backcast to 1995 and a forecast to 2012.

The City of Grand Forks had a population of 4,159 in 2006 (BC Statistics). The City provided SENES with an estimate of 3,213 to represent the rural population outside of the City yet within the airshed. Although the population and activity levels within the airshed may not be considered high when compared to other airsheds within B.C., the region can at times experience relatively high suspended particulate matter concentrations during stagnant weather conditions.

The Boundary Air Quality Committee (BAQC), made up of representatives from the City, the B.C. Ministry of Environment, local industry and community members, prepared criteria to define the scope of the emissions inventory. The following air contaminants were identified to be included within the inventory: nitrogen oxides (NO_x), sulphur oxides (SO_x), suspended particulate matter (PM), carbon monoxide (CO), hydrocarbons (HC), ammonia (NH_3) and the greenhouse gases carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Additionally, PM must be expressed as total suspended particulate (TSP), inhalable PM (PM_{10} – particulate matter of diameter 10 microns or smaller) and respirable PM ($PM_{2.5}$ – particulate matter of diameter 2.5 microns or smaller). The BAQC also requires estimates of secondary particulate matter such as sulphates, nitrates and organic aerosols, which are formed in the atmosphere over time due to chemical reactions involving primary air contaminants. These estimates have a much higher degree of uncertainty when compared to primary emission estimates.

The emission inventory is an Activity Based Inventory (ABI), meaning that emission estimates are achieved by multiplying an activity measure or estimate with appropriate emission factors. For example, emissions due to automobiles were determined by multiplying an estimate for the total kilometres of travel by motor vehicles within the airshed and emission factors in grams of pollutant per kilometre of travel. An exception was made for several industrial point sources. For these sources, emission amounts were directly available from either Ministry of Environment (MoE) permit levels or previous stack measurements.

Figure 1.1
Grand Forks Emissions Inventory Airshed Boundary (graphic provided by MoE)



A database model (in MS Access) was constructed to contain all of the activity data collected for the inventory, appropriate emission factors and the algorithms necessary to complete and organize the emission estimates. The emission calculations were linked to the activity data, meaning that a future change to the activity levels in the database will result in revised emission totals. In this way, the BAQC will be able to account for changes in emission behaviours in the near future (should they occur), or make use of better activity estimates if they become available. In addition, the database model may help in the process of preparing for airshed dispersion modelling, if in fact the BAQC determines that this is necessary for the future.

The collection of activity data represents the greatest challenge in the production of an accurate community emissions inventory. A number of data collection techniques were employed with the help of the BAQC, including:

- A residential survey of household vehicle and small engine use, use of heating fuels and backyard burning activities;
- Analysis of local vehicle registration data from the Insurance Corporation of British Columbia (ICBC);
- A local study of traffic patterns and volumes along Highway #3;
- Specific data requests to the large industries;
- A tour of the city and surroundings to note emission characteristics and related activity patterns;
- An assessment of statistical information relating to agricultural activity within the airshed; and,
- Operational information from City and Regional District staff.

Emission factors were determined that best relate to the conditions in the airshed. In general, these factors were determined through emissions modelling that accounts for the size and age of engines used in Grand Forks, or from the United States Environmental Protection Agency (EPA) 'AP-42' compilation of emission factors[1]. As requested by the BAQC, SENES determined an uncertainty measure for each activity level and emission factor used in the inventory. These uncertainty measures allow for an upper and lower bound estimate to be determined for the emissions attributable to each source.

The inventoried amounts are categorized by type of source. There are three main types of emission sources that historically have been used in the development of common air contaminant (CAC) emissions inventories. ***Point sources*** describe large industrial or commercial facilities with emissions from fixed locations such as stacks. ***Mobile sources*** are sources of emissions that are not fixed in location, and can be further grouped as on-road or non-road vehicles, or by

[1] See http://www.epa.gov/ttn/chief/ap42/

transportation category (for example, aircraft). Finally, ***area source*** designation includes all other types of emission sources, including sources that are spread out over a larger area or are aggregate representations of many minor individual emitters (for example, residential wood stoves or furnaces).

1.1 INVENTORY DATABASE TOOL

The GFEI has been constructed within an MS Access database that simplifies the interaction of activity levels, emission rates and reporting in a useful and dynamic manner. The tool is shown in Figure 1.2 with the two main components clearly identified. From the main welcome screen the user can enter activity for all the sources identified in the airshed, including seasonal activities levels and uncertainty factors. The inventory tool recalculates the emissions based on the activity levels entered and displays the results.

Figure 1.2 – Screen Shot of Database Inventory Tool

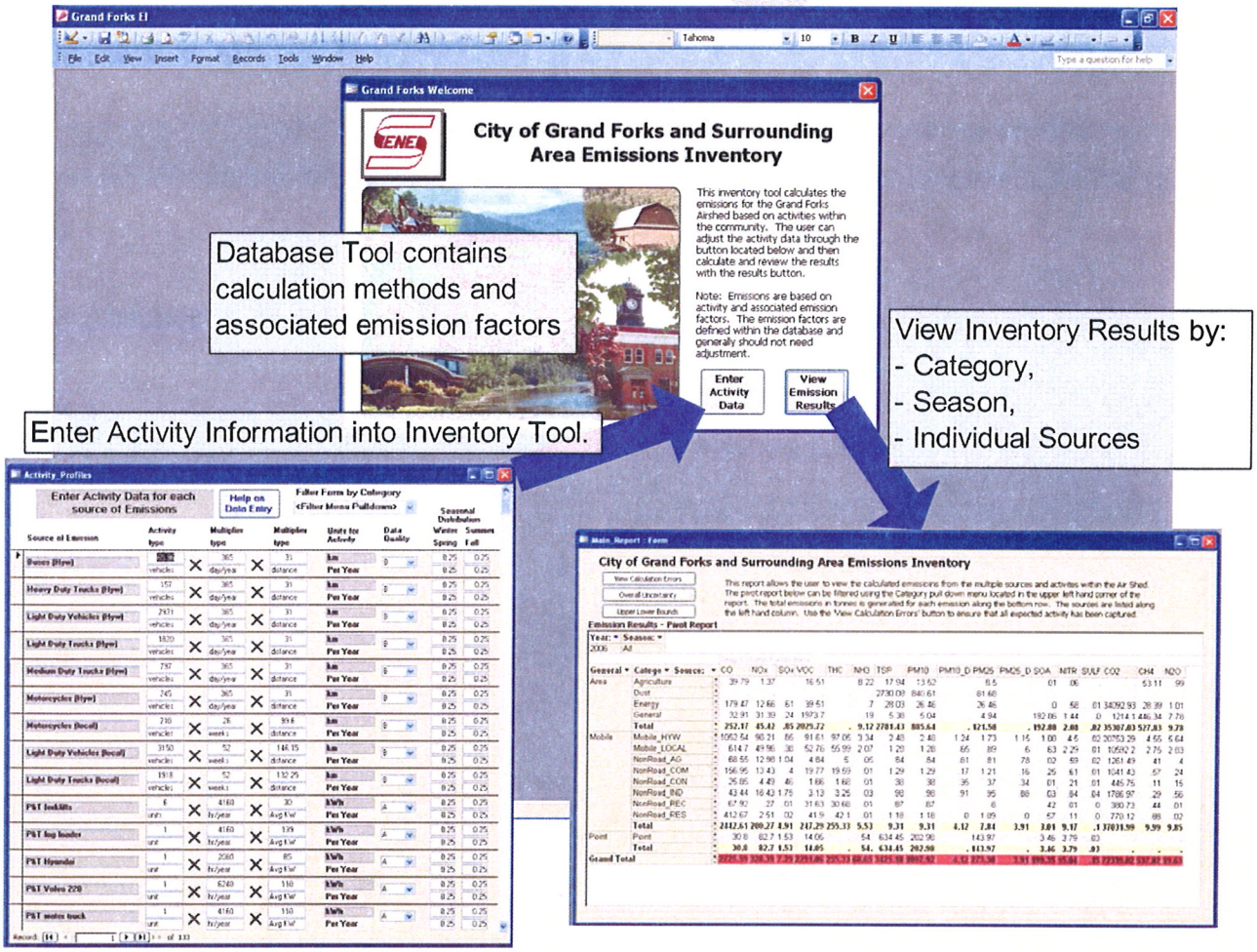
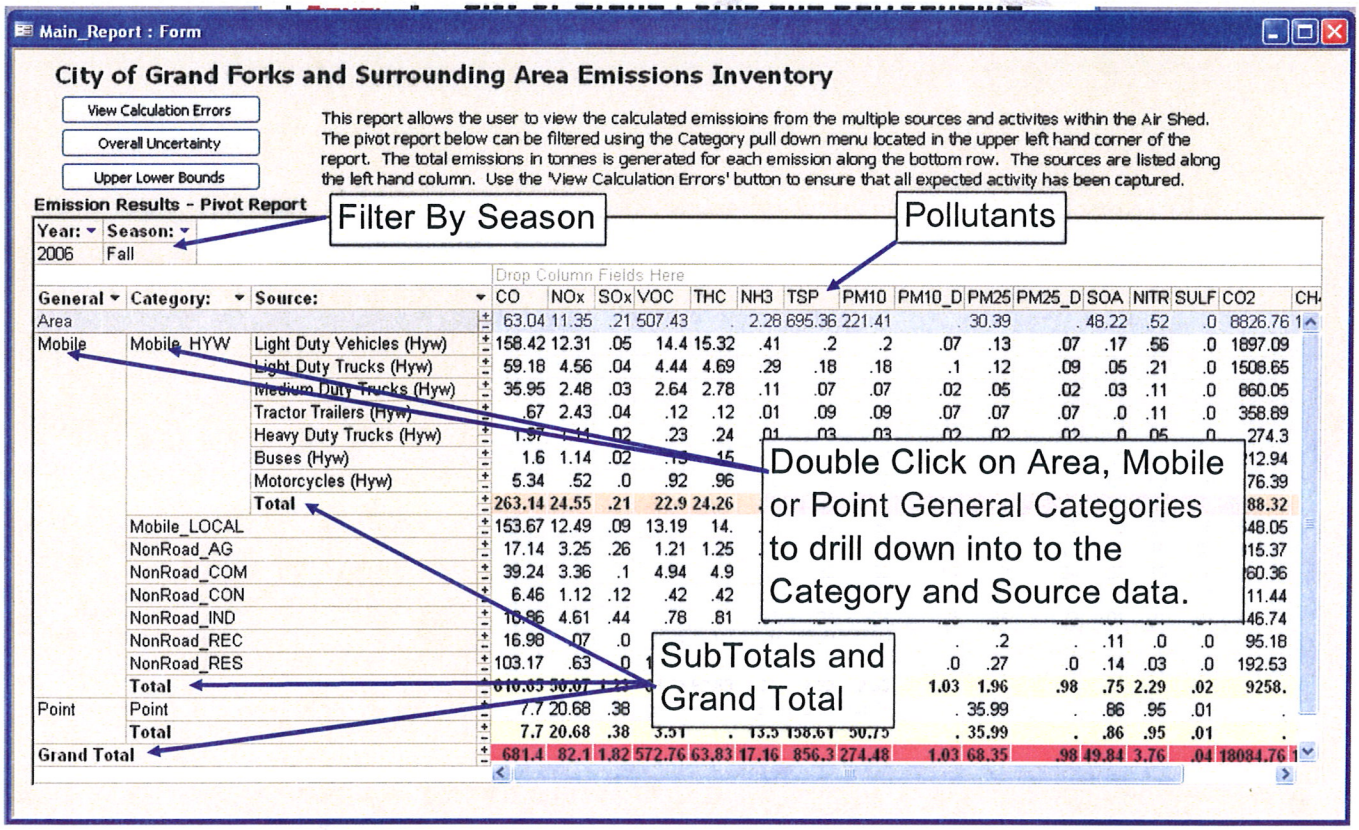


Figure 1.3 shows the database report form in more detail. The inventory results are displayed with internal pivot reports that allow the user to filter the data and view sources in logical groupings. In addition, the main report form allows the user to view any calculation errors that may arise (due to missing inputs or other issue), the overall uncertainty for the entire inventory and the expected upper and lower bounds on emission estimates for individual sources.

The dynamic nature of the inventory tool provides the user with an improved understanding of the emission results that would otherwise occur with simple static tables within a report. In addition, the structure provides an excellent platform for scenario testing due to changes in activity levels within the air shed.

Figure 1.3 – Screen Shot of Database Reporting within Inventory Tool



2.0 SUMMARY OF LOCAL DATA COLLECTION ACTIVITIES

SENES used a number of data collection strategies that were first proposed to the BAQC and subsequently refined based on local interpretation and availability of support. The collection method requiring the greatest level of combined effort was a survey of residential vehicle use, small engine use, fuels for heating and burning activities. Although a telephone delivery mechanism was proposed, the BAQC decided that use of the municipal newsletter would constitute a much more efficient form of delivery for the survey, with greater certainty of gaining a sufficient number of completed returns. A weakness of this form of delivery includes greater likelihood of response errors due to interpretation and greater uncertainty regarding appropriate representation. However, the community response to the survey was positive, and answers to most questions were sufficient to imply reasonable statistical error[2]. Some questions did not receive enough responses to assume a reasonable margin of error and were therefore not considered directly (and alternative estimates were determined).

Completion of the questionnaire was entirely voluntary and a total of 136 household responses were received from city residents (designated as urban respondents), and an additional 54 responses were received from residents within the airshed but outside of the city (designated as rural respondents). Average usage values were determined for urban and rural responses and a weighted average was then determined for the airshed as a whole (based on number of rural versus urban households).

The BAQC designated a number of volunteers to complete a basic traffic count form designed by SENES so that both traffic distribution (type of vehicle) and volume rates (vehicles per hour) could be assessed along Highway #3. This allowed characterization of the 'transient' highway traffic passing through Grand Forks.

Statistics Canada data were used to establish agricultural activity data in the Kootenay Boundary D Census Consolidated Subdivision (CCS), which was the greatest data resolution available from that source. Due to the small number of commercial farms in the Grand Forks area, Statistics Canada does not use a smaller subdivision to represent agricultural activity levels in and near the City. The Ministry of Agriculture was consulted for help to designate the appropriate ratio of Grand Forks agricultural activity to that within Area D CCS. The Ministry used local landuse information to determine the number of hectares of land used for agricultural purposes in the airshed.

[2] Assuming that the 190 questionnaire responses returned are unbiased, the true response for yes/no questions for the entire airshed is within 7% of the survey results 19 times out of 20.

Specific information requests were sent to both industry and fuel providers in Grand Forks. Although SENES had access to industrial stack data from Ministry of Environment (MoE) permit information and other assessment reports, there were additional operational activities that required independent assessment. The response from industry was very good, with all major industries providing detailed description of heavy duty trucking and off-road equipment usage volumes and patterns. However, responses from the fuel providers had not yet been received at the time of report preparation.

Finally, a number of email and phone requests were made to solicit additional activity information. In particular, energy consumption amounts were obtained from Terasen Gas and Fortis BC, while rail activity levels were established through communication with the Grand Forks Railway and Pope & Talbot.

2.1 RESIDENTIAL SURVEY

For ease of reporting, residential energy use is summarised by personal vehicle, residential heating, non-road engine and residential burning usage rates.

Table 2.1 provides a summary of personal vehicle use in the airshed for 2006, as derived from residential survey responses. In general, vehicle fuel consumption and kilometres of travel were higher for rural households than urban households (not shown in table). In addition, rural residents were more likely to own a truck than urban residents.

Table 2.1
Personal Vehicle Usage (from residential survey)

	Total in Community	Average Summer Use		Average Winter Use		Total Annual Fuel Cost	Total Annual Kms
		$/week	kms/week	$/week	kms/week		
Cars	3,150	$21.33	143.7	$23.41	148.6	$3,664,331	23,946,306
Trucks	1,918	$27.89	131.1	$31.98	133.4	$2,985,142	13,186,992
Motorcycles	210	$7.93	99.6	$0.00	0.0	$43,345	544,365

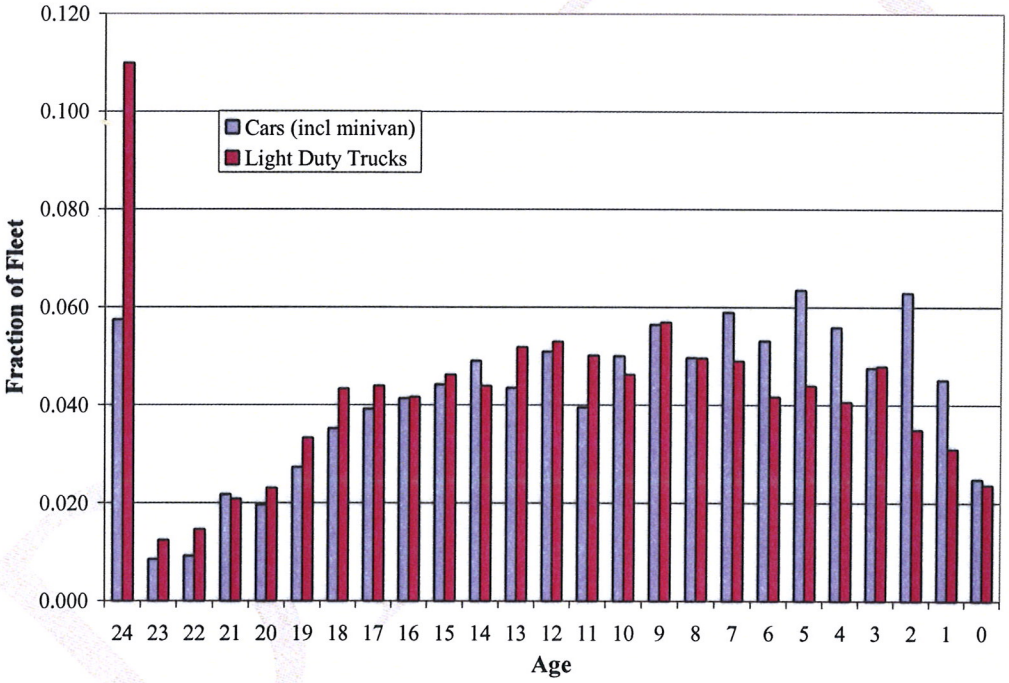
The 'Total in Community' summaries were a good match to Insurance Corporation of British Columbia (ICBC) registration data. The ICBC data for registrations within the airshed[3] showed that 3,257 cars and 1,884 light and medium duty trucks were registered in 2006. This comparison confirmed that vehicle responses from the survey were representative of the community.

[3]Articulation of registrations within the airshed was achieved through conveyance of appropriate postal codes to ICBC.

Estimates for kilometres of vehicle travel are required for both tailpipe emissions and fugitive road dust emissions. Based on estimates from the BAQC, SENES assumed that 85% of personal vehicle travel occurred on paved roadways, and 15% of the kilometres indicated in Table 2.1 occurred over unpaved roads[4].

The ICBC data were used to establish the distribution of cars and light duty trucks by age, so that appropriate emission rates could be determined for the local fleet. Figure 1 provides the fleet fraction by age, with '0' representing a 2006 model vehicle.

Figure 2.1
Residential Vehicle Distribution by Age



The vehicle distribution required for emissions modelling only spans 25 years[5]. Therefore, all vehicles of age 25 years or greater were characterized as 25 years old.

Table 2.2 provides a summary of residential heating patterns in the airshed. The survey responses indicated that little-to-no propane or fuel oil is used for residential heating within the airshed. A considerable amount of natural gas is consumed, as well as electricity (however,

[4] This is based on the observation that approximately 90% of roadways in the city are paved, and approximately 80% of the roadways in the regional district are paved.

[5] The US EPA MOBILE model uses the distribution of vehicle age over 25 years to establish emission rates in g/km. The Canadianized version 6.2C was used for all on-road vehicle emission rates.

electrical consumption for heating was not requested in the survey). It was also evident that very few pellet stoves exist in the community. Since total natural gas consumption in the airshed was available from Terasen, the survey-derived gas consumption rate was not used. The total annual consumption of wood (1976 cords) was used to characterize wood stove use. The survey also indicated that the wood species used for heating were largely fir and pine. Both the number of woodstoves and the amount of wood used per woodstove were substantially higher for rural residents compared to urban residents (not shown). The average consumption amount (2.28 cords/winter) is representative of all homes that rely on wood for any fraction of the total fuels used for heating. This includes homes that use wood on an infrequent basis (and mainly rely on natural gas or electricity).

Table 2.2
Residential Fuel Use for Heating

Appliance	Number of Households	Coldest Month		Entire Winter		Total Consumption
		Consumption ($)	Consumption (cords)	Consumption ($)	Consumption (cords)	
Natural Gas	0.6446	$174.24		$690.72		$1,430,495
Wood Stove	0.2694		0.88		2.28	1,976
Wood Pellet	0.0081	Insufficient Information				

The number and usage patterns for non-road engines in the community are summarised in Table 2.3. In four cases, lack of complete responses on the survey forms prevented determination of engine hours. In these cases, the total engine activity is likely quite small. Since non-road engine emissions can be significant in a community, the survey-derived activity rates were compared to estimates determined through an independent process. This is discussed in more detail in Chapter 4 and Appendix B.

Table 2.3
Residential Non-road Engine Use

Equipment	Engine Type	% households	summer hours/wk	winter hours/wk	Total Hours
4-wheeler	2-stroke	0.0081	5.50		16,812
	4-stroke	0.0285			
3-wheeler	insufficient information				
dirt bike	insufficient information				
snow machine	insufficient information				
lawn/garden tractor	n/a	0.1591	4.79		63,580
push mower	n/a	0.6470	1.93		104,435
ride on mower	n/a	0.2206	3.28		60,352
snow blower	n/a	0.0899		1.04	7,835
rotary tiller	n/a	0.1871	0.66		10,253
chain saw	n/a	0.2734	0.50	1.59	47,642
brush/weed trimmer	n/a	0.4454	1.36		50,452
generator	n/a	0.0367	1.25	6.49	23,767
leaf blower	n/a	0.0696	1.04		6,065
water pump	insufficient information				

Residential burning rates were determined in a relatively simple fashion. Since it would be unlikely that residents could describe the mass and composition of material burned, the survey asked whether or not open burning, barrel burning and smokehouse burning occurred and how many hours burning occurred by season. These results are shown in Table 2.4. No smokehouse use was reported. Additional discussion relating to assumed amount and composition of material burned is provided in Chapter 3.

Table 2.4
Residential Burning Rates

	% Households	Average Summer Hours	Average Winter Hours	Total Annual Hours for Community
Open Burn	0.2238	2.16	4.58	4,845
Burn Barrel	0.1424	1.30	1.17	1,131

2.2 HIGHWAY TRAFFIC COUNTS

Transient highway traffic was treated separately from residential traffic in the inventory. This presented a small problem, since some of the traffic on the highway at any given time would likely be residential in origin. SENES obtained a traffic count summary that was compiled by the Ministry of Transportation and Highways (MoTH) for July 22, 2005. The vehicle counts

were made in both directions at the corner of Highway #3 and 27th Street, which is near the western edge of town. The counts also included those vehicles that turned on or off of the highway, and these counts were ignored, since they would likely be representative of local traffic. Six hours in total were included in the counting exercise and an average one-way traffic volume of 3880/day was determined by multiplying the MoTH average hourly traffic rate by 16 hours.

Other traffic studies have indicated that multiplying the peak hour rate by 10-12 can provide a reasonable estimate of total daily traffic volume. This method yields a daily one-way volume between 3300-4000, based on the peak MoTH data. The 3880/day estimate was used to represent summer traffic volume for the GFEI.

To account for seasonal differences, a traffic counting exercise that was performed by the Focus Corporation in January 2005 was considered. This counting occurred on a Saturday, along Highway #3 (and 5th Street), over several different 15 minute periods. The average peak hour volume indicated by the work was 325 vehicles/hour (one way). One counting period representative of peak summer traffic on a Saturday within the city (near 5th Street) was included in the BAQC summaries. This count indicated an average one-way volume of 504 vehicles/hour. The ratio of the winter count average completed by Focus to the BAQC summer count (approximately 0.65) was considered a reasonable estimate of a non-summer reduction ratio that could be used to estimate the traffic volumes on Highway #3 for seven months of the year. The daily volume determined by the BAQC counts described above was used for the other five months of the year. A resulting annual average of 3088 one-way trips per day was used for the inventory activity rate.

The local traffic counting exercise conducted by BAQC volunteers was primarily designed to establish the distribution of highway vehicles by type. These counts were made just outside of the City to screen out local traffic to the degree possible. The average hourly one-way traffic volume derived from these counts was 377, which is supportive of the MoTH derived daily total.

The local counts indicated an average traffic distribution as follows:

- 3.9% motorcycles;
- 46.7% cars (incl minivans);
- 29.0% light duty trucks (incl SUVs);
- 12.7% medium duty trucks;
- 2.5% heavy duty trucks;
- 1.6% buses; and,
- 3.7% tractor trailers.

This distribution was used to establish representative emission rates for transient traffic. However, it was clear that some of the tractor trailers counted were local in origin/destination. Industry tractor trailer trips were accounted for separately based on information provided by the industries (see Section 2.4). Although tractor trailer trips represent a small fraction of transient highway trips, total emissions from these vehicles for some pollutants are much higher than from other sources. To more reasonably account for the tractor trailer contribution to average transient highway traffic emission rates, a lower assumption of 2% was used in the highway fleet distribution.

An estimate of 31 km was used to represent the length of highway passing through the airshed. Additional discussion of emission characteristics for transient highway traffic is provided in Chapter 3.

2.3 STATISTICAL DATA

Table 2.5 provides a summary of agricultural activity measures available from Statistics Canada for the Kootenay Boundary D Census Consolidated Subdivision (CCS). The B.C. Ministry of Agriculture estimated that a total of 7.1 square miles (or 1840 ha) were used for agricultural purposes in the community[6]. The ratio of agricultural area within the airshed and total agricultural area in the CCS was used to derive estimates for all agricultural activities needed for the inventory emission estimates. Table 2.5 shows that an alternative ratio based on number of farms would produce similar (but lower) activity estimates for the community. Additional discussion relating to engine size, usage patterns and other necessary characteristics is provided in Chapter 3.

[6] Personal communication with Carl Withler, BC Ministry of Agriculture. October 4, 2007.

Table 2.5
Derived Agricultural Activity Estimates for the Airshed

Measure	Kootenay Boundary D CCS	EI Airshed	Units	Ratio
Total Area of Farms	9190	**1840**	ha	0.20
Total Farms < 10 acres	131		farm	
Total Farms > 10 acres	74	**12**	farm	0.16
Total Area in Tillage	469	**93.9**	ha	
Total Area with Manure	147	**29.4**	ha	
Hogs/Pigs Farms	2			
Cattle Ranching Farms	35			
Greenhouse/Nursery	12			
Cattle	2579	**516**	head	
pigs	84	**17**	head	
sheep	361	**72**	head	
horses	278	**56**	head	
hens/chickens	1757	**352**	head	
tractors	326	**65**	unit	
farm trucks	212	**42**	unit	
pickup and van	165	**33**	unit	
other farm truck	115	**23**	unit	
swathers	72	**14**	unit	
balers	74	**15**	unit	

LEGEND: Local Estimate
Derived Estimate

2.4 INDUSTRY DATA REQUESTS

Due to competition and confidentiality issues, industry activity levels are summarised here for the community as a whole. Table 2.6 provides a summary of all activity information that was gained through letter requests and phone conversations.

Table 2.6
Industry Heavy Duty Equipment Activity

Equipment	Trips Through Community	Trips Intra Community	Total Hours
Heavy Duty Highway Truck	36,051	14,500	n/a
Forklift	n/a	n/a	25,056
Loader/Mover	n/a	n/a	25,213
Facility Truck	n/a	n/a	1,311
Switch Locomotive	n/a	n/a	1,043
Line Haul Locomotive	n/a	n/a	521

The activity rates shown in Table 2.6 have relevance to both exhaust emissions and fugitive dust emissions. Truck trips were characterised as 'through community' (total travel of 32 km) or 'intra community' (total travel ranging from 1 km to 6 km). The highway trucks were characterized by weight based on number of axles. The locomotive engines were characterized based on comments provided by the Grand Forks Railway[7]. Additional discussion relating to engine size, usage patterns and other necessary characteristics is provided in Chapter 3.

2.5 ENERGY CONSUMPTION DATA BY SUPPLIER

Table 2.7 provides a summary of energy consumption data provided by the energy providers in the community. The amounts are representative of calendar year 2006, with the exception of Terasen Gas natural gas amounts, which are representative of 2005 (Terasen is currently extracting the 2006 amounts and may be able to provide these in the future). The Terasen data provided to SENES showed that there were 1,911 residential customers in 2005, which supports that the survey responses gained from residents were reasonably accurate (the survey indicated 2,071 households used natural gas).

Table 2.7
Community Energy Consumption Totals

Provider	Consumption By Account Type				Total	Units
	Residential	Municipal	Commercial	Industrial		
Fortis	713,802	0	244,244	107,089,930	108,047,976	kWh
GF Electric	100,000	100,000	100,000	0	300,000	kWh
Terasen Gas	134,179	0	76,678	426,228	637,085	GJ

[7] Personal communication with Rick Hammond, GF Railway. October 11, 2007.

3.0 EMISSION RATES AND RELATED ASSUMPTIONS

With the exception of point sources, all other emission sources required emission factors or emission equations to use with the activity data described in Chapter 2. Point source emission estimates were obtained directly from MoE data and are presented in Chapter 4.

Qualitative discussion is provided for the uncertainty associated with some of the emission factors described in this section. A full listing of numerical uncertainty values for both emission factors and activity rates is provided in Appendix A.

3.1 AREA SOURCES

The 'area source' category is used to represent emission sources that span a sizeable area or a type of emission source that has many point emitters that cannot be characterised on an individual basis. An example of an area source is residential furnace use: there are no data available for individual furnaces, but total gas consumption is available for all furnaces combined.

In some cases, there is a greater level of uncertainty associated with area source emission factors than with other sources. This is due to the fact that the source characteristics commonly cannot be characterised to the level of other sources (for example, cars and trucks). There are many area sources that have little significance to the full emissions inventory. Rather than ignoring these sources, SENES applied a simplified estimation methodology that borrows from earlier investigation completed by Metro Vancouver for their most recent emissions inventory of the Fraser Valley[8]. Additionally, open burning and agricultural burning emission rates from AP-42 were used, which are identical to the rates used by Metro Vancouver. Emission factors for general area sources are shown in Table 3.1.

Table 3.1 includes emission factors for several sources that were considered to emit zero emissions for 2006. These were included in the report in the event that the City may wish to consider related emissions that may have occurred in other years (for example, due to forest fires or prescribed burning). Although the biomass sources (burning) clearly would have CO_2 emissions along with other air contaminant emissions, biomass sources are considered carbon neutral due to the assumption that new growth captures the emitted carbon over an extended time frame.

[8] Greater Vancouver Regional District, 2003. 2000 Emission Inventory for the Canadian Portion of the Lower Fraser Valley Airshed. Produced in partnership with the Fraser Valley Regional District.

Table 3.1
General Area Source Emission Factors

Source	Emission Factors (kg/base quantity) and Base Quantities											
	NO_x	SO_x	TSP	PM_{10}	$PM_{2.5}$	CO	VOC	NH_3	CO_2	CH_4	N_2O	Base Quantity
Agricultural Sources												
Fertilizer appln			2.2	1.1	0.3			136.0			19.60	ha/year
Manure appln											31.40	ha/year
Pesticide			1.7	0.8	0.2							ha/year
Tilling Soil			15.8	3.3	0.7							ha/year
Land clearing	3.0	0.5	8.0	8.0	8.0	42.0	15.0	0.3	-	6.5	16.00	tonne material
cattle			15.1	9.6	1.5		18.3	14.2		73.3		head/year
Cattle manure										19.3	0.12	head/year
Pigs			1.2	1.0	0.2		0.2	7.3		0.9		head/year
Pig manure										3.9	0.02	head/year
Sheep			1.5	1.0	0.2		1.4	2.0		5.7		head/year
Sheep manure										0.3	0.00	head/year
Poultry			0.4	0.3	0.0		1.6	0.4		6.3		head/year
Poultry manure										0.2	0.00	head/year
Horses			15.1	9.6	1.5		4.1	8.7		10.0		head/year
Horse manure										2.0		head/year
Burning												
Forest fire	1.5	0.0	17.0	12.0	4.3	101.0	13.0	0.3	-	5.7	0.29	tonne material
Prescribed	2.0	0.0	13.3	10.3	9.4	111.1	12.0	0.3	-	6.1	0.23	tonne material
Agricultural	2.0	0.0	11.0	11.0	11.0	58.0	9.0	-	-	2.7	-	tonne material
Open burn	3.0	0.5	8.0	8.0	8.0	42.0	15.0	0.3	-	6.5	16.00	tonne material
Miscellaneous												
Fuel marketing							0.2					litre/year
Human perspiration								0.3				capita/year
Dog perspiration								2.5				capita/year
Cat perspiration								0.8				capita/year
Charbroiling of meat			40.0	40.0	40.0							capita/year
Consumer products							2.8					capita/year

The emission factors for open burning in Table 3.1 require an estimate of mass consumed rather than hours burning occurred (as was captured in the residential survey). A previous study (with survey) conducted in New Zealand found that for those families that burned household or yard refuse, an average of 5 burns per winter occurred[9]. A further assumption of 174 kg per burn was applied.

The New Zealand work found that a relatively small percentage of households carried out open burning (4%). Work previously conducted in Prince George BC indicated that approximately 8% of households conducted open burning[10]. The implications from the Grand Forks survey include a higher percentage of households that carry out open burning.

[9] Environet, 2004. Taupo Emission Inventory 2004. Prepared for Environment Waikaito, New Zealand.
[10] Fudge, D., 1996. Appendix D: Emission Inventory Assumptions and Factors. Prepared for the Prince George Airshed Technical Management Committee, October 11, 1996.

An assumption of 100 kg of material consumed for every hour of residential burning (open burning or barrel burning) was applied. Both the residential burning activity rate and the residential burning emission factors were considered to have a relatively high degree of uncertainty in the Grand Forks inventory.

Other inventory efforts elsewhere have shown that agricultural burning can be a significant contributor to total particulate within an airshed that has a considerable amount of agricultural activity. SENES was not able to obtain any specific information regarding agricultural burning in and near Grand Forks. The 2000 emission amounts in the BC Inventory (allocated to the Grand Forks airshed) that relate to agricultural burning indicate that 686 tonnes of material were consumed locally in that year. This amount was assumed to be reasonable for 2006. A check of this amount against the agricultural burning rates in the Lower Fraser Valley suggests that the Grand Forks burning activity in terms of material consumed per hectare is twice as high on average. However, the uncertainty associated with agricultural burning in the GFEI is also quite high.

Fugitive road dust emission factors require particular consideration, since road dust emissions are significant to the inventory and the equations used to determine locally-appropriate emission rates are very sensitive to input parameters. A full accounting of the methodology and equations used to estimate road dust is provided in Appendix A. SENES determined locally representative inputs to the emissions equations, as described in Table 3.2.

Table 3.2
Sensitive Input Parameters for EPA Fugitive Dust Equations

Base silt loading (sL) – highway 3	0.10 g/m2
Base silt loading (sL) – other paved roads	0.60 g/m2
Average vehicle weight in tons (W) – highway 3	3.0 tons
Average vehicle weight in tons (W) – other roads	2.7 tons
Average vehicle weight in tons (W) – industrial sites	40 tons
Average silt % (s) - industrial sites	8.4 %
Average silt % (s) - unpaved roads	6.0 %
Surface moisture content (M) – unpaved roads	5.0 %

The silt loading to paved roads and percentage of silt in gravel on unpaved roads used in the GFEI are derived from EPA documentation, since no local tests have been done in Grand Forks. Even with a testing program, experiences from emissions inventory work conducted in Prince

George B.C. show considerable uncertainty with the silt parameters[11]. Annual average fugitive dust emission factors for roads in Grand Forks (expressed as grams of dust per vehicle kilometre travelled, or VKT) are provided in Table 3.3.

Table 3.3
Annual Fugitive PM Emission Factors

Road Type	Base Emission Factors (g/VKT)		
	TSP	PM_{10}	$PM_{2.5}$
Highway 3	4.13	0.69	0.02
Residential, paved	14.77	2.73	0.32
Residential, unpaved	284.42	107.36	10.68
Industrial, unpaved	1158.58	330.25	33.02

The uncertainty associated with the emission rates in Table 3.3 is relatively high. In addition, these rates should be considered reasonable only for average emission rates over the year and would certainly be too low for shorter periods following the application of gravel or other material to improve traction in the winter.

The "Industrial, unpaved" emission rates were used to represent the P&T log loader in addition to the industrial tractor trailer trips for all industries. In reality, the unpaved surfaces the log loader moves across within the yard likely do not relate well to some of the assumptions applied to unpaved roads (e.g., silt content). However, no alternate parameters were available to use.

It is also important to recognize the difference between suspendable and transportable fugitive dust emissions. A comprehensive review of fugitive dust was conducted in 1998, involving a panel of experts including several members of the EPA[12]. The goal of the review was to establish a better understanding of fugitive dust emission levels and resultant ambient concentrations due to common industrial activities such as heavy machinery movements. Of interest to the GFEI, one statement the panel made was that the majority of coarse suspended particulate matter (i.e., TSP and $PM_{2.5-10}$) remains within one to two metres above the ground. Previous studies have shown that 60 – 90% of suspended PM_{10} remain within 2m of the ground, and that deposition to the ground or impaction to a vertical structure occurs within a few minutes after suspension. Consequently, there is often a large disparity between the magnitudes of fugitive dust emissions as calculated in emission inventories versus their relative magnitude as observed in ambient air quality samples.

[11] See details on current progress at http://web.unbc.ca/~jspagnol/

[12] Watson, J.G., and J.C. Chow, 2000. *Reconciling Urban Fugitive Dust Emissions Inventory and Ambient Source Contribution Estimates: Summary of Current Knowledge and Needed Research.* Desert Research Institute, DRI Document No. 6110.4F, May, 2000.

For this reason, reduction factors of 60% and 75% were applied to the fugitive PM_{10} and TSP emission rates in Table 3.3 respectively. No reductions were applied to the $PM_{2.5}$ emission rates, since, due to the small size of the particles, respirable PM is considered to be dispersed in a manner similar to a gas in the atmosphere. This effectively means that only 40% and 25% of the fugitive PM_{10} and TSP dust estimates were considered to be released into the airshed (with the remaining amounts assumed to be deposited near their sources).

Generalized emission equations from the EPA were also used for handling and stockpiling of slag material in Grand Forks. These emissions are representative of actions at the slag pile itself and not at the Pacific Abrasives facility (emissions at this location are represented by MoE permit-related point source emissions, as described in Chapter 4). Additional description of the estimation methods is provided in Appendix B. Table 3.4 provides the emission factors determined for the inventory.

Table 3.4
Fugitive Dust Emission Rates for Transfer and Storage of Slag Material

Activity	Base Emission Factors		
	TSP	PM_{10}	$PM_{2.5}$
Material Transfer (kg/tonne)	0.0393	0.0186	0.0028
Pile Erosion (kg/ha)	1,703	806	122

As is the case for road dust emission rates, there is considerable uncertainty associated with the slag material rates shown in Table 3.4. One source of uncertainty in particular is the silt content of slag material (assumed to be 5.3% based on EPA suggestions for iron and steel slag material). SENES assumes this value is reasonably representative of the slag pile material in Grand Forks.

Additional fugitive dust emissions not accounted for in the equations presented here would be caused by the wood products movement from P & T to CanPar. Specifically, these actions can be described as follows: trucks are loaded by covered chute at P & T, the trucks travel to CanPar to unload by dumping to a stockpile and a bulldozer shapes the pile for longer term storage. It must be noted that other wood product conveyance mechanisms, such as the wood chip rail car loading system, sawmill exhaust, chip conveyer etc. at P & T are represented in the MoE permit-related point source emission levels.

SENES was informed that most of the wood product transferred is coarse, which would result in relatively low fugitive emission levels in general. However, the truck dumps and bulldozer actions at CanPar may have a greater likelihood for fugitive emissions (due to uncovered movements and machinery pulverizing the wood product). During a site visit by SENES in early August, fugitive dust emissions were in fact evident one morning from the wood product storage

bins at CanPar. The emissions were short lived due to the action of water sprays that surround the yard. Once the sprays were in operation (and after), the emissions dropped to insignificant levels. The CanPar permit requires dust mitigation within the operation area. SENES does not have sufficient information to account for these additional dust emission sources, even as a rough approximation.

Table 3.5 provides emission factors for use of heating fuels. The wood stove and pellet stove emission factors derive from a previous study of wood stove emissions in B.C. conducted by the Ministry of Environment[13]. The wood stove factors require a wood density estimate of 472 kg/m^3, representative of both fir and pine species, which were identified in the residential survey as the most common wood fuels used. The factors also require a conversion of wood volume in cords (as determined from the residential survey) to cubic metres. A conversion value of 2.27 m^3/cord was available from the same provincial study.

The natural gas emission factors originate from AP-42 (Ch 1.4). SENES adjusted the SO_x emission rates based on the local sulphur content of natural gas (as determined by Metro Vancouver in their 2000 Inventory assessment). SENES further assumed that commercial use of natural gas is appropriately characterised with the use of 'large boiler' emission rates from AP-42.

The common air contaminant emissions for natural gas use by industry are included in the provincial point source permit levels (since natural gas is used to fire kilns and boilers, which are included in the permit levels). Therefore, the CAC emissions for industrial use of gas are not accounted for within area sources. However, the provincial permit levels do not cover GHGs, and therefore the GHGs associated with industrial use of natural gas are included within area sources, as indicated in Table 3.5.

Table 3.5
Emission Factors for Heating Fuels

Source	Emission Factors (kg/base quantity) and Base Quantities											
	NO_x	SO_x	TSP	PM_{10}	$PM_{2.5}$	CO	VOC	NH_3	CO_2	CH_4	N_2O	Base Quantity
Space Heating												
Nat' gas-residential furnace	1504.0	31.5	121.6	121.6	121.6	640.0	88.0	7.8	1920000	36.8	35.2	million m3
Nat'l gas-commercial	2240.0	31.5	121.6	121.6	121.6	1344.0	88.0	7.8	1920000	36.8	35.2	million m3
Nat'l gas-industry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1920000	36.8	35.2	million m3
Woodstove; advanced tech	1.4	0.2	5.1	4.8	4.8	70.4	7.0	0.3	0	6.8	0.2	tonne wood
Woodstove; catalytic	1.4	0.2	5.1	4.8	4.8	70.4	7.0	0.3	0	6.8	0.2	tonne wood
Woodstove; conventional	1.4	0.2	24.6	23.2	23.2	100.0	35.5	0.3	0	15.0	0.2	tonne wood
Wood pellet stove	1.4	0.2	1.2	1.1	1.1	8.8	1.5	0.3	0	15.0	0.2	tonne wood

[13] B.C. Ministry of Environment, 2004. *Residential Wood Burning Emissions in British Columbia*. Revised May 17, 2005.

Due to the fact that burning does not occur at the regional landfill within the airshed, air emissions from the landfill are insignificant to the inventory, with the exception of GHGs. SENES used the EPA LandGEM model (V 3.02) to estimate CO_2 and organic compound emissions (most notably methane) from the regional landfill in the airshed. The model is described in its documentation as a 'screening level' model based on empirical data from U.S. landfills (although local field test data can be used in place of model defaults if available)[14].

The regional district was able to provide a rough estimate of landfill opening year (1981) and material inputs (5,600 tonnes/year in 1996, 5,199 in 2006). SENES assumed 5,600 tonnes/year input from 1981 – 1999 with 5,200 tonnes/year from the year 2000 on. Landfill emission estimates for 2006 are provided in Table 3.6. Due to use of default parameters in LandGEM, the emission estimates were considered to have a high degree of uncertainty.

Table 3.6
Annual Landfill Emissions*

Year	Waste Accepted (Mg/year)	Waste-In-Place (Mg)	Total landfill gas (Mg/year)	Methane (Mg/year)	Carbon dioxide (Mg/year)	NMOC (Mg/year)
2006	5,200	137,600	1,656.6	442.5	1,214.1	19.0

*NMOCs are non-methane organic compounds

Biogenic emissions within the airshed were estimated using the Global Biosphere Emissions and Interactions System (GloBEIS) model (V 3.1), which was developed by the National Center for Atmospheric Research (U.S.) and Environ International Corporation. Environment Canada has used this modelling system in the past for national and provincial biogenic emission estimates. The model requires landcover data, which were supplied by the Ministry of Environment for the area defined as the Grand Forks airshed. Additional information relating to the GloBEIS simulation is provided in Appendix B. Annual emission estimates of nitrogen oxide (NO), isoprene (ISOP), total monoterpenes (TMT) and other volatile organic compounds (OVC) are presented in Table 3.7.

Table 3.7
Annual Biogenic Emission Estimates for the Airshed (kg released)*

NO	ISOP	TMT	OVC
29,710	106,473	876,227	772,917

* NO – nitrogen oxides, ISOP – isoprene, TMT – total monoterpenes, OVC – other volatile organic compounds

[14] http://www.epa.gov/ttn/chief/efpac/efsoftware.html

3.2 MOBILE SOURCES

There were several different sets of mobile emission factors used for the emissions inventory. The mobile factors account for exhaust emissions and not the additional dust emissions that can be released with vehicle movements over roadways (which are accounted for within area sources). The emission rates derive from emission factor modelling, which incorporates fleet characteristics (age of engines, size of engines, use of gasoline versus diesel, etc.). The accuracy of the emission factors relates to the availability and quality of inputs used in modelling. In the case of residential vehicles, the inputs were of a high quality and therefore the emission factors have a relatively low uncertainty when applied to fleet emissions over the year. In the case of non-road engines, some model inputs such as age were not available and therefore assumptions had to be used - leading to higher uncertainty. In all cases, the degree to which assumptions had to be applied is reflected in the established emission factor uncertainty measures (which are expressed in Appendix B).

3.2.1 Residential and Highway Traffic (On-road)

The EPA MOBILE 6.2C emissions model was used to determine on-road emission factors in grams of pollutant per kilometre of travel. The model is the Canadian version of the U.S. EPA's model which incorporates different vehicle characteristics and driving conditions which are specific to Canada.

Table 3.8 provides the on-road emission factors for both the fleet of transient vehicles travelling along the highway and the local fleet travelling the roadways within the airshed. The 'KeyID' field shows the vehicle class mapping that was used to relate local and highway vehicles to the available vehicle classes in the MOBILE 6.2C emissions model.

Table 3.8
Vehicle Exhaust Emission Factors used for the Grand Forks Inventory

MOBILE 6.2c Highway Traffic Emission Factors (g/km)

KeyID	CO	NOx	SOx	VOC	TOG	THC	TSP	NH3	PM10	PM25	CO2	CH4	N2O	PM10 frac	PM25 frac
HDB	8.573	6.085	0.112	0.797	0.844	0.823	0.191	0.020	0.191	0.164	1,141	0.040	0.032	0.823	0.886
HDV(4)	4.428	2.502	0.055	0.518	0.545	0.534	0.069	0.020	0.069	0.053	618	0.022	0.091	0.582	0.702
HDV(8b)	1.889	6.816	0.119	0.341	0.357	0.345	0.240	0.017	0.240	0.202	1,007	0.015	0.030	0.874	0.956
LDT(1,2)	11.494	0.887	0.009	0.862	0.924	0.911	0.034	0.056	0.034	0.024	293	0.044	0.114	0.544	0.706
LDT(3,4)	15.947	1.101	0.013	1.171	1.249	1.233	0.032	0.051	0.032	0.021	381	0.052	0.143	0.265	0.383
LDV	19.108	1.485	0.006	1.737	1.868	1.847	0.024	0.050	0.024	0.015	229	0.086	0.053	0.363	0.536
MC	7.708	0.751	0.002	1.332	1.424	1.388	0.023	0.007	0.023	0.013	110	0.081	0.002	0.000	0.000

MOBILE 6.2c Local Traffic Emission Factors (g/km)

KeyID	CO	NOx	SOx	VOC	TOG	THC	TSP	NH3	PM10	PM25	CO2	CH4	N2O	PM10 frac	PM25 frac
HDV(8b)	1.729	6.392	0.117	0.320	0.335	0.324	0.233	0.017	0.233	0.196	988	0.014	0.029	0.871	0.955
LDT(1,2)	19.660	1.356	0.010	1.714	1.833	1.806	0.044	0.049	0.044	0.033	291	0.082	0.109	0.634	0.774
LDV	14.523	0.996	0.005	1.174	1.270	1.257	0.017	0.058	0.017	0.009	230	0.067	0.056	0.097	0.178
MC	10.332	0.938	0.002	3.048	3.153	3.089	0.023	0.007	0.023	0.013	110	0.085	0.002	0.000	0.000

For highway traffic, the following mapping was used:

Tractor trailers – HDV(8b);
Buses – HDB;
Heavy duty trucks – HDV(4);
Medium Duty Trucks (e.g., 1 ton) – LDT(3,4);
Light Duty Trucks – LDT(1,2);
Passenger cars and minivans – LDV;
Motorcycles – MC

For local traffic, the following mapping was used:

Tractor trailers – HDV(8b);
Trucks – LDT(1,2);
Cars and minivans – LDV;
Motorcycles – MC

Table 3.8 also shows the fraction of coarse and fine particulate matter (PM_{10} frac and $PM_{2.5}$ frac) that relate to diesel combustion rather than gasoline use. For example, heavy duty tractor trailer $PM_{2.5}$ emissions on the highway are 95.6% diesel particulate.

3.2.2 Non-road Vehicles and Engines

Table 3.9 provides the emission factors for non-road vehicle and engine use. In this case, the 'KeyID' field shows emission factors that relate to agricultural vehicles/engines ('Ag'), commercial vehicles/engines ('Com'), construction vehicles/engines ('Con'), industrial vehicles/engines ('Ind') and residential vehicles/engines ('Res'). The emission factors were developed from the EPA NONROAD emissions model (2005 version), with the inherent use of average engine size and engine age distribution from the model. These model averages relate to the State of Washington for engine size and the U.S. as a whole for engine age distribution. There were no Canadian sources of information available that could replace the NONROAD model assumptions.

As with the on-road motor vehicle emission rates, PM_{10}_frac and PM_{25}_frac represent the fraction of PM emissions that relate to diesel combustion. Further description of the non-road modelling and a comparison of emission estimates with those generated from an alternate methodology are presented in Appendix B.

Table 3.9
Non-road Vehicle and Engine Emission Factors*

NONROAD Emission Factors (g/kw-hr) (g/km for Dirtbikes and ATV)

KeyID	CO	NOx	SOx	VOC	TOG	THC	TSP	NH3	PM10	PM25	CO2	CH4	N2O	PM10 frac	PM25 frac
AG-Balers	97.461	6.600	0.110	8.002	8.466	8.276	0.155	0.010	0.155	0.148	578	0.574	0.043	0.738	0.748
AG-FarmTruck	72.787	5.838	0.209	3.920	4.262	4.119	0.164	0.009	0.164	0.158	530	0.432	0.072	0.813	0.820
AG-OtherTruck	72.787	5.838	0.209	3.920	4.262	4.119	0.164	0.009	0.164	0.158	530	0.432	0.072	0.813	0.820
AG-P/U-Vans	60.955	5.584	0.259	3.329	3.615	3.492	0.192	0.009	0.192	0.185	508	0.364	0.087	0.867	0.873
AG-Swathers	25.872	5.721	0.407	2.358	2.480	2.409	0.475	0.007	0.475	0.460	444	0.159	0.131	0.979	0.980
AG-Tractors	7.223	4.560	0.481	0.633	0.664	0.628	0.368	0.007	0.368	0.357	409	0.054	0.153	0.993	0.993
COM-AirComp	45.308	5.306	0.207	2.735	2.967	2.869	0.126	0.009	0.126	0.121	522	0.424	0.071	0.757	0.766
COM-ChainSaw	278.863	0.883	0.010	77.718	78.376	75.480	7.269	0.009	7.269	6.688	531	0.608	0.011	0.000	0.000
COM-Chippers	34.840	2.382	0.003	1.655	1.815	1.742	0.020	0.004	0.020	0.019	225	0.220	0.005	0.000	0.000
COM-Generator	3.046	0.487	0.025	0.534	1.015	0.993	0.075	0.001	0.075	0.070	40	0.102	0.008	0.218	0.227
COM-L/Gtractors	444.196	2.891	0.096	7.371	7.999	7.748	0.144	0.013	0.144	0.136	737	0.771	0.041	0.480	0.493
COM-LeafBlow	194.479	2.580	0.013	39.242	39.726	38.216	4.057	0.013	4.057	3.732	729	0.834	0.015	0.000	0.000
COM-Mower	214.662	3.645	0.313	8.087	8.607	8.380	0.310	0.011	0.310	0.298	634	0.463	0.105	0.857	0.863
COM-PresWash	472.389	3.133	0.020	13.448	14.374	14.012	0.097	0.014	0.097	0.089	828	0.943	0.019	0.034	0.035
COM-Pumps	176.710	4.728	0.036	52.706	53.447	51.267	1.972	0.010	1.972	1.815	606	0.668	0.020	0.009	0.009
COM-RideMower	522.951	2.663	0.014	9.208	9.939	9.653	0.088	0.014	0.088	0.081	788	0.901	0.017	0.000	0.000
COM-Tiller	430.264	2.771	0.016	46.749	49.561	47.852	1.356	0.015	1.356	1.247	857	0.981	0.018	0.000	0.000
COM-Trimmer	245.043	1.069	0.014	57.050	57.534	55.551	5.489	0.013	5.489	5.050	782	0.895	0.017	0.000	0.000
COM-TurfEquip	76.167	3.860	0.021	3.799	4.094	3.959	0.117	0.010	0.117	0.108	555	0.625	0.015	0.072	0.075
COM-Welder	57.062	5.843	0.300	3.393	3.653	3.517	0.412	0.009	0.412	0.398	533	0.357	0.100	0.938	0.941
CON-Backhoe	9.076	5.391	0.634	1.480	1.515	1.421	0.985	0.008	0.985	0.956	517	0.046	0.202	0.998	0.999
CON-BoreDrill	73.493	6.352	0.202	4.807	5.154	5.008	0.167	0.009	0.167	0.160	530	0.434	0.070	0.813	0.821
CON-Compactor	340.198	3.366	0.177	9.025	9.565	9.261	0.510	0.012	0.510	0.478	693	0.649	0.065	0.322	0.334
CON-Crusher	51.751	5.338	0.305	3.989	4.203	4.049	0.413	0.008	0.413	0.387	488	0.296	0.101	0.379	0.392
CON-Dozer	1.728	4.067	0.507	0.244	0.248	0.231	0.252	0.006	0.252	0.244	400	0.020	0.161	1.000	1.000
CON-Excavator	1.535	3.826	0.507	0.201	0.205	0.191	0.224	0.006	0.224	0.217	400	0.020	0.161	1.000	1.000
CON-Forklift	4.582	4.250	0.486	0.494	0.514	0.483	0.309	0.007	0.309	0.299	405	0.037	0.155	0.994	0.994
CON-Loader	4.746	4.455	0.487	0.410	0.428	0.403	0.288	0.007	0.288	0.279	405	0.037	0.155	0.993	0.994
CON-Mixer	461.401	3.258	0.035	17.117	18.075	17.700	0.108	0.014	0.108	0.100	823	0.924	0.023	0.132	0.138
CON-Paving	118.646	6.419	0.021	8.687	9.211	8.929	0.342	0.011	0.342	0.315	615	0.683	0.016	0.019	0.020
CON-Rollers	10.491	4.172	0.457	0.735	0.782	0.744	0.273	0.007	0.273	0.265	416	0.076	0.146	0.982	0.982
CON-SigBoard	100.047	4.301	0.448	3.152	3.304	3.185	0.578	0.008	0.578	0.554	509	0.199	0.145	0.767	0.776
CON-SkidLoad	10.460	5.745	0.626	1.820	1.865	1.750	1.087	0.008	1.087	1.054	517	0.048	0.199	0.998	0.998
CON-Tampers	267.689	1.341	0.091	76.679	77.404	74.276	6.400	0.010	6.400	5.890	592	0.606	0.037	0.006	0.007
CON-Trencher	32.393	4.983	0.332	1.762	1.902	1.826	0.264	0.008	0.264	0.256	458	0.221	0.109	0.933	0.935
IND-Forklift	35.316	6.744	0.030	0.349	24.853	24.787	0.078	0.006	0.078	0.076	377	3.728	0.020	0.472	0.465
IND-Lift	37.432	6.891	0.394	2.726	2.913	2.762	0.637	0.010	0.637	0.618	533	0.194	0.129	0.970	0.971
IND-Refrig	17.268	3.649	0.541	0.597	0.624	0.595	0.346	0.007	0.346	0.336	450	0.049	0.172	0.992	0.993
IND-Trucks	0.906	3.124	0.507	0.243	0.247	0.231	0.215	0.006	0.215	0.209	400	0.020	0.161	1.000	1.000
REC-ATV	33.409	0.233	0.002	15.720	15.978	15.391	0.499	0.002	0.499	0.459	122	0.139	0.003	0.000	0.000
REC-DirtBike	35.037	0.161	0.002	28.004	28.319	27.190	0.989	0.002	0.989	0.910	129	0.147	0.003	0.000	0.000
REC-GolfCart	585.313	2.550	0.014	9.509	10.264	9.969	0.094	0.013	0.094	0.086	778	0.890	0.016	0.000	0.000
REC-SnowMach	235.500	0.760	0.027	92.594	93.471	89.610	2.167	0.026	2.167	1.994	1,497	1.713	0.032	0.000	0.000
REC-SpVeh	386.483	2.261	0.058	145.212	146.711	140.602	4.527	0.011	4.527	4.168	633	0.676	0.028	0.013	0.014
RES-ChainSaw	256.440	0.837	0.014	109.050	109.803	106.488	5.959	0.013	5.959	5.483	778	0.890	0.016	0.000	0.000
RES-L/Gtractors	424.915	2.587	0.017	31.094	32.247	31.796	0.089	0.016	0.089	0.082	914	1.045	0.019	0.000	0.000
RES-mower	467.207	3.266	0.016	52.636	56.012	54.692	0.207	0.015	0.207	0.191	888	1.016	0.019	0.000	0.000
RES-RideMower	492.108	2.950	0.015	25.058	25.878	25.557	0.090	0.014	0.090	0.083	810	0.927	0.017	0.000	0.000
RES-SnowBlow	452.762	1.774	0.012	105.482	106.901	102.829	3.291	0.012	3.291	3.027	683	0.782	0.014	0.000	0.000
RES-tiller	429.683	2.790	0.016	67.216	70.236	68.323	1.387	0.015	1.387	1.276	874	1.000	0.019	0.000	0.000
RES-trimmer	244.183	0.797	0.013	102.661	103.375	100.234	5.650	0.013	5.650	5.198	739	0.845	0.016	0.000	0.000

*PM10_frac and PM25_frac represent PM_{10} and $PM_{2.5}$ emission rates for diesel combustion

3.2.3 Aircraft

Aircraft emissions are relatively minor contributors to the GFEI. Due to a limited amount of information available from the regional airport, all flights were characterised as single engine piston, which matches reasonably well with a small Cessna plane. The emission factors for aircraft are based on a landing take-off cycle (LTO), which includes a climb out portion that would overestimate the time spent by aircraft (and resulting emissions) within the inventory boundaries. The emission factors themselves were determined through previous work by Environment Canada and were listed in an inventory report completed for Transport Canada.[15] The emission rates shown in Table 3.10 are not overly representative of aircraft flights in Grand Forks, but were considered reasonable due to the low level of activity for this emission source.

Table 3.10
Aircraft Emission Factors

Fuel Cons	Emission Factors in kg/LTO										
litres/LTO	NO_x	SO_x	TSP	PM_{10}	$PM_{2.5}$	CO	VOC	NH_3	CO_2	CH_4	N_2O
12.7	0.0322	0.0057	0.0021	0.0011	0.0008	9.0084	0.1964	0.00037	29.5628	0.02779	0.00292

3.2.4 Rail

The Grand Forks Railway operates one of the oldest working diesel locomotives in Canada. The engine was characterised as an 800 hp, 1950 GE model that is 'well maintained'[16]. In addition, the locomotive is used for duties typically considered those of a switch engine, with a sizeable amount of idle time between car movements. The emission factors for this locomotive were assumed to be similar to those of an EMD SW-9 locomotive, which is a relatively small switch locomotive dating back to 1956 for which emissions data are available. An average engine power level of 150 hp was assumed at all times, which is a harmonized power level inclusive of 'work' settings and idle (the engine was reported to idle approximately 40% of the time).

The GF locomotive shuttles cars to the Kettle Falls interchange where 1 or 2 line haul locomotives from the Burlington Northern Santa Fe (BNSF) rail company take the cars south and out of the airshed. The emission factors for this locomotive were assumed to be similar to those from a year 2000 era GE AC4400 line haul locomotive at lower notch settings. An average engine power level of 800 hp was assumed at all times. SENES did not receive any engine details for this locomotive, and therefore these emission factors have a significant degree of

[15] Tradewind Scientific Ltd., 2000. Victoria Harbour Air Quality Impact Study. Prepared for Transport Canada, Pacific Region.
[16] Personal communication with Rick Hammond of GF Railway, October 11 2007.

uncertainty in the GFEI. This was not considered a problematic issue, since rail activity rates in the airshed are low.

Table 3.11
Rail Emission Factors

Locomotive	Fuel Cons (litres/hr)	Emission Rates in kg/hour										
		NO_x	SO_x	TSP	PM_{10}	$PM_{2.5}$	CO	HC	NH_3	CO_2	CH_4	N_2O
GF Switch	32.75	2.78	0.02	0.05	0.05	0.05	0.27	0.12	0.0002	89.40	0.0049	0.0360
BNSF Line Haul	165.87	10.37	0.11	0.14	0.14	0.14	1.84	0.29	0.0008	452.83	0.0249	0.1825

4.0 EMISSION ESTIMATES

Emission summaries for the Grand Forks airshed and their associated uncertainties were calculated based on the activity estimates described in Chapter 2 and the emission factors described in Chapter 3. Point source (industrial) emission sources were the exception, and the emission estimates in the inventory are based on 2006 monitoring results or the most recent available emissions estimates from the MoE.

The emission inventory requires both filterable and condensable amounts of primary particulate matter emissions to be included. For area and mobile source emission factors, both filterable and condensable PM fractions are represented in the emission factors presented in Chapter 3. Industrial point source PM emissions data did not include condensable portions for one facility in particular (Pope & Talbot). However, in that case the condensable portion of PM represents a small fraction of the total PM released from the facility.

Uncertainty estimates were determined for both activity values (e.g., number of cords of wood consumed by wood stoves) and emission factors (e.g., kg of PM released per cord of wood). In most cases the uncertainty estimates were based on experience, but they also relate to documentation provided by sources such as the EPA. A consistent approach was used that applies one multiplicative uncertainty factor to each activity number and associated emission factor group. For ease of communication, six possible uncertainty factors were established and used, which range from 'A' (greatest accuracy) to 'F' (lowest accuracy). A weakness of this approach stems from the fact that emission factors for some air contaminants are more accurate than others for the same source (for example, a carbon dioxide emission factor may be more accurate than a particulate matter emission factor for residential furnaces). However, a rigorous treatment of errors in the emission inventory is beyond the scope of this project. The method used for error propagation in the GFEI is relatively simple and is suggested as a reasonable method by the Intergovernmental Panel on Climate Change (IPCC). A full description of the uncertainty estimation methodology is provided in Appendix A, along with the derived uncertainty estimate for each emission source.

Speciation of VOC emission estimates was required to produce estimates of secondary organic particulate formation in the airshed. The degree to which the speciation was accurately achieved depends on the source in question – those sources that are relatively well understood (with a considerable history of emissions testing data) have more trustworthy speciation profiles. Secondary inorganic particulate formation (nitrates, sulphates) was based on the emission levels of NO_x and SO_x in the airshed. A complete accounting of the estimation methodologies used for secondary PM is provided in Appendix C.

4.1 POINT SOURCE EMISSIONS

It should be recognized that the scope of work in generating the GFEI did not include a detailed analysis of industrial operations and related emission estimates. Emission measurements from stack or other industrial sources should always be considered superior to use of an estimation methodology based on material throughputs (i.e., production in a given year). Emissions measurements for industry were available, but have the following constraints:

- May not account for all sources on facility grounds (i.e., less significant sources may not be accounted for);
- Represent a 'snapshot' in time that may or may not be representative of average annual conditions;
- Do not include all air contaminants (for example, PM may be measured but not NO_x, SO_x and other gases); and,
- Account for filterable particulate but may not account for condensable particulate matter.

Industrial point source emissions measurements were available for PM and, in most cases, relate to tests completed for the MoE in 2006[17]. There were no emissions data available for Selkirk Paving and emissions from this facility were estimated based on reported activity rates in 2006 (tonnes of asphalt produced). Additional emissions data were available for formaldehyde (Roxul 2006, CanPar 2005). Formaldehyde emissions were not directly estimated for other sources in the airshed, but were determined through speciation of primary emission amounts.

Condensable PM emissions were accounted for in the 2006 CanPar and Roxul emissions data. Condensable PM mainly consists of organic aerosols, although other aerosols are present in addition. Condensable organic aerosols are distinguished from secondary organic aerosols and secondary inorganic aerosols (see Chapter 4.4) in that condensable PM forms relatively quickly in an emitted plume as the gas temperature drops. Stack sampling methods for industrial sources measure the condensable portion of emissions either in the back-half of the sampling train, or through specialized sampling equipment that allows the exhaust gas to cool prior to deposition on a filter.

Pope and Talbot PM emission estimates do not include condensable particulate matter. Of the emission sources listed under Pope & Talbot's permit, the three dry kilns would release terpenes and other organic compounds (VOCs). Although these emissions would eventually lead to some secondary particulate formation, there would be little condensable (primary) PM.

[17] As published on the BAQC website, http://www.city.grandforks.bc.ca/air/.

PM emissions from Pacific Abrasives have no associated secondary particulate matter, since the emissions are fugitive in nature (due to slag material handling). Only a total TSP emission was available from the MoE, which derives from dust monitoring. To be consistent in the inventory, SENES applied the same fines fraction used for slag material handling dust estimates (5.3%). Both PM_{10} and $PM_{2.5}$ were estimated to be 5.3% of annual TSP emissions. These PM estimates have a high degree of uncertainty.

Emissions of other air contaminants from industrial processes are not measured on an ongoing basis, since they do not have the same level of potential significance to the airshed. However, estimates of NO_x, SO_x, CO, and VOC were made, based on a number of alternative sources of information, including the National Pollutant Release Inventory (NPRI) and the 2000 emissions inventory completed by the MoE (which included the Grand Forks industries). Environment Canada requires industry to estimate air contaminant emissions on an annual basis if set criteria are met (emissions exceed threshold values). However, these NPRI submissions are not examined by Environment Canada in most cases.

Both the 2000 provincial inventory and the NPRI do not contain GHG amounts. Since use of biomass (wood chips) is considered carbon-neutral, the industrial point source GHG emissions largely relate to natural gas consumption, which was accounted for under area sources – industrial use of natural gas. Gas use by individual industry was not available.

The 2006 emissions estimates in Table 4.1 include those emissions associated with the Selkirk Paving production facility, which operated for approximately 200 hours during the year. Emissions from this facility were estimated using AP-42 emission factors for asphalt production (Ch. 11.1-1).

Table 4.1
Point Source Primary Emission Estimates*

Facility	NOx	SOx	NH_3	TSP	PM_{10}	$PM_{2.5}$	CO	VOC	formaldehyde
Roxul	n/a	n/a	3.31	84.22	78.22	74.22	n/a	26.04	2.70
Selkirk Paving	0.20	0.03	0.00	0.25	0.18	0.17	1.00	0.25	0.00
Pacific Abrasives	0.00	0.00	0.00	68.00	3.60	3.60	0.00	0.00	0.00
Pope and Talbot	72.68	0.43	0.00	62.00	54.00	34.00	14.52	50.00	n/a
CanPar	81.66	1.14	0.50	420.00	87.00	66.00	116.40	293.13	8.03

Legend:
- from MoE monitoring data, 2006
- from AP-42 Calculation using material throughput
- Based on NPRI submission, Environment Canada
- from provincial inventory, 2000
- n/a not available. No estimates could be made.

* GHGs are accounted for in area source (natural gas) emissions

The industrial point source emission amounts in Table 4.1 are colour coded to indicate the source of information. At this time, no estimates for Roxul could be made for NO_x, SO_x and CO. The 2000 BC inventory indicates 'zero'[18] for the three air contaminants, but it was not clear whether these relate to actual emission estimates or were simply ignored due to lack of data. The NPRI amounts (indicated in yellow) were submitted to Environment Canada for the 2006 operating year. An exception was made for Roxul; the last NPRI submission for VOCs was made in 2003. The 2003 amount was scaled upwards for 2006 by the increase in reported PM_{10} emissions from 2003 to 2006 (NPRI submissions included PM_{10} for both years).

Formaldehyde is included in Table 4.1 since the data were available from emissions tests for 2006. However, these figures may not represent the total formaldehyde emissions from the two facilities indicated[19]. The formaldehyde should be considered as part of the total VOC amounts estimated and not in addition to.

Table 4.2 provides the secondary PM formation estimates for point sources in the GFEI. Secondary organic aerosols (SOA) make up a small portion of the inventory totals (approximately 7%), whereas nitrate formation due to point sources accounts for 39% of the GFEI total. Sulphate production due to point source emissions is very low, as is the case for all of the sources in the GFEI.

[18] As provided to SENES from the Ministry.
[19] These amounts are substantially lower than the permit levels. Therefore, they may not represent facility-total formaldehyde emissions.

Table 4.2
Point Source Secondary Particulate Formation Estimates*

Source Type	Category	Common Air Contaminants (tonnes)			Secondary PM (tonnes)		
		NOx	SOx	VOC	SOA	NITR	SULF
POINT	CanPar	81.66	1.14	269.13	1.70	3.74	0.02
	Pacific Abrasives	0.00	0.00	0.00	0.00	0.00	0.00
	Pope & Talbot	72.68	0.43	50.00	13.07	3.33	0.01
	Roxul	0.00	0.00	26.04	0.00	0.00	0.00
	Selkirk Paving	0.20	0.03	0.25	0.00	0.01	0.00
	POINT TOTAL	**154.5**	**1.6**	**345.4**	**14.8**	**7.1**	**0.0**

*NOx, SOx and VOC precursor concentrations are shown for comparative purposes

4.2 AREA SOURCE EMISSIONS

Agricultural area source emissions are shown in Table 4.3. Although there are many area sources accounted for in the GFEI, most are relatively minor in significance. Agricultural area emissions are very low for all air contaminants, with the exception of PM emissions from agricultural burning and cattle movements. Dust emissions from area sources are relatively large for $PM_{2.5}$ and represent the largest emission source for the entire GFEI for PM_{10} and TSP amounts. As indicated in Chapter 3, the fugitive dust emissions for TSP and PM_{10} relate to transportable fractions of emitted dust only (e.g., a sizeable fraction of the dust generated would be deposited very near the source).

Energy area emissions are significant to the GFEI only when considering CO_2 and respirable particulate matter ($PM_{2.5}$). The CO_2 emissions associated with electricity consumption are not as representative as the CO_2 amounts for other fuels. A 'greenhouse gas intensity factor' (eCO_2/GWh) was not available for 2006 from Fortis in time for this report. A value of 25 tonnes eCO2/GWh was used primarily as a 'placeholder' to indicate a reasonable estimate of the emission rate. This is based on recent BC Hydro annual GHG intensity rates. A GHG intensity factor accounts for the fraction of electricity consumption that relates to fossil fuel combustion due to thermal generation in the province, or electricity import from out of province. In comparative terms, the GHG intensity for B.C. is relatively low, due to primary reliance on hydroelectric power generation. All of the electricity-related emissions were assumed to be in the form of CO_2 for the inventory.

Woodstoves are known to be a significant $PM_{2.5}$ emission source for some BC airsheds in winter. The annual amount in the GFEI (25.7 tonnes) relates to the wood consumption estimates from the community residential survey. Previous wood stove emission estimates completed by the MoE for the Kootenay-Boundary region, further allocated to the GF airshed based on population,

indicate an annual total of approximate 44 tonnes of $PM_{2.5}$. The two independent emission estimates agree within the (relatively high) margin of error determined for woodstoves in the GFEI (see Table A.2).

'Other' area sources include biogenic emissions, which in this case are those associated with vegetation. Biogenic emissions are minor, with the clear exception of VOCs. The coniferous forests surrounding Grand Forks are primarily made up of fir and pine, which naturally emit isoprene and monoterpenes (and other hydrocarbons), which in turn form secondary organic aerosols (SOA). Although the SOA estimates are high, it must be recognized that the emissions are released throughout the entire airshed, at differing heights in the atmosphere. In addition, the SOA estimates have a relatively high margin of error. For these reasons, the SOA estimates are not added to the primary PM estimates.

Table 4.3
Area Source Emissions (Primary and Secondary)*

	Source	Common Air Contaminants (tonnes)								Secondary PM (tonnes)			GHGs (tonnes)		
		CO	NOx	SOx	VOC	NH3	TSP	PM10	PM25	SOA	NITR	SULF	CO2	CH4	N2O
AGRICULTURE	Agriculture burning	39.79	1.37	0.00	6.17	0.00	7.55	7.55	7.55	0.01	0.06	0.00	0.00	1.85	0.00
	cattle	0.00	0.00	0.00	9.44	7.33	7.79	4.95	0.77	0.00	0.00	0.00	0.00	37.82	0.00
	cattle manure	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.96	0.06
	Fertilizer application	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	horses	0.00	0.00	0.00	0.23	0.49	0.85	0.54	0.08	0.00	0.00	0.00	0.00	0.56	0.00
	horses manure	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00
	Land clearing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Manure application	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.92
	Pesticide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	pigs	0.00	0.00	0.00	0.00	0.12	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00
	pigs manure	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00
	poultry	0.00	0.00	0.00	0.56	0.14	0.14	0.09	0.01	0.00	0.00	0.00	0.00	2.22	0.00
	poultry manure	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00
	sheep	0.00	0.00	0.00	0.10	0.14	0.11	0.07	0.01	0.00	0.00	0.00	0.00	0.41	0.00
	sheep manure	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
	Tilling Soil	0.00	0.00	0.00	0.00	0.00	1.48	0.31	0.07	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL	**39.79**	**1.37**	**0.00**	**16.51**	**8.22**	**17.94**	**13.52**	**8.50**	**0.01**	**0.06**	**0.00**	**0.00**	**53.11**	**0.99**
DUST	Dust Susp - Hyw3	0.00	0.00	0.00	0.00	0.00	246.53	32.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dust Susp - Industry Paved	0.00	0.00	0.00	0.00	0.00	12.40	1.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dust Susp - Industry Unpaved	0.00	0.00	0.00	0.00	0.00	5.21	1.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dust Susp - Material Transfer	0.00	0.00	0.00	0.00	0.00	3.24	1.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dust Susp - Pile Erosion	0.00	0.00	0.00	0.00	0.00	5.11	1.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dust Susp - Res Paved	0.00	0.00	0.00	0.00	0.00	331.12	52.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dust Susp - Res Unpaved	0.00	0.00	0.00	0.00	0.00	1,205.58	364.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dust Tran - Hyw3	0.00	0.00	0.00	0.00	0.00	82.18	21.86	1.58	0.00	0.00	0.00	0.00	0.00	0.00
	Dust Tran - Industry Paved	0.00	0.00	0.00	0.00	0.00	4.13	1.31	0.38	0.00	0.00	0.00	0.00	0.00	0.00
	Dust Tran - Industry Unpaved	0.00	0.00	0.00	0.00	0.00	1.74	0.79	0.20	0.00	0.00	0.00	0.00	0.00	0.00
	Dust Tran - Material Transfer	0.00	0.00	0.00	0.00	0.00	1.08	0.82	0.31	0.00	0.00	0.00	0.00	0.00	0.00
	Dust Tran - Pile Erosion	0.00	0.00	0.00	0.00	0.00	1.70	1.29	0.49	0.00	0.00	0.00	0.00	0.00	0.00
	Dust Tran - Res Paved	0.00	0.00	0.00	0.00	0.00	110.36	34.97	10.25	0.00	0.00	0.00	0.00	0.00	0.00
	Dust Tran - Res Unpaved	0.00	0.00	0.00	0.00	0.00	401.86	242.70	60.36	0.00	0.00	0.00	0.00	0.00	0.00
	Dust Susp - Loader	0.00	0.00	0.00	0.00	0.00	36.15	8.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dust Tran - Loader	0.00	0.00	0.00	0.00	0.00	12.05	5.50	1.37	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**615.10**	**309.24**	**74.94**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
ENERGY	Comercial NatGas	2.64	4.40	0.06	0.17	0.02	0.24	0.24	0.24	0.00	0.20	0.00	3,774.77	0.07	0.07
	Commercial - Electric	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.00	0.00	0.00
	Industrial - Electric	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2,677.50	0.00	0.00
	Industry NatGas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20,982.69	0.40	0.38
	Municipal - Electric	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.50	0.00	0.00
	Res NatGas furnace	2.20	5.17	0.11	0.30	0.03	0.42	0.42	0.42	0.00	0.24	0.00	6,605.47	0.13	0.12
	Residential - Electric	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.00	0.00	0.00
	Woodstove advanced tech	44.65	0.89	0.13	4.44	0.19	3.23	3.04	3.04	0.00	0.04	0.00	0.00	4.31	0.13
	Woodstove catalytic	44.65	0.89	0.13	4.44	0.19	3.23	3.04	3.04	0.00	0.04	0.00	0.00	9.51	0.13
	Woodstove conventional	84.57	1.18	0.17	30.02	0.25	20.80	19.62	19.62	0.00	0.05	0.00	0.00	12.69	0.17
	Woodstove pellet	0.75	0.12	0.02	0.13	0.03	0.10	0.09	0.09	0.00	0.01	0.00	0.00	1.27	0.02
	TOTAL	**179.47**	**12.66**	**0.61**	**39.51**	**0.70**	**28.03**	**26.46**	**26.46**	**0.00**	**0.58**	**0.01**	**34,092.93**	**28.39**	**1.01**
OTHER	Biogenic (airshed)	0.00	29.71	0.00	1,755.62	0.00	0.00	0.00	0.00	189.66	1.36	0.00	0.00	0.00	0.00
	Burning Barrel	12.57	0.23	0.00	1.36	0.04	1.50	1.16	1.06	0.00	0.01	0.00	0.00	0.69	0.03
	Burning Open	20.35	1.45	0.24	7.27	0.16	3.88	3.88	3.88	0.00	0.07	0.00	0.00	3.15	7.75
	Fuel marketing	0.00	0.00	0.00	190.46	0.00	0.00	0.00	0.00	2.53	0.00	0.00	0.00	0.00	0.00
	Landfill	0.00	0.00	0.00	19.00	0.00	0.00	0.00	0.00	0.66	0.00	0.00	1,214.10	442.50	0.00
	TOTAL	**32.91**	**31.39**	**0.24**	**1,973.70**	**0.19**	**5.38**	**5.04**	**4.94**	**192.86**	**1.44**	**0.00**	**1,214.10**	**446.34**	**7.78**
	AREA TOTAL	**252.2**	**45.4**	**0.9**	**2,029.7**	**9.1**	**666.5**	**354.3**	**114.8**	**192.9**	**2.1**	**0.0**	**35,307.0**	**527.8**	**9.8**

* SOA = secondary organic aerosols, NITR = nitrate aerosols, SULF = sulphate aerosols
Suspendable ('Susp') dust emissions are not included in source group totals

4.3 MOBILE SOURCE EMISSIONS

Mobile source emission estimates are shown in Table 4.4 and Table 4.5. There are many individual mobile sources represented in the GFEI, with activity rates largely defined by local survey results, the industry data requests and Statistics Canada data. Some activity estimates (for the less significant sources) were derived from the EPA NONROAD model population and usage patterns defined for Ferry County (location shown in Figure 4.1). Ferry County was chosen since it is close to Grand Forks and has a similar population. A description of the Ferry County characteristics, as well as other considerations for the NONROAD emissions modelling is provided in Appendix B.

Due to competitiveness issues, the mobile emissions that specifically relate to individual industrial facility equipment are not shown. Therefore, 'TOTAL LOCAL' and 'TOTAL INDUSTRY' emissions are not broken down, although the activity details were available to both SENES and the BAQC for review.

Motor vehicle emissions dominate the mobile category totals for most air contaminants. These emissions primarily relate to individually owned passenger vehicles that either travel through Grand Forks ('HIGHWAY') or are owned by residents ('LOCAL'). However, LOCAL also includes the local industry tractor trailer movements through town. Highway traffic exhaust emissions are approximately double those due to local travel.

An exception to the comparison noted above is evident for respirable particulate matter ($PM_{2.5}$). In this case, both highway and local road traffic emissions combined make up 34% of the total mobile category emission total. There were significant contributions of fine particulate matter emissions from all of the mobile emission categories. Although fuel use from non-road engines was far lower than that from on-road vehicles, the non-road PM emission rates are higher (and in some cases much higher) on a per litre of fuel basis.

Figure 4.1
Map of Washington, Highlighting Ferry County

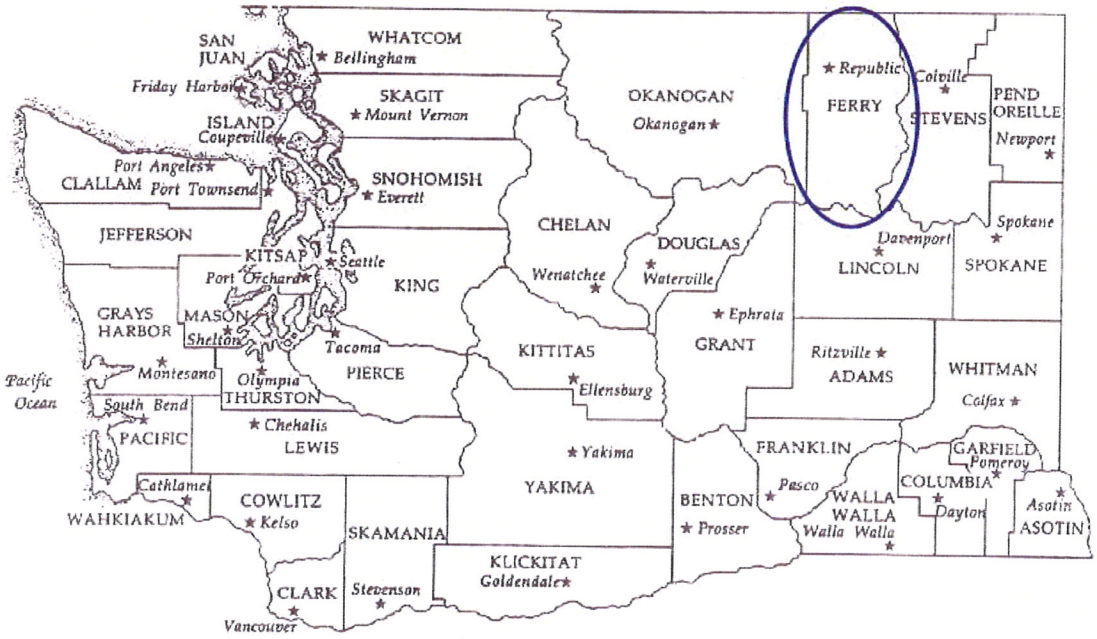


Table 4.4
CAC and GHG Emissions from Mobile Sources

	Source	Common Air Contaminants (tonnes)											GHGs (tonnes)		
		CO	NOx	SOx	VOC	THC	NH3	TSP	PM10	PM10_D	PM25	PM25_D	CO2	CH4	N2O
MOBILE VEHICLE	Buses (Hwy)	9.70	6.88	0.13	0.90	0.93	0.02	0.22	0.22	0.18	0.19	0.16	1,291.35	0.05	0.04
	Heavy Duty Trucks (HWY)	7.87	4.44	0.10	0.92	0.95	0.04	0.12	0.12	0.07	0.09	0.07	1,097.20	0.04	0.16
	Light Duty Trucks (Hwy)	236.71	18.26	0.18	17.75	18.76	1.14	0.70	0.70	0.38	0.50	0.35	6,034.59	0.90	2.35
	Light Duty Vehicles (Hwy)	633.70	49.24	0.20	57.61	61.27	1.65	0.81	0.81	0.29	0.51	0.27	7,588.37	2.86	1.77
	Medium Duty Trucks (Hwy)	143.81	9.93	0.11	10.56	11.12	0.46	0.29	0.29	0.08	0.19	0.07	3,440.20	0.47	1.29
	Motorcycles (Hwy)	21.37	2.08	0.01	3.69	3.85	0.02	0.06	0.06	0.00	0.04	0.00	305.58	0.22	0.01
	Tractor Trailers (Hwy)	2.69	9.72	0.17	0.49	0.49	0.02	0.34	0.34	0.30	0.29	0.28	1,435.58	0.02	0.04
	TOTAL HIGHWAY	**1,055.84**	**100.56**	**0.89**	**91.91**	**97.37**	**3.35**	**2.55**	**2.55**	**1.30**	**1.79**	**1.20**	**21,192.87**	**4.56**	**5.65**
	TOTAL LOCAL	**614.70**	**49.96**	**0.38**	**52.76**	**55.99**	**2.07**	**1.28**	**1.28**	**0.65**	**0.89**	**0.60**	**10,592.20**	**2.75**	**2.83**
NONROAD	farm bailers	7.50	0.51	0.01	0.62	0.64	0.00	0.01	0.01	0.01	0.01	0.01	44.44	0.04	0.00
	farm PU / Van	5.19	0.36	0.00	0.45	0.48	0.01	0.01	0.01	0.01	0.01	0.01	76.71	0.02	0.03
	farm swathers	2.39	0.53	0.04	0.22	0.22	0.00	0.04	0.04	0.04	0.04	0.04	40.99	0.01	0.01
	farm tractors	13.38	8.45	0.89	1.17	1.16	0.01	0.68	0.68	0.68	0.66	0.66	757.78	0.10	0.28
	farm trucks	6.61	0.46	0.00	0.58	0.61	0.02	0.01	0.01	0.01	0.01	0.01	97.63	0.03	0.04
	farm trucks other	33.48	2.69	0.10	1.80	1.89	0.00	0.08	0.08	0.06	0.07	0.06	243.95	0.20	0.03
	TOTAL AGRICULTURAL	**68.55**	**12.98**	**1.04**	**4.84**	**5.00**	**0.05**	**0.84**	**0.84**	**0.81**	**0.81**	**0.78**	**1,261.49**	**0.41**	**0.40**
	Aircraft Land/Takeoff	7.37	0.03	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.20	0.02	0.00
	Commercial Chain Saw	1.96	0.01	0.00	0.55	0.53	0.00	0.05	0.05	0.00	0.05	0.00	3.74	0.00	0.00
	Commercial Chippers	3.84	0.60	0.04	0.21	0.21	0.00	0.03	0.03	0.03	0.03	0.03	53.63	0.03	0.01
	Commercial L/G Tractor	17.80	0.12	0.00	0.30	0.31	0.00	0.01	0.01	0.00	0.01	0.00	29.51	0.03	0.00
	Commercial Leaf Blower	23.06	0.31	0.00	4.65	4.53	0.00	0.48	0.48	0.00	0.44	0.00	86.48	0.10	0.00
	Commercial Mower	3.68	0.06	0.01	0.14	0.14	0.00	0.01	0.01	0.00	0.01	0.00	10.88	0.01	0.00
	Commercial Press Washer	43.21	0.29	0.00	1.23	1.28	0.00	0.01	0.01	0.00	0.01	0.00	75.78	0.09	0.00
	Commercial Pumps	38.81	1.04	0.01	11.57	11.31	0.00	0.43	0.43	0.00	0.40	0.00	132.85	0.16	0.00
	Commercial RideMower	0.97	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	1.46	0.00	0.00
	Commercial Tiller	2.04	0.01	0.00	0.22	0.23	0.00	0.01	0.01	0.00	0.01	0.00	4.07	0.00	0.00
	Commercial Turf Equip	12.10	0.61	0.00	0.60	0.63	0.00	0.02	0.02	0.00	0.02	0.00	88.17	0.10	0.00
	Construction Dozer	0.87	2.05	0.26	0.12	0.12	0.00	0.13	0.13	0.13	0.12	0.12	201.50	0.01	0.08
	Rail - BNSF line haul	0.96	5.40	0.06	0.00	0.15	0.00	0.07	0.07	0.00	0.07	0.00	235.92	0.01	0.10
	Rail - GF switch locomotive	0.28	2.90	0.02	0.00	0.13	0.00	0.05	0.05	0.00	0.05	0.00	93.24	0.01	0.04
	TOTAL COMMERCIAL	**156.95**	**13.43**	**0.40**	**19.77**	**19.59**	**0.01**	**1.29**	**1.29**	**0.17**	**1.21**	**0.16**	**1,041.43**	**0.57**	**0.24**
	Construction Backhoe	1.43	0.85	0.10	0.23	0.22	0.00	0.15	0.15	0.15	0.15	0.15	81.26	0.01	0.03
	Construction BoreDrill	3.85	0.33	0.01	0.25	0.26	0.00	0.01	0.01	0.01	0.01	0.01	27.74	0.02	0.00
	Construction Compactor	0.77	0.01	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	1.57	0.00	0.00
	Construction Crusher	0.41	0.04	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	3.87	0.00	0.00
	Construction Excavator	0.52	1.29	0.17	0.07	0.06	0.00	0.08	0.08	0.08	0.07	0.07	135.25	0.01	0.05
	Construction Forklift	0.15	0.14	0.02	0.02	0.02	0.00	0.01	0.01	0.01	0.01	0.01	13.47	0.00	0.01
	Construction Loader	1.14	1.07	0.12	0.10	0.10	0.00	0.07	0.07	0.07	0.07	0.07	97.25	0.01	0.04
	Construction Mixer	10.76	0.08	0.00	0.40	0.41	0.00	0.00	0.00	0.00	0.00	0.00	19.19	0.02	0.00
	Construction Paving	3.20	0.17	0.00	0.23	0.24	0.00	0.01	0.01	0.00	0.01	0.00	16.61	0.02	0.00
	Construction Roller	0.47	0.19	0.02	0.03	0.03	0.00	0.01	0.01	0.01	0.01	0.01	18.61	0.00	0.01
	Construction Signal Board	0.81	0.03	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	4.12	0.00	0.00
	Construction Tamper	0.53	0.00	0.00	0.15	0.15	0.00	0.01	0.01	0.00	0.01	0.00	1.18	0.00	0.00
	Construction Trencher	1.81	0.28	0.02	0.10	0.10	0.00	0.01	0.01	0.01	0.01	0.01	25.63	0.01	0.01
	TOTAL CONSTRUCTION	**25.85**	**4.49**	**0.46**	**1.66**	**1.68**	**0.01**	**0.38**	**0.38**	**0.35**	**0.37**	**0.34**	**445.75**	**0.11**	**0.15**
	TOTAL INDUSTRY	**43.44**	**18.43**	**1.75**	**3.13**	**3.25**	**0.03**	**0.98**	**0.98**	**0.91**	**0.95**	**0.88**	**1,786.97**	**0.29**	**0.56**
	ATVs	8.43	0.06	0.00	3.96	3.88	0.00	0.13	0.13	0.00	0.12	0.00	30.72	0.04	0.00
	Motorcycle Off road (dirt)	10.51	0.05	0.00	8.40	8.16	0.00	0.30	0.30	0.00	0.27	0.00	38.57	0.04	0.00
	Snow Machine	48.98	0.16	0.01	19.26	18.64	0.01	0.45	0.45	0.00	0.41	0.00	311.44	0.36	0.01
	TOTAL RECREATIONAL	**67.92**	**0.27**	**0.01**	**31.63**	**30.68**	**0.01**	**0.87**	**0.87**	**0.00**	**0.80**	**0.00**	**380.73**	**0.44**	**0.01**
	Residential mower	82.95	0.58	0.00	9.34	9.71	0.00	0.04	0.04	0.00	0.03	0.00	157.72	0.18	0.00
	Residential Chain saw	26.88	0.09	0.00	11.43	11.16	0.00	0.62	0.62	0.00	0.57	0.00	81.50	0.09	0.00
	Residential generator	0.14	0.02	0.00	0.03	0.04	0.00	0.00	0.00	0.00	0.00	0.00	1.96	0.00	0.00
	Residential L&G tractor	126.98	0.77	0.00	9.29	9.50	0.00	0.03	0.03	0.00	0.02	0.00	273.07	0.31	0.01
	Residential leaf blower	4.72	0.06	0.00	0.95	0.93	0.00	0.10	0.10	0.00	0.09	0.00	17.70	0.02	0.00
	Residential riding mower	124.74	0.75	0.00	6.35	6.48	0.00	0.02	0.02	0.00	0.02	0.00	205.28	0.23	0.00
	Residential Snow Blower	8.87	0.03	0.00	2.07	2.01	0.00	0.06	0.06	0.00	0.06	0.00	13.38	0.02	0.00
	Residential Tillller	5.73	0.04	0.00	0.90	0.91	0.00	0.02	0.02	0.00	0.02	0.00	11.65	0.01	0.00
	Residential trimmer	12.32	0.04	0.00	5.18	5.06	0.00	0.29	0.29	0.00	0.26	0.00	37.27	0.04	0.00
	Residential water pump	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL RESIDENTIAL	**393.32**	**2.39**	**0.02**	**45.54**	**45.80**	**0.01**	**1.18**	**1.18**	**0.00**	**1.09**	**0.00**	**799.52**	**0.92**	**0.02**
	MOBILE TOTAL	**2,426.6**	**202.5**	**5.0**	**251.2**	**259.3**	**5.5**	**9.4**	**9.4**	**4.2**	**7.9**	**4.0**	**37,501.0**	**10.0**	**9.9**

Table 4.5
Estimates of Precursor CAC and Secondary PM Products from Mobile Sources*

	Source	Precursor CACs (tonnes)			Secondary PM (tonnes)		
		NOx	SOx	VOC	SOA	NITR	SULF
MOBILE VEHICLE	Buses (Hwy)	6.88	0.13	0.90	0.01	0.32	0.00
	Heavy Duty Trucks (HWY)	4.44	0.10	0.92	0.01	0.20	0.00
	Light Duty Trucks (Hwy)	18.26	0.18	17.75	0.21	0.84	0.00
	Light Duty Vehicles (Hwy)	49.24	0.20	57.61	0.68	2.26	0.00
	Medium Duty Trucks (Hwy)	9.93	0.11	10.56	0.12	0.45	0.00
	Motorcycles (Hwy)	2.08	0.01	3.69	0.04	0.10	0.00
	Tractor Trailers (Hwy)	9.72	0.17	0.49	0.01	0.45	0.00
	TOTAL HIGHWAY	**100.56**	**0.89**	**91.91**	**1.08**	**4.61**	**0.02**
	TOTAL LOCAL	**49.96**	**0.38**	**52.76**	**0.63**	**2.29**	**0.01**
NONROAD	farm bailers	0.51	0.01	0.62	0.00	0.02	0.00
	farm PU / Van	0.36	0.00	0.45	0.01	0.02	0.00
	farm swathers	0.53	0.04	0.22	0.00	0.02	0.00
	farm tractors	8.45	0.89	1.17	0.00	0.39	0.02
	farm trucks	0.46	0.00	0.58	0.01	0.02	0.00
	farm trucks other	2.69	0.10	1.80	0.00	0.12	0.00
	TOTAL AGRICULTURAL	**12.98**	**1.04**	**4.84**	**0.02**	**0.59**	**0.02**
	Aircraft Land/Takeoff	0.03	0.00	0.16	0.00	0.00	0.00
	Commercial Chain Saw	0.01	0.00	0.55	0.01	0.00	0.00
	Commercial Chippers	0.60	0.04	0.21	0.00	0.03	0.00
	Commercial L/G Tractor	0.12	0.00	0.30	0.00	0.01	0.00
	Commercial Leaf Blower	0.31	0.00	4.65	0.06	0.01	0.00
	Commercial Mower	0.06	0.01	0.14	0.00	0.00	0.00
	Commercial Press Washer	0.29	0.00	1.23	0.02	0.01	0.00
	Commercial Pumps	1.04	0.01	11.57	0.16	0.05	0.00
	Commercial RideMower	0.00	0.00	0.02	0.00	0.00	0.00
	Commercial Tiller	0.01	0.00	0.22	0.00	0.00	0.00
	Commercial Turf Equip	0.61	0.00	0.60	0.00	0.03	0.00
	Construction Dozer	2.05	0.26	0.12	0.00	0.09	0.01
	Rail - BNSF line haul	5.40	0.06	0.00		0.25	0.00
	Rail - GF switch locomotive	2.90	0.02	0.00		0.13	0.00
	TOTAL COMMERCIAL	**13.43**	**0.40**	**19.77**	**0.25**	**0.61**	**0.01**
	Construction Backhoe	0.85	0.10	0.23	0.00	0.04	0.00
	Construction BoreDrill	0.33	0.01	0.25	0.00	0.02	0.00
	Construction Compactor	0.01	0.00	0.02	0.00	0.00	0.00
	Construction Crusher	0.04	0.00	0.03	0.00	0.00	0.00
	Construction Excavator	1.29	0.17	0.07	0.00	0.06	0.00
	Construction Forklift	0.14	0.02	0.02	0.00	0.01	0.00
	Construction Loader	1.07	0.12	0.10	0.00	0.05	0.00
	Construction Mixer	0.08	0.00	0.40	0.00	0.00	0.00
	Construction Paving	0.17	0.00	0.23	0.00	0.01	0.00
	Construction Roller	0.19	0.02	0.03	0.00	0.01	0.00
	Construction Signal Board	0.03	0.00	0.03	0.00	0.00	0.00
	Construction Tamper	0.00	0.00	0.15	0.00	0.00	0.00
	Construction Trencher	0.28	0.02	0.10	0.00	0.01	0.00
	TOTAL CONSTRUCTION	**4.49**	**0.46**	**1.66**	**0.01**	**0.21**	**0.01**
	TOTAL INDUSTRY	**18.43**	**1.75**	**3.13**	**0.03**	**0.84**	**0.04**
	ATVs	0.06	0.00	3.96	0.05	0.00	0.00
	Motorcycle Off road (dirt)	0.05	0.00	8.40	0.11	0.00	0.00
	Snow Machine	0.16	0.01	19.26	0.26	0.01	0.00
	TOTAL RECREATIONAL	**0.27**	**0.01**	**31.63**	**0.42**	**0.01**	**0.00**
	Residential mower	0.58	0.00	9.34	0.13	0.03	0.00
	Residential Chain saw	0.09	0.00	11.43	0.15	0.00	0.00
	Residential generator	0.02	0.00	0.03	0.00	0.00	0.00
	Residential L&G tractor	0.77	0.00	9.29	0.13	0.04	0.00
	Residential leaf blower	0.06	0.00	0.95	0.01	0.00	0.00
	Residential riding mower	0.75	0.00	6.35	0.09	0.03	0.00
	Residential Snow Blower	0.03	0.00	2.07	0.03	0.00	0.00
	Residential Tillller	0.04	0.00	0.90	0.01	0.00	0.00
	Residential trimmer	0.04	0.00	5.18	0.07	0.00	0.00
	Residential water pump	0.00	0.00	0.00		0.00	0.00
	TOTAL RESIDENTIAL	**2.39**	**0.02**	**45.54**	**0.62**	**0.11**	**0.00**
	MOBILE TOTAL	**202.5**	**5.0**	**251.2**	**3.1**	**9.3**	**0.1**

*Precursor NOx, SOx and VOC emissions are shown for comparative purposes.

4.4 SECONDARY PARTICULATE MATTER

Secondary particulate matter estimates have been included in the point, area and mobile emissions summaries in sections 4.1 – 4.3. The term 'secondary particulate matter' implies that the emissions are not directly released from emission sources, but instead form in the atmosphere over time from precursor emissions of gaseous CAC species (i.e., SO_x, NO_x and VOC). Determining estimates of secondary particulate matter within an airshed requires the characterization of meteorological conditions (i.e., temperature, humidity, solar insolation, wind speed), as well as the spatial (both horizontal and vertical) and temporal distribution of precursor compounds and free radicals that undergo chemical reactions in the atmosphere. For this reason, the estimation or simulation of secondary particulate matter generation is more appropriately conducted within photochemical computer models. However, the application of a sophisticated computer model was beyond the scope of this work.

The secondary PM estimates made for the GFEI are empirical in nature, and rely on averaged ambient meteorological conditions and formation rates. In effect, it was assumed that secondary particulate formations occur through the same chemical mechanisms and with the same rates of formation as have been determined in past investigations in other geographical locations and in smog chamber studies. Although this is a reasonable assumption, the literature clearly suggests that there exists a high degree of uncertainty in the resultant estimates of secondary PM that may be produced within the Grand Forks study area.

Secondary PM can be inorganic or organic in nature. Secondary inorganic PM includes nitrates and sulphates generated from chemical reactions involving primary SO_x, NO_x and NH_3 emissions. Secondary organic PM results from chemical reactions involving primary volatile organic compound (VOC) emissions. Estimates for the secondary inorganic concentrations are achieved from primary SO_x and NO_x emissions, whereas estimates for secondary organics require speciation of primary VOC emissions before the emission estimates can be achieved.

It should be recognized that the GFEI only accounts for secondary PM formation due to precursor emissions that are released into the airshed, and not precursor compounds that are 'imported' to the airshed.

A detailed description of the methodology used to estimate secondary PM for the GFEI is provided in Appendix C.

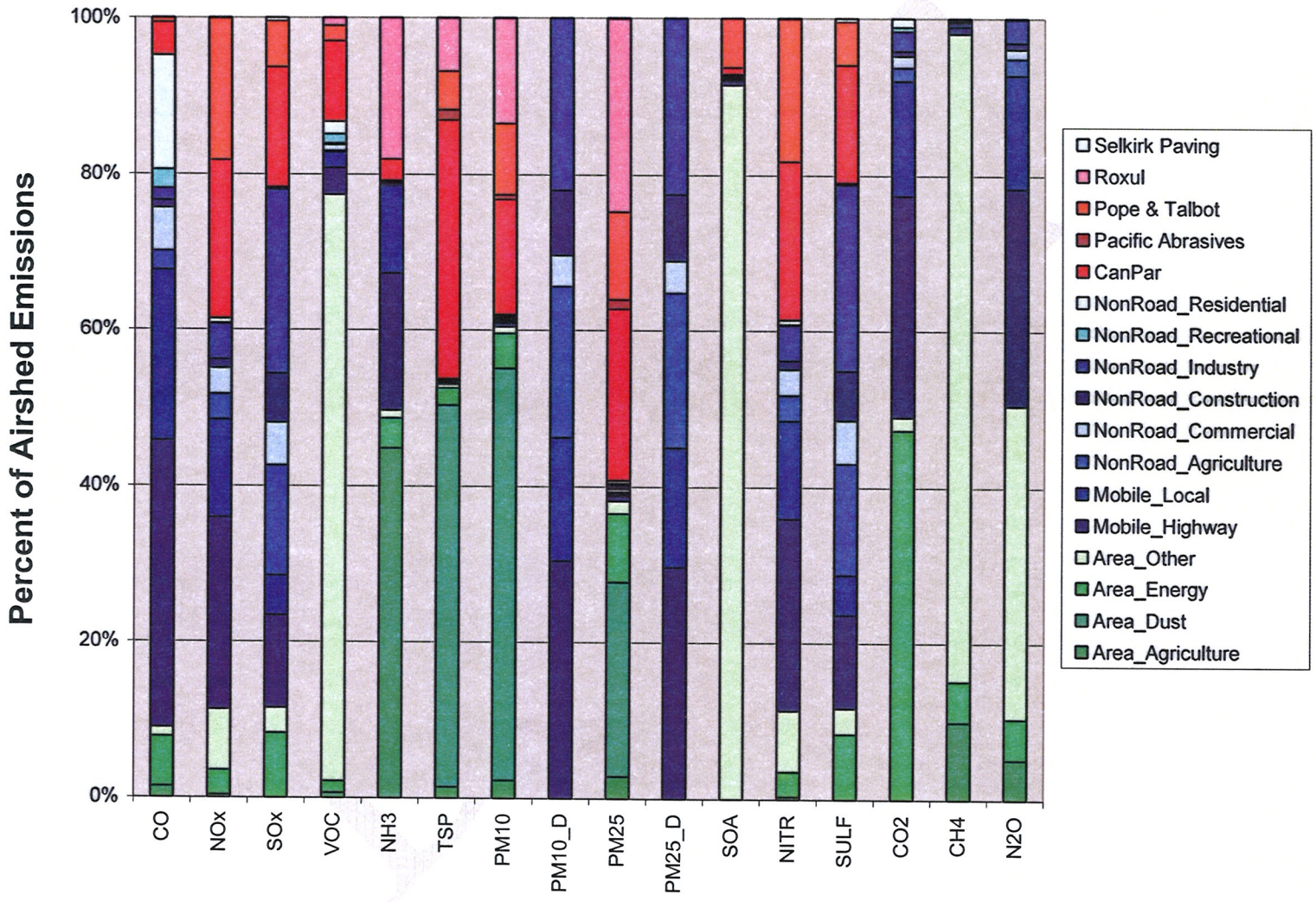
4.5 ANNUAL EMISSION COMPARISONS BY SOURCE TYPE

Figure 4.2 provides a bar chart showing each CAC, GHG, diesel PM sub_fraction and secondary PM compound group represented in the GFEI, with the relative contribution from each emission source sub-group. The chart is colour-organized with shades of green for area sources, shades of blue for mobile sources and shades of red for point sources.

The following patterns can be identified:

- Area sources are significant for suspended particulate matter and greenhouse gases only;
- Mobile sources are significant for the gaseous emissions and not for suspended particulate matter totals. However, mobile sources account for all diesel particulate emissions.
- Point sources (industry) are significant for NO_x, NH_3, suspended particulate matter and CO_2 emissions only (industrial CO_2 emissions are accounted for in the area_energy sub-category, but should be associated with industry for this comparison).

Figure 4.2: GFEI Emissions by Source Sub-Category*



*SOA = secondary organic aerosols, NITR = nitrates, SULF = sulphates

4.5 SEASONAL EMISSION RATES

Allocation fractions (totalling to 1.0) were used for the four seasons, for each individual emission source. For some sources, no distinction could be made for seasonal differences (for example, point sources). For others, the seasonal allocation was relatively straightforward (for example, use of home heating fuels). In some cases, the allocation ratios are simply based on the author's judgment, which could be inferior to a 'local expert'. This certainly would be the case for industrial point source emissions. The allocation ratios can be changed in the database inventory should superior estimates become available. Seasonal emissions inventories are presented in Tables 4.6 to 4.9. Point source emissions are not shown by individual facility, since the emission rates for point sources were considered to be equally allocated for each of the seasons.

Table 4.6: Winter Emissions Inventory (Dec – Feb)

Source Type	Category	CACs (tonnes)											Secondary PM (tonnes)			GHGs (tonnes)		
		CO	NOx	SOx	VOC	THC	NH3	TSP	PM10	PM10_D	PM25	PM25_D	SOA	NITR	SULF	CO2	CH4	N2O
AREA	Area_Agriculture	0.00	0.00	0.00	2.58	0.00	2.06	2.23	1.42	0.00	0.22	0.00	0.00	0.00	0.00	0.00	12.81	0.02
	Area_Dust	0.00	0.00	0.00	0.00	0.00	0.00	172.12	82.83	0.00	20.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Area_Energy	133.39	7.10	0.42	29.51	0.00	0.52	20.86	19.68	0.00	19.68	0.00	0.00	0.33	0.01	11,118.29	21.04	0.52
	Area_Other	9.87	2.29	0.07	150.77	0.00	0.06	1.61	1.51	0.00	1.48	0.00	12.05	0.10	0.00	303.53	111.78	2.33
	AREA TOTAL	**143.3**	**9.4**	**0.5**	**182.9**	**0.0**	**2.6**	**196.8**	**105.4**	**0.0**	**41.4**	**0.0**	**12.1**	**0.4**	**0.0**	**11,421.8**	**145.6**	**2.9**
MOBILE	Mobile_Highway	207.42	20.40	0.19	17.71	18.78	0.67	0.52	0.52	0.28	0.37	0.26	0.21	0.93	0.00	4,304.10	0.87	1.14
	Mobile_Local	152.27	12.36	0.09	12.78	13.58	0.52	0.32	0.32	0.16	0.22	0.15	0.15	0.57	0.00	2,633.06	0.68	0.71
	NonRoad_Agriculture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	NonRoad_Commercial	39.02	2.84	0.04	4.91	4.87	0.00	0.29	0.29	0.01	0.27	0.01	0.06	0.13	0.00	209.98	0.14	0.04
	NonRoad_Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	NonRoad_Industry	10.86	4.61	0.44	0.78	0.81	0.01	0.24	0.24	0.23	0.24	0.22	0.01	0.21	0.01	446.74	0.07	0.14
	NonRoad_Recreational	41.29	0.14	0.00	16.40	15.88	0.00	0.39	0.39	0.00	0.36	0.00	0.22	0.01	0.00	256.84	0.29	0.01
	NonRoad_Residential	13.85	0.06	0.00	4.52	4.41	0.00	0.21	0.21	0.00	0.19	0.00	0.06	0.00	0.00	31.57	0.04	0.00
	MOBILE TOTAL	**464.7**	**40.4**	**0.8**	**57.1**	**58.3**	**1.2**	**2.0**	**2.0**	**0.7**	**1.7**	**0.6**	**0.7**	**1.9**	**0.0**	**7,882.3**	**2.1**	**2.0**
	POINT TOTAL	**33.0**	**38.6**	**0.4**	**86.4**	**0.0**	**1.0**	**158.6**	**55.7**	**0.0**	**44.5**	**0.0**	**3.7**	**1.8**	**0.0**	**0.0**	**0.0**	**0.0**
Grand Total		***641.0***	***88.4***	***1.7***	***326.3***	***58.3***	***4.8***	***357.4***	***163.2***	***0.7***	***87.5***	***0.6***	***16.5***	***4.1***	***0.0***	***19,304.1***	***147.7***	***4.9***

Table 4.7: Spring Emissions Inventory (Mar – May)

Source Type	Category	CACs (tonnes)											Secondary PM (tonnes)			GHGs (tonnes)		
		CO	NOx	SOx	VOC	THC	NH3	TSP	PM10	PM10_D	PM25	PM25_D	SOA	NITR	SULF	CO2	CH4	N2O
AREA	Area_Agriculture	0.00	0.00	0.00	2.58	0.00	2.06	3.71	1.73	0.00	0.29	0.00	0.00	0.00	0.00	0.00	12.81	0.94
	Area_Dust	0.00	0.00	0.00	0.00	0.00	0.00	135.43	71.79	0.00	17.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Area_Energy	0.61	1.20	0.02	0.06	0.00	0.01	0.08	0.08	0.00	0.08	0.00	0.00	0.05	0.00	7,225.70	0.13	0.12
	Area_Other	6.58	5.68	0.05	370.10	0.00	0.04	1.08	1.01	0.00	0.99	0.00	34.94	0.26	0.00	303.53	111.39	1.56
	AREA TOTAL	**7.2**	**6.9**	**0.1**	**372.7**	**0.0**	**2.1**	**140.3**	**74.6**	**0.0**	**18.8**	**0.0**	**34.9**	**0.3**	**0.0**	**7,529.2**	**124.3**	**2.6**
MOBILE	Mobile_Highway	265.67	25.31	0.22	23.27	24.65	0.84	0.64	0.64	0.33	0.45	0.30	0.27	1.16	0.00	5,322.66	1.16	1.41
	Mobile_Local	154.12	12.53	0.09	13.32	14.13	0.52	0.32	0.32	0.16	0.22	0.15	0.16	0.57	0.00	2,652.85	0.69	0.71
	NonRoad_Agriculture	19.94	4.06	0.34	1.36	1.41	0.02	0.27	0.27	0.26	0.26	0.25	0.01	0.19	0.01	399.86	0.12	0.13
	NonRoad_Commercial	39.31	3.52	0.12	4.95	4.91	0.00	0.33	0.33	0.05	0.31	0.05	0.06	0.16	0.00	276.48	0.14	0.07
	NonRoad_Construction	8.53	1.48	0.15	0.55	0.55	0.00	0.13	0.13	0.11	0.12	0.11	0.00	0.07	0.00	147.10	0.04	0.05
	NonRoad_Industry	10.86	4.61	0.44	0.78	0.81	0.01	0.24	0.24	0.23	0.24	0.22	0.01	0.21	0.01	446.74	0.07	0.14
	NonRoad_Recreational	9.63	0.04	0.00	5.02	4.87	0.00	0.15	0.15	0.00	0.14	0.00	0.07	0.00	0.00	48.47	0.06	0.00
	NonRoad_Residential	159.90	0.97	0.01	14.58	14.73	0.01	0.33	0.33	0.00	0.30	0.00	0.20	0.04	0.00	291.43	0.33	0.01
	MOBILE TOTAL	**668.0**	**52.5**	**1.4**	**63.8**	**66.1**	**1.4**	**2.4**	**2.4**	**1.1**	**2.0**	**1.1**	**0.8**	**2.4**	**0.0**	**9,585.6**	**2.6**	**2.5**
	POINT TOTAL	**33.0**	**38.6**	**0.4**	**86.4**	**0.0**	**1.0**	**158.6**	**55.7**	**0.0**	**44.5**	**0.0**	**3.7**	**1.8**	**0.0**	**0.0**	**0.0**	**0.0**
Grand Total		***708.1***	***98.0***	***1.8***	***522.9***	***66.1***	***4.4***	***301.3***	***132.8***	***1.1***	***65.3***	***1.1***	***39.4***	***4.5***	***0.0***	***17,114.8***	***126.9***	***5.1***

Table 4.8: Summer Emissions Inventory (Jun – August)

Source Type	Category	CACs (tonnes)											Secondary PM (tonnes)			GHGs (tonnes)		
		CO	NOx	SOx	VOC	THC	NH3	TSP	PM10	PM10_D	PM25	PM25_D	SOA	NITR	SULF	CO2	CH4	N2O
AREA	Area_Agriculture	0.00	0.00	0.00	2.58	0.00	2.06	2.23	1.42	0.00	0.22	0.00	0.00	0.00	0.00	0.00	12.81	0.02
	Area_Dust	0.00	0.00	0.00	0.00	0.00	0.00	135.43	71.79	0.00	17.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Area_Energy	0.61	1.20	0.02	0.06	0.00	0.01	0.08	0.08	0.00	0.08	0.00	0.00	0.05	0.00	7,225.70	0.13	0.12
	Area_Other	6.58	16.38	0.05	1,011.65	0.00	0.04	1.08	1.01	0.00	0.99	0.00	103.34	0.75	0.00	303.53	111.39	1.56
	AREA TOTAL	**7.2**	**17.6**	**0.1**	**1,014.3**	**0.0**	**2.1**	**138.8**	**74.3**	**0.0**	**18.7**	**0.0**	**103.3**	**0.8**	**0.0**	**7,529.2**	**124.3**	**1.7**
MOBILE	Mobile_Highway	305.03	28.61	0.25	26.73	28.32	0.95	0.71	0.71	0.35	0.50	0.33	0.31	1.31	0.00	5,938.66	1.33	1.57
	Mobile_Local	154.12	12.53	0.09	13.32	14.13	0.52	0.32	0.32	0.16	0.22	0.15	0.16	0.57	0.00	2,652.85	0.69	0.71
	NonRoad_Agriculture	19.36	3.94	0.33	1.32	1.37	0.02	0.26	0.26	0.25	0.25	0.24	0.01	0.18	0.01	388.10	0.11	0.13
	NonRoad_Commercial	39.32	3.54	0.12	4.95	4.91	0.00	0.33	0.33	0.05	0.31	0.05	0.06	0.16	0.00	278.49	0.14	0.07
	NonRoad_Construction	8.79	1.53	0.16	0.57	0.57	0.00	0.13	0.13	0.12	0.12	0.11	0.00	0.07	0.00	151.55	0.04	0.05
	NonRoad_Industry	10.86	4.61	0.44	0.78	0.81	0.01	0.24	0.24	0.23	0.24	0.22	0.01	0.21	0.01	446.74	0.07	0.14
	NonRoad_Recreational	7.36	0.04	0.00	5.19	5.05	0.00	0.18	0.18	0.00	0.17	0.00	0.07	0.00	0.00	26.97	0.03	0.00
	NonRoad_Residential	153.29	0.93	0.01	13.47	13.62	0.00	0.31	0.31	0.00	0.28	0.00	0.18	0.04	0.00	278.44	0.32	0.01
	MOBILE TOTAL	**698.1**	**55.7**	**1.4**	**66.3**	**68.8**	**1.5**	**2.5**	**2.5**	**1.2**	**2.1**	**1.1**	**0.8**	**2.6**	**0.0**	**10,161.8**	**2.7**	**2.7**
	POINT TOTAL	**33.0**	**38.6**	**0.4**	**86.4**	**0.0**	**1.0**	**158.6**	**55.7**	**0.0**	**44.5**	**0.0**	**3.7**	**1.8**	**0.0**	**0.0**	**0.0**	**0.0**
	Grand Total	***738.3***	***111.9***	***1.9***	***1,167.0***	***68.8***	***4.6***	***299.9***	***132.5***	***1.2***	***65.3***	***1.1***	***107.8***	***5.1***	***0.0***	***17,691.0***	***127.1***	***4.4***

Table 4.9: Fall Emissions Inventory (Sept – Nov)

Source Type	Category	CACs (tonnes)											Secondary PM (tonnes)			GHGs (tonnes)		
		CO	NOx	SOx	VOC	THC	NH3	TSP	PM10	PM10_D	PM25	PM25_D	SOA	NITR	SULF	CO2	CH4	N2O
AREA	Area_Agriculture	39.79	1.37	0.00	8.76	0.00	2.06	9.77	8.96	0.00	7.77	0.00	0.01	0.06	0.00	0.00	14.67	0.02
	Area_Dust	0.00	0.00	0.00	0.00	0.00	0.00	172.12	82.83	0.00	20.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Area_Energy	44.87	3.16	0.15	9.88	0.00	0.18	7.01	6.62	0.00	6.62	0.00	0.00	0.14	0.00	8,523.23	7.10	0.25
	Area_Other	9.87	7.04	0.07	441.19	0.00	0.06	1.61	1.51	0.00	1.48	0.00	42.53	0.32	0.00	303.53	111.78	2.33
	AREA TOTAL	**94.5**	**11.6**	**0.2**	**459.8**	**0.0**	**2.3**	**190.5**	**99.9**	**0.0**	**35.9**	**0.0**	**42.5**	**0.5**	**0.0**	**8,826.8**	**133.5**	**2.6**
MOBILE	Mobile_Highway	253.84	24.39	0.21	22.39	23.71	0.78	0.61	0.61	0.31	0.43	0.28	0.26	1.12	0.00	5,020.93	1.11	1.30
	Mobile_Local	154.12	12.53	0.09	13.32	14.13	0.52	0.32	0.32	0.16	0.22	0.15	0.16	0.57	0.00	2,652.85	0.69	0.71
	NonRoad_Agriculture	29.25	4.98	0.37	2.16	2.23	0.02	0.31	0.31	0.30	0.30	0.29	0.01	0.23	0.01	473.53	0.17	0.14
	NonRoad_Commercial	39.31	3.52	0.12	4.95	4.91	0.00	0.33	0.33	0.05	0.31	0.05	0.06	0.16	0.00	276.48	0.14	0.07
	NonRoad_Construction	8.53	1.48	0.15	0.55	0.55	0.00	0.13	0.13	0.11	0.12	0.11	0.00	0.07	0.00	147.10	0.04	0.05
	NonRoad_Industry	10.86	4.61	0.44	0.78	0.81	0.01	0.24	0.24	0.23	0.24	0.22	0.01	0.21	0.01	446.74	0.07	0.14
	NonRoad_Recreational	9.63	0.04	0.00	5.02	4.87	0.00	0.15	0.15	0.00	0.14	0.00	0.07	0.00	0.00	48.47	0.06	0.00
	NonRoad_Residential	85.63	0.55	0.00	9.33	9.34	0.00	0.34	0.34	0.00	0.31	0.00	0.13	0.03	0.00	168.69	0.19	0.00
	MOBILE TOTAL	**591.2**	**52.1**	**1.4**	**58.5**	**60.6**	**1.3**	**2.4**	**2.4**	**1.2**	**2.1**	**1.1**	**0.7**	**2.4**	**0.0**	**9,234.8**	**2.5**	**2.4**
	POINT TOTAL	**33.0**	**38.6**	**0.4**	**86.4**	**0.0**	**1.0**	**158.6**	**55.7**	**0.0**	**44.5**	**0.0**	**3.7**	**1.8**	**0.0**	**0.0**	**0.0**	**0.0**
	Grand Total	***718.7***	***102.3***	***2.0***	***604.7***	***60.6***	***4.6***	***351.6***	***158.1***	***1.2***	***82.4***	***1.1***	***46.9***	***4.7***	***0.0***	***18,061.5***	***136.0***	***5.0***

4.6 BACKCAST AND FORECAST

Backcast and forecast emissions inventories were estimated for the airshed, based on the years 1995 and 2012. The significant emission differences accounted for in the backcast/forecast estimates relate primarily to engine emission rates for older or newer engines. MOBILE and NONROAD modelling was conducted to determine appropriate backcast/forecast emission rates, which necessarily assumed similar age distributions for those years as was determined for 2006. In effect, this is explained in the following way: If 30% of personal vehicles were 3 years old or newer in 2006, this same characteristic was assumed for 1995 personal vehicles.

The emission rates for some sources could not be altered for the backcast and forecast years, simply due to lack of information. This was the case for the industrial point sources, even though it is evident that emissions do change on a year-to-year basis. For the forecast, there is considerable uncertainty with the industrial sources, since one or more facility may in fact close down by 2012, or change in operation. Energy consumption from both Terasen and Fortis was not available for 1995.

BC Statistics shows that the population of BC was 88.5% of the 2006 population, whereas the population of Grand Forks in 1995 was almost equal to the 2006 value. An increase in population of 7.4% was assumed by 2012, based on the increasing trend from 2005 to 2006 (BC Statistics). The ratio of provincial population in 1995 to 2006 was used to decrease the activity rates for transient highway traffic and fuel marketing. A similar approach (increase) was used for 2012 activity. An assumption that wood stove usage (cords/winter) was the same in 1995 as 2006 was applied, but with the further assumption that all wood stove appliances were 'conventional' rather than catalytic or advanced technology types. No change to wood consumption or wood stove distribution by type was applied for 2012.

For the reasons described above, some degree of caution is warranted when considering the backcast/forecast inventories. A 1995 CAC and GHG emissions inventory is shown in Figure 4.10 and a forecast 2012 inventory is shown in Figure 4.11. CanPar activity was set to zero for the forecast.

It can be seen that the major differences in estimated 1995 $PM_{2.5}$ emissions to those projected for 2012 are due to differences in CanPar operations. However, wood stove emissions were nearly double in 1995 compared to 2012 and Mobile emissions are projected to be far lower by 2012 when compared to 1995, due to significant improvements in emissions controls. Carbon dioxide emissions in reality would be lower in 2012 than presented in Table 4.11. However, an estimate of the natural gas consumption by CanPar was not available (and therefore could not be accounted for in a reduced natural gas consumption for the year).

Table 4.10
Backcast (1995) CAC and GHG Emissions Inventory*

SOURCE	Common Air Contaminants (tonnes)											Greenhouse Gases (tonnes)		
	CO	NOx	SOx	VOC	THC	NH3	TSP	PM10	PM10_D	PM25	PM25_D	CO2	CH4	N2O
Area_Agriculture	39.79	1.37	0.00	16.51	0.00	8.22	17.94	13.52	0.00	8.50	0.00	0.00	53.11	0.99
Area_Dust	0.00	0.00	0.00	0.00	0.00	0.00	605.65	306.73	0.00	74.76	0.00	0.00	0.00	0.00
Area_Energy	217.02	12.66	0.61	75.66	0.00	0.70	52.77	49.80	0.00	49.80	0.00	34,092.93	33.59	1.01
Area_General	32.91	31.39	0.24	1,951.80	0.00	0.19	5.38	5.04	0.00	4.94	0.00	1,214.10	446.34	7.78
AREA TOTAL	**289.72**	**45.42**	**0.85**	**2,043.97**	**0.00**	**9.12**	**681.74**	**375.10**	**0.00**	**138.00**	**0.00**	**35,307.03**	**533.03**	**9.78**
Mobile_Highway	2,122.62	181.82	3.92	189.94	199.01	1.76	5.40	5.40	3.62	4.39	3.33	20,464.49	8.67	5.34
Mobile_Local	1,389.77	110.36	2.36	125.19	131.37	1.33	2.50	2.50	1.61	1.98	1.48	11,953.67	5.88	3.21
Nonroad_Agricultural	93.91	19.34	1.07	7.62	7.80	0.04	2.01	2.01	1.97	1.94	1.91	1,289.06	0.48	0.41
Nonroad_Commercial	220.37	15.53	0.40	43.04	42.32	0.01	1.56	1.56	0.36	1.46	0.35	1,082.46	0.62	0.24
Nonroad_Construction	31.17	6.59	0.46	2.81	2.82	0.01	0.68	0.68	0.65	0.66	0.63	451.25	0.12	0.15
Nonroad_Industry	55.88	29.00	1.75	5.93	5.99	0.03	2.03	2.03	1.96	1.97	1.90	1,812.79	0.31	0.56
Nonroad_Recreational	70.00	0.24	0.01	32.92	31.94	0.01	0.90	0.90	0.00	0.83	0.00	380.40	0.44	0.01
Nonroad_Residential	498.21	1.67	0.02	79.43	79.42	0.02	1.31	1.31	0.00	1.20	0.00	922.00	1.06	0.02
MOBILE TOTAL	**4,481.92**	**364.56**	**9.98**	**486.89**	**500.68**	**3.21**	**16.39**	**16.39**	**10.16**	**14.43**	**9.60**	**38,356.13**	**17.56**	**9.94**
POINT TOTAL	**30.80**	**154.56**	**1.53**	**332.62**	**0.00**	**3.81**	**634.45**	**222.98**	**0.00**	**177.97**	**0.00**	**0.00**	**0.00**	**0.00**
Grand Total	***4,802.4***	***564.5***	***12.4***	***2,863.5***	***500.7***	***16.1***	***1,332.6***	***614.5***	***10.2***	***330.4***	***9.6***	***73,663.2***	***550.6***	***19.7***

*Assumes 2006 emission levels for point sources

Table 4.11
Forecast (2012) CAC and GHG Emissions Inventory*

SOURCE	Common Air Contaminants (tonnes)											Greenhouse Gases (tonnes)		
	CO	NOx	SOx	VOC	THC	NH3	TSP	PM10	PM10_D	PM25	PM25_D	CO2	CH4	N2O
Area_Agriculture	39.79	1.37	0.00	16.51	0.00	8.22	17.94	13.52	0.00	8.50	0.00	0.00	53.11	0.99
Area_Dust	0.00	0.00	0.00	0.00	0.00	0.00	829.71	329.53	0.00	75.06	0.00	0.00	0.00	0.00
Area_Energy	179.47	12.66	0.61	39.51	0.00	0.70	28.03	26.46	0.00	26.46	0.00	34,092.93	28.39	1.01
Area_General	32.91	31.39	0.24	1,987.79	0.00	0.19	5.38	5.04	0.00	4.94	0.00	1,214.10	446.34	7.78
AREA TOTAL	**252.17**	**45.42**	**0.85**	**2,043.81**	**0.00**	**9.12**	**881.06**	**374.56**	**0.00**	**114.96**	**0.00**	**35,307.03**	**527.83**	**9.78**
Mobile_Highway	660.49	60.69	0.94	58.14	61.23	3.80	1.87	1.87	0.69	1.17	0.63	22,047.24	2.69	5.82
Mobile_Local	370.21	28.57	0.37	30.91	32.53	2.22	0.96	0.96	0.35	0.59	0.32	10,524.45	1.41	2.82
Nonroad_Agricultural	42.37	8.69	0.02	3.00	3.09	0.05	0.49	0.49	0.46	0.47	0.44	1,245.80	0.36	0.40
Nonroad_Commercial	119.58	11.45	0.10	9.25	9.29	0.01	1.21	1.21	0.09	1.13	0.09	1,038.42	0.56	0.24
Nonroad_Construction	20.76	2.99	0.01	1.14	1.14	0.01	0.26	0.26	0.23	0.26	0.23	440.11	0.10	0.15
Nonroad_Industry	18.75	7.33	0.02	1.26	1.34	0.03	0.44	0.44	0.38	0.43	0.36	1,395.11	0.24	0.43
Nonroad_Recrreational	55.94	0.38	0.01	23.62	22.92	0.01	0.69	0.69	0.00	0.64	0.00	383.17	0.44	0.01
Nonroad_Residential	410.31	2.05	0.01	30.70	30.90	0.01	1.09	1.09	0.00	1.00	0.00	741.80	0.85	0.02
MOBILE TOTAL	**1,698.40**	**122.15**	**1.48**	**158.01**	**162.44**	**6.14**	**7.02**	**7.02**	**2.19**	**5.68**	**2.08**	**37,816.09**	**6.66**	**9.89**
POINT TOTAL	**15.50**	**72.90**	**0.43**	**76.29**	**0.00**	**3.31**	**214.45**	**135.98**	**0.00**	**111.97**	**0.00**	**0.00**	**0.00**	**0.00**
Grand Total	***1,966.1***	***240.5***	***2.8***	***2,278.1***	***162.4***	***18.6***	***1,102.5***	***517.6***	***2.2***	***232.6***	***2.1***	***73,123.1***	***534.5***	***19.7***

*Assumes CanPar will not be operating in 2012

APPENDIX A: UNCERTAINTY ESTIMATES

Description of Uncertainty Calculations

The estimates of uncertainty within the emission inventory follow the recommended practice of the IPCC[20]. Approach 1 within the recommended practices is applied to this inventory, providing a method to quantify the uncertainty of both the activity and the emission factors for each individual source (approximately 135) identified in the air shed. Table A.1 lists seven bins, identified by the letter Quality Code used to describe the level of uncertainly for each source input (activity, emission factors).

Table A.1
Uncertainty Bins Used To Classify Uncertainty

Quality Code	Factor	Description
A	1.1	10% error factor (upper bound factor)
B	1.2	20% error factor (upper bound factor)
C	1.3	30% error factor (upper bound factor)
D	1.5	50% error factor (upper bound factor)
E	2	100 % error factor (upper bound factor)
F	3	200 % error factor (upper bound factor)
N	1	no uncertainly

For each source within the inventory, a Quality Code has been identified for the associated emission factors and Activity levels. Table A.2 contains a listing by source containing details on the uncertainly levels. The Upper and Lower bounds represent the weighted uncertainty factor for each source and can be used to determine the bounds for each emission source (for example, the upper bound emission estimate for a particular source is generated by multiplying the emission estimate by the Upper Bound factor). The Upper Bound individual source uncertainties in the GFEI range from +23% to +500%. The Lower Bound uncertainties range from -19% to -83%. In both cases, the highest magnitude uncertainties relate to the slag pile fugitive dust emissions.

Table A.2
Uncertainties by Source: Upper and Lower Bounds

Source	Uncertainty Code		Bounds	
	Emission Factors	Activity	Upper	Lower
Roxul Hwy Truck B	B	A	1.23	0.81
P&T HwyTruck (hog)	B	A	1.23	0.81
Buses (Hwy)	A	B	1.23	0.81
Commercial NatGas	B	A	1.23	0.81

[20] Intergovernmental Panel on Climate Change (IPCC)., 2006. IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. OECD, Paris.

	Uncertainty Code		Bounds	
P&T Hwy Truck (Logging)	B	A	1.23	0.81
P&T Hwy Truck (Shavings)	B	A	1.23	0.81
P&T Hwy Truck (Chips)	B	A	1.23	0.81
Kleenblast Hwy Truck (slag)	B	A	1.23	0.81
Canpar Hwy Truck (product)	B	A	1.23	0.81
Canpar Hwy Truck (fibre)	B	A	1.23	0.81
Canpar Hwy Truck (additives)	B	A	1.23	0.81
P&T Hwy Truck (shipping)	B	A	1.23	0.81
Industry NatGas	B	A	1.23	0.81
Roxul Hwy Truck A	B	A	1.23	0.81
Light Duty Trucks (local)	A	B	1.23	0.81
Light Duty Vehicles (local)	A	B	1.23	0.81
Motorcycles (local)	A	B	1.23	0.81
P&T Hwy truck (trim blocks)	B	A	1.23	0.81
Medium Duty Trucks (Hwy)	A	B	1.23	0.81
Light Duty Trucks (Hwy)	A	B	1.23	0.81
Light Duty Vehicles (Hwy)	A	B	1.23	0.81
Res NatGas furnace	B	A	1.23	0.81
Heavy Duty Trucks (Hwy)	A	B	1.23	0.81
Roxul Hwy Truck C	B	A	1.23	0.81
Canpar (point)	C	N	1.30	0.77
Pope & Talbot (point)	C	N	1.30	0.77
Biogenic (airshed)	C	N	1.30	0.77
Landfill	C	N	1.30	0.77
Roxul (point)	C	N	1.30	0.77
Tractor Trailers (Hwy)	B	B	1.31	0.76
Motorcycles (Hwy)	B	B	1.31	0.76
P&T water truck	C	A	1.33	0.75
P&T Volvo 220	C	A	1.33	0.75
Commercial - Electric	C	A	1.33	0.75
Municipal - Electric	C	A	1.33	0.75
Industrial - Electric	C	A	1.33	0.75
Residential - Electric	C	A	1.33	0.75
P&T Volvo 180	C	A	1.33	0.75
P&T log loader	C	A	1.33	0.75
P&T Hyundai	C	A	1.33	0.75
Kleenblast Loader	C	A	1.33	0.75
Canpar Loader	C	A	1.33	0.75
P&T forklifts	C	A	1.33	0.75
Residential trimmer	B	C	1.40	0.72
Residential Tillller	B	C	1.40	0.72
Residential L&G tractor	B	C	1.40	0.72
Residential mower	B	C	1.40	0.72
Residential Snow Blower	B	C	1.40	0.72
Residential Chain saw	B	C	1.40	0.72
Residential water pump	B	C	1.40	0.72

	Uncertainty Code		Bounds	
Residential leaf blower	B	C	1.40	0.72
Residential generator	B	C	1.40	0.72
Residential riding mower	B	C	1.40	0.72
Selkirk Paving (point)	D	N	1.50	0.67
Pacific Abrasives (point)(susp)	D	N	1.50	0.67
Pacific Abrasives (point)(tran)	D	N	1.50	0.67
ATVs	B	D	1.59	0.63
Motorcycle Off road (dirt)	B	D	1.59	0.63
Commercial Mower	B	D	1.59	0.63
Construction Backhoe	B	D	1.59	0.63
Construction Trencher	B	D	1.59	0.63
Construction Tamper	B	D	1.59	0.63
Construction Signal Board	B	D	1.59	0.63
Construction Roller	B	D	1.59	0.63
Construction Paving	B	D	1.59	0.63
Construction Mixer	B	D	1.59	0.63
Construction Loader	B	D	1.59	0.63
Construction Excavator	B	D	1.59	0.63
Construction Dozer	B	D	1.59	0.63
Construction Crusher	B	D	1.59	0.63
Construction Compactor	B	D	1.59	0.63
Commercial L/G Tractor	B	D	1.59	0.63
Construction BoreDrill	B	D	1.59	0.63
Commercial Turf Equip	B	D	1.59	0.63
Commercial Chain Saw	B	D	1.59	0.63
Commercial RideMower	B	D	1.59	0.63
Commercial Pumps	B	D	1.59	0.63
Commercial Press Washer	B	D	1.59	0.63
Commercial Leaf Blower	B	D	1.59	0.63
Commercial Chippers	B	D	1.59	0.63
Commercial Tiller	B	D	1.59	0.63
Rail - GF switch locomotive	D	B	1.59	0.63
Woodstove pellet	B	D	1.59	0.63
Industrial AC\Refrigeration	C	D	1.68	0.59
Construction Forklift	C	D	1.68	0.59
Woodstove advanced tech	C	D	1.68	0.59
Woodstove conventional	C	D	1.68	0.59
Industrial Welder	C	D	1.68	0.59
Industriall Air Compressor	C	D	1.68	0.59
Industrial Generator	C	D	1.68	0.59
Woodstove catalytic	C	D	1.68	0.59
Fuel_marketing	D	D	1.89	0.53
Aircraft Land/Takeoff	E	A	2.03	0.49
farm trucks other	B	E	2.11	0.47
Snow Machine	B	E	2.11	0.47
farm PU / Van	B	E	2.11	0.47

	Uncertainty Code		Bounds	
farm tractors	B	E	2.11	0.47
farm swathers	B	E	2.11	0.47
farm trucks	B	E	2.11	0.47
farm bailers	B	E	2.11	0.47
horses	D	E	2.51	0.40
Rail - BNSF line haul	E	D	2.51	0.40
Pesticide	D	E	2.51	0.40
Fertilizer application	D	E	2.51	0.40
horses manure	D	E	2.51	0.40
poultry manure	D	E	2.51	0.40
poultry	D	E	2.51	0.40
sheep manure	D	E	2.51	0.40
Land clearing	D	E	2.51	0.40
pigs manure	D	E	2.51	0.40
pigs	D	E	2.51	0.40
cattle manure	D	E	2.51	0.40
cattle	D	E	2.51	0.40
sheep	D	E	2.51	0.40
Tilling Soil	D	E	2.51	0.40
Manure application	D	E	2.51	0.40
Dust Susp - Material Transfer	F	A	3.06	0.33
Dust Tran - Material Transfer	F	A	3.06	0.33
Dust Tran - Res Paved	F	B	3.20	0.31
Dust Susp - Res Paved	F	B	3.20	0.31
Dust Susp - Res Unpaved	F	B	3.20	0.31
Dust Tran - Res Unpaved	F	B	3.20	0.31
Dust Tran - Industry Paved	F	C	3.40	0.29
Dust Tran - Hyw3	F	C	3.40	0.29
Dust Susp - Hyw3	F	C	3.40	0.29
Dust Susp (P&T loader)	F	C	3.40	0.29
Dust Susp - Industry Paved	F	C	3.40	0.29
Dust Trans (P&T loader)	F	C	3.40	0.29
Burning Open	E	E	3.41	0.29
Agriculture burning	E	E	3.41	0.29
Burning Barrel	E	E	3.41	0.29
Dust Susp - Industry Unpaved	F	D	3.93	0.25
Dust Tran - Industry Unpaved	F	D	3.93	0.25
Dust Susp - Pile Erosion	F	E	6.00	0.17
Dust Tran - Pile Erosion	F	E	6.00	0.17

Description of Uncertainty Calculations:

The uncertainties defined within the inventory cause an error to propagate through the results in two steps. The first is when activity and emission values are multiplied, as when the emissions

are calculated for each individual source (Activity X Emission Factor), and second when total emissions are summed for an inventory total. Following the recommended practice from the IPCC, two equations are defined for error propagation when multiplying (equation 1) and when summing (equation 2).

The Uncertainty in the IPCC equations is based upon the coefficient of variation which describes the extent of the error from the emission estimate as a relative quantity. In order to convert the uncertainty factors used within the inventory (e.g., 1.2) to the coefficient of variation, the expression (1- 1 / U_{factor}) is used.

Equation 2 is used to determine the overall uncertainty for individual pollutants for the inventory as a whole when summing estimates for the individual sources.

Combining Uncertainties – Approach 1 – Multiplication

$$U_{total} = \sqrt{\left(1 - \frac{1}{U_{EmissionFactor}}\right)^2 + \left(1 - \frac{1}{U_{ActivityFactor}}\right)^2} \quad \textbf{\{Equation 1\}}$$

- U_{total} = Combined uncertainty for the individual source
- $U_{EmissionFactor}$ = Uncertainty for the Emission Factors
- $U_{ActivityFactor}$ = Uncertainty for the Activity level

Combining Uncertainties – Approach 2 – Addition

$$U_{total} = \frac{\sqrt{(U_1 * X_1)^2 + (U_2 * X_2)^2 + \ldots + (U_n * X_n)^2}}{|X_1 + X_2 + \ldots + X_n|} \quad \textbf{\{Equation 2\}}$$

- U_{total} = Combined uncertainty for the pollutant compound
- U_1 and X_1 = Uncertainty and associated Emission quantities, resulting from the individual sources

In addition to individual uncertainty, the overall uncertainty for the GFEI primary emission estimates has been calculated and is provided in Table A.3.

Table A.3
Overall Uncertainty for GFEI Primary Emission Totals

Emission	Overall Uncertainty
CO	6.60%
NO_x	6.90%
SO_x	8.54%
VOC	18.11%
TSP	29.47%
PM_{10}	29.75%
$PM_{2.5}$	18.38%
NH_3	19.27%
CO_2	6.79%
CH_4	19.53%
N_2O	28.31%

APPENDIX B: EMISSION ESTIMATION METHODOLOGIES

B.1 FUGITIVE DUST

The U.S EPA has developed and supported empirical roadway fugitive dust emission equations that date back to the 1980s for both paved and non-paved roads. These equations are:

Paved Road Surfaces (AP-42, 13.2.1-6, Nov 2006)

$$E = \left[k(sL/2)^{0.65}(W/3)^{1.5} - C\right](1 - P/4N) \qquad (1)$$

Where:

E = particulate emission factor with same units as 'k'
k = particle size multiplier for particle size range of interest (g/VKT)
sL = silt loading of road surface in g/m^2
W = average weight in tons for vehicles travelling on roadway
C = emission factor for 1980's vehicle fleet exhaust, brake wear and tire wear
P = number of 'wet' days in averaging period 'N'
N = averaging period in days

Unpaved road surfaces (AP-42 13.2.2-1, Nov 2006)

$$E = \frac{k(s/12)^a (S/30)^d}{(M/0.5)^c} - C \qquad (2)$$

Where:

k, a, c and d are empirical constants that vary with particle size range
s = surface material silt content (%)
W = mean vehicle weight (tons)
M = surface material moisture content (%)
S = mean vehicle speed (mph)
C = emission factor for 1980s vehicle fleet exhaust, brake wear and tire wear

Unpaved road surfaces at industrial sites (AP-42, 13.2.2-1, Nov 2006)

$$E = k(s/12)^a (W/3)^b$$

Where:

a and b are empirical constants that vary with particle size range
s = surface material silt content (%)
W = mean vehicle weight (tons)

EPA documentation suggests that estimates for unpaved roads should be multiplied by the fraction of 'dry' days in the year (days with no precipitation, or precipitation less than 0.254 mm), which assumes that emissions on days with precipitation are minimal.

Mean vehicle weight applies to all vehicles travelling on a particular roadway. The EPA cautions that the equations should not be used to determine emission factors for specific weight classes (such as tractor trailers). For the three equations, silt levels and moisture content are important and local values are not available. Therefore, estimates must be made based on studies performed elsewhere. Table B.1 provides the average equation parameter values determined for Grand Forks roadways. The silt and moisture values were based on EPA default values by roadway type.

Table B.1
Input Parameters for EPA Fugitive Dust Equations

Silt loading (sL) – highway 3	0.10 g/m2
Silt loading (sL) – other paved roads	0.60 g/m2
Average weight in tons (W) – highway 3	3.0 tons
Average weight in tons (W) – other roads	2.7 tons
Average weight in tons (W) – industrial sites	40 tons
Average silt % (s) - industrial sites	8.4 %
Average silt % (s) - unpaved roads	6.0 %
Surface moisture content (M) – unpaved roads	5.0 %

All three equations represent 'uncontrolled' conditions. Any actions taken to reduce dust emissions lower the equation estimates. Since the industrial sites in Grand Forks are subject to water sprays, a control efficiency of 50% was applied. This assumes use of a formal mitigation plan, which is reasonable for the major industries[21]. Preliminary and adjusted PM emission factors are presented in Table B.2.

[21] Both anecdotal remarks and description of facility equipment (e.g., water trucks) resulting from the industrial information requests imply use of a regular watering program.

Table B.2
Preliminary Fugitive PM Emission Factors

Road Type	Base Emission Factors (g/VKT)			Control Factor?	Adjusted Emission Factors (g/VKT)		
	TSP	PM_{10}	$PM_{2.5}$		TSP	PM_{10}	$PM_{2.5}$
Highway 3	3.02	0.48	0.00	no	3.02	0.48	0.00
Residential, paved	8.48	1.53	0.16	no	8.48	1.53	0.16
Residential, unpaved	284.42	107.36	10.68	no	284.42	107.36	10.68
Industrial, unpaved	2317.16	660.50	66.05	yes, 50%	1158.58	330.25	33.02

EPA documentation suggests use of multipliers to adjust silt loading values in winter time conditions, to reflect use of antiskid abrasives. Following these recommendations, the silt loading on 'other residential' roads was increased to 2.4 g/m2 for half of the year and on 'Highway 3' to 0.20 g/m2. No adjustments are necessary for the unpaved road equations. Winter fugitive PM emission factors are shown in Table B.3. Finalized annual fugitive emission factors are presented in Table B.4.

Table B.3
Winter Fugitive PM Emission Factors

Road Type	Base Emission Factors (g/VKT)		
	TSP	PM_{10}	$PM_{2.5}$
Highway 3	5.24	0.90	0.05
Residential, paved	21.05	3.94	0.49
Residential, unpaved	284.42	107.36	10.68
Industrial, unpaved	1158.58	330.25	33.02

Table B.4
Finalized Annual Fugitive PM Emission Factors

Road Type	Base Emission Factors (g/VKT)		
	TSP	PM_{10}	$PM_{2.5}$
Highway 3	4.13	0.69	0.02
Residential, paved	14.77	2.73	0.32
Residential, unpaved	284.42	107.36	10.68
Industrial, unpaved	1158.58	330.25	33.02

The uncertainty associated with the emission rates in Table B.4 is relatively high. In addition, these rates should be considered reasonable only for average emission rates over the year and

would certainly be too low for shorter periods following the application of gravel or other material to improve traction in the winter.

Additional fugitive dust emissions can be associated with material handling. The EPA suggests that the following equation should be used for general handling or transfer activities (Ch. 13.2.4-1):

$$E = k * 0.016 \left(\frac{U}{2.2}\right)^{1.3} \left(\frac{M}{2}\right)^{-1.4} \; kg / tonne$$

Where:

k = empirical constant that depends on particle size category (0.74, 0.35, 0.053)
U = mean wind speed (m/s)
M = material moisture content

For iron and steel slag material, the EPA suggests values of s = 5.3% and M = 0.92 % are appropriate default values. SENES assumes these values are reasonably representative of the slag pile material in Grand Forks. The local Ministry of Forests meteorological station yields an average wind speed of 2.4 m/s for 2006.

The slag pile at the north end of the city may cause infrequent dusting events when the local wind speeds are relatively high. An accounting of these emissions requires consideration of wind speeds by hour of day, exposure of the pile(s) to the wind and the particle size distribution of material on the slag pile (finer particles become airborne more easily than coarser particles).

The current recommended approach for estimating dust emissions from storage piles primarily relates to coal storage. The equation was developed based on storage piles of approximate height 10m and requires an assessment of the frequency of local wind speed above a threshold considered able to liberate dust from the pile(s)[22]. This approach also requires an estimate of the frequency of disturbance of the storage pile (and fraction that is disturbed). SENES decided to use a different, simpler approach, for two reasons:

1) the inputs required for the approach described above are not available and reasonable estimates could not be made, and
2) the storage piles considered for the determination of the equation are quite different than the slag piles in Grand Forks.

[22] See AP-42, chapter 13.2.5 for a full accounting of the methodology. http://www.epa.gov/ttn/chief/ap42/ch13/index.html.

The EPA previously developed a more general wind erosion emission factor equation that is still used by some jurisdictions[23]. This equation can be used to give a rough indication of fugitive dust from a storage pile with minimal input data. The equation was developed for coal storage piles, but the EPA also recommends default parameters for other materials. The equation is described as follows:

$$E = 1.9 * \left(\frac{s}{1.5}\right) * 365 * \left(\frac{365 - P}{235}\right)\left(\frac{f}{15}\right) kg / ha / year$$

Where:

s = silt content (5.3%)
P = days of precipitation above 0.254 mm (120)
f = frequency of wind speed above 5.4 m/s (6.4%)

5.3% is the mean silt value suggested by the EPA for iron and steel production slag material. A frequency of wind speed above 5.4 m/s of 6.4% was determined from the local Ministry of Forests station data for 2006. Due to the height of the storage piles and exposure to higher level winds, SENES arbitrarily increased the frequency parameter to 10% in order to account for increasing wind speeds with height above ground.

This approach also is to be used with 'active' storage piles. As a conservative estimate, SENES considered 4 ha to be representative of the active area of the storage pile, including the ground level processing. The equation yields TSP estimates; the same fractions used for PM_{10} and $PM_{2.5}$ for material transfer were applied to the erosion total.

Table B.5
Dust Emissions from Slag Handling and Erosion

Activity	Base Emission Factors		
	TSP	PM_{10}	$PM_{2.5}$
Material Transfer (kg/tonne)	0.0393	0.0186	0.0028
Pile Erosion (kg/ha)	1,703	806	122

B.2 GLOBEIS MODELLING (BIOGENICS)

The GloBEIS model (version 3.1) requires landcover data, with hourly wind, temperature, humidity and cloud cover as minimum requirements. Leaf area index and drought index information can also be used if available (in this case they were not). The MoE provided the

[23] For example the Emission Estimation Technique Manual for Environment Australia – fugitive dust from mining.

necessary meteorological inputs, with the exception of cloud cover. SENES prepared a 'dummy' input file of cloud cover, setting cloud amounts to zero each hour. A brief sensitivity study was conducted by changing the cloud fraction amounts (applied continuously throughout the year), which clearly showed little model sensitivity to cloud cover. For this reason, consistent use of clear skies for the model simulation was considered reasonable for the GFEI.

The MoE provided landcover data from the Integrated Land Management Bureau (ILMB) GIS files, based on a data extraction for the area defined as the Grand Forks airshed. The ILMB data do not include vegetation cover for non-forested areas, such as those within the Grand Forks municipal boundary and Area D of the Kootenay Boundary Regional District. The ILMB database showed that non-forested areas account for 48% of the airshed. This portion of the domain modeled in GloBEIS was characterized as grassland (40%) and urban (8%). An urban category defined as 20% grassland and 20% general forest (with 60% non-emitting) was available in the model database. VOC emissions from grasslands are relatively low compared to forested areas.

Model selection 3 was used (GloBEIS3) with five canopy layers and internal leaf temperature calculation. Table B.6 provides the landcover codes and fractions used to characterize the Grand Forks airshed.

Table B.6
GloBEIS Landcover Categories used for Grand Forks Airshed

Vegetation Type	GloBEIS Code	Fraction of Domain
Fir	99124	0.2946
Lodgepole Pine	99166	0.0453
Ponderosa Pine	99183	0.0173
Western Larch	99153	0.1386
Aspen	99063	0.0219
Cedar	99020	0.0019
Birch	99013	0.0009
Spruce	99157	0.0011
Grassland	98070	0.4000
Urban	98117	0.0784

APPENDIX C: SECONDARY PM ESTIMATION METHODOLOGY

C.1 SECONDARY INORGANIC AEROSOLS (SULPHATES, NITRATES)

Secondary particles/aerosols are those that form in the atmosphere from gases emitted directly from a variety of sources. The major portion of aerosol sulphates and nitrates in the atmosphere is of secondary origin, resulting from emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_x) and ammonia (NH_3). The end products of the conversion of SO_2 and NO_x into secondary aerosols are ammonium sulphate ($(NH_4)_2SO_4$) and ammonium nitrate (NH_4NO_3) particles. Organic aerosols result from the atmospheric transformation of various volatile organic compounds (VOC).

Though complex, the mechanisms for the formation of sulphates and nitrates in the atmosphere are reasonably well understood. The conversion of SO_2 to sulphate (SO_4) is governed by a complex series of interactions which include transport and diffusion of the emitted SO_2, gas-phase and aqueous-phase chemistry, meteorology, cloud physics, and dry and wet scavenging processes. For example, the chemical interactions between nitrogen and organic chemicals are important to the chemical processes involved in the transformation of SO_2 into sulphate. The gas-phase chemistry involved in the transformation of SO_2 and NO_x alone consists of at least 100 chemical reactions among 50 chemical species (Venkatram 1990). Consequently, in order to fully understand conversion of SO_2 into secondary SO_4, it is also necessary to determine concurrent changes in the conversion of NO_x and VOC compounds into secondary nitrates (NO_3) and organic aerosols.

The atmospheric oxidation of sulphur-bearing compounds to sulphates can occur:

1. through gas-phase (homogeneous) reactions;
2. on the surface of particles (heterogeneous gas-solid reactions); and,
3. within aqueous droplets (homogeneous liquid-phase reactions).

Oxidation by the hydroxyl (OH) radical is of major importance in the troposphere. The rate of gas-phase oxidation by ozone (O_3) is negligible, except in the presence of alkenes, when oxidation proceeds very rapidly (Radojevic 1992). Aqueous-phase oxidation of SO_2 in the atmosphere can occur in cloudwater, in fogwater and rainwater, in deliquescent aerosol droplets at high relative humidity and in the liquid surface film condensed on aerosol particles (Radojevic 1992). Field studies of oxidation rates in clouds suggest that aqueous-phase oxidation mechanisms are considerably faster at converting SO_2 to SO_4 than gas-phase reactions.

The slowest SO_2 oxidation rates have been reported for plumes in relatively pristine air in the Arctic (0.04% to 0.2 % per hour), while in-plume oxidation rates for power plant plumes range have been reported to range from 0.2% per hour to 8% per hour (Radojevic 1992). Oxidation rates of <0.5% per hour in power plant plumes were reported for night time plumes, and >1% per

hour for daytime plumes. Studies of in-plume oxidation rates from the Kuwait oil fires were reported at 1% per hour (Smyth et al. 1994). Oxidation rates in fog have been reported to be as high as 3-30% per hour, and in-cloud rates of 5-21% per hour. Average SO_2 oxidation rates over long periods are typically assumed to be on the order of 1-2% per hour. For the purposes of the emission inventory in Grand Forks, it has been assumed that average daytime conversion rates are about 2% per hour in the warmer months of the year, and an order of magnitude lower in the night time and colder months of the year.

Inorganic aerosol nitrates (NO_3) are one of the end-products of photochemical reactions of NO_x in the atmosphere. Most of the NO_x (i.e., 90-95%) emitted from stationary and mobile sources of fuel combustion is emitted as NO, which is subsequently converted to NO_2 by several pathways, including the reactions of NO with peroxy radicals and ozone. The NO_2 is converted to organic and inorganic products. The inorganic products, nitric acid (HNO_3) and subsequently particulate nitrate (NO_3), are formed by the reaction of NO_2 with the hydroxyl radical (OH). Concentrations of fine particulate nitrate are generally reported to be higher during the day than at night, consistent with the higher contribution of motor vehicle-derived NO_x emissions during the daytime and the photochemical origin of most of the fine nitrate aerosol in the atmosphere (Grosjean and Bytnerowicz 1993). However, night time particulate nitrate may be formed by the reactions of the gas-phase nitrate radical (NO_3) and dinitrogen pentoxide (N_2O_5) with pre-existing particulate matter in the atmosphere.

Field studies have determined that gas-phase reactions are the predominant reaction mechanisms for the oxidation of NO_2. In the presence of ozone, the oxidation rate of NO to NO_2 may be as high as 8% per second; however, field studies of the in-plume conversion rates for NO_x to NO_2 in Kuwaiti oil fires were reported to be on the order of 2-30% per hour (Smyth et al. 1994). In polluted atmospheres, an effective second-order rate constant for the reaction of NO_2 with the OH radical to form HNO_3 can be on the order of 18% per hour (Radojevic 1992). In cold temperatures (i.e., in winter) and during the night, conversion rates would be about an order of magnitude lower than in the daytime and in warmer atmospheres. For the purposes of the emission inventory in Grand Forks, it has been assumed that average daytime NO_x to aerosol nitrate conversion rates was 5.4% per hour in the warmer months of the year (i.e., NO to NO_2 conversion rate of 20% per hour combined with NO_2 to NO_3 conversion rate of 18% per hour), and an order of magnitude lower in the night time and colder months of the year (i.e., 0.54% per hour).

For both sulphate and nitrate production, two other assumptions were applied. The first assumption is that the average residence of precursor compounds in the atmosphere, within the airshed, was 1 ½ hours, based on the horizontal extent of the airshed and the average annual wind speed. However, it should be noted that precursor compounds could also escape the airshed through vertical diffusion. The second assumption was that the final nitrate and sulphate

mass estimates are gained by multiplying the conversion rates by the ratio of SO_2 and NO_2 molar mass to ammonium sulphate and ammonium nitrate molar mass (e.g., the ammonium mass is included in the secondary inorganic PM estimates).

C.2 SECONDARY ORGANIC AEROSOLS

Chemical reaction between organic gases, NO_x and NH_3 are capable of forming secondary fine particulate organic aerosols. Organic compounds that are gaseous precursors to secondary organic aerosols (SOA) include terpenoids from biogenic sources (i.e., trees), alkanes from both vehicular and biological sources, as well as aldehydes, ketones, carboxylic acids, lactones and furans from photochemical reactions in the atmosphere (Greaves et al. 1987). According to Grosjean and Seinfeld (1989), the principal oxidizing species for VOC in urban atmospheres are ozone (daytime and night time), the hydroxyl radical (daytime only) and the nitrate radical (night time only). Recently published research (Chen Song et al. 2007) suggests that SOA production is hindered by the presence of higher concentrations of NO_x in polluted urban atmospheres because the NO competes in chemical reactions with intermediary reaction products. In cleaner atmospheres with relatively lower NO_x concentrations, reactions with HO_2 and organic hydroperoxides become an important contributor to SOA formation, especially in relation to natural emissions of monoterpenes.

The chemical composition of organic aerosols have been identified for some precursor reaction products, but not for the majority of the potential chemical reactions due to the lack of direct chemical analysis methods for separating the primary and secondary organic aerosol components from the complex mixture of hundreds of chemical compounds in ambient aerosol samples (Pandis et al. 1993), as well as by the time-consuming and costly analytical methods required to identify even a small fraction of the total organic carbon compounds in a sample (Grosjean 1992).

The formation of SOA for individual reactive organic gases (ROG) has been estimated through laboratory smog chamber studies to determine the fraction of total organic gas present in an atmosphere that is converted to SOA. By multiplying the actual ROG emission rate for each species with the fractional aerosol coefficient (FAC), the total mass of secondary aerosol formed from the emission of each ROG can then be crudely estimated, although with a relatively high degree of uncertainty.

Specific Approach:

In order to determine SOA formation, the composition of gaseous VOC compounds from the sources within the inventory needs to be defined. The EPA has developed a database (SPECIATE 4.0) that contains a large listing of source types and provides information on the

compounds present in the gaseous VOC emissions by type. Table C.1 lists the gas profiles chosen from within the SPECIATE Database that apply to sources within the Grand Forks inventory. There is a significant amount of uncertainty associated with using the profiles and data from the SPECIATE database, since there is not always a clear match between sources within the Grand Forks airshed and the source types identified in the SPECIATE database. Best judgment has been applied to match together profiles within the database and sources in the inventory.

Table C.1 Gas Profiles Used in the GFEI

EPA SPECIATE Profile Number	Gas Profile Name
0	n/a
0003	External Combustion Boiler - Natural Gas
0025	Asphaltic Concrete - Natural Gas Rotary Dryer
0076	General Pesticides
0121	Open Burning Dump - Landscape/Pruning
0195	Residential Fuel - Natural Gas
0202	Solid Waste Landfill Site - Class II
0203	Solid Waste - Animal Waste Decomposition
0307	Miscellaneous Burning - Forest Fires
1084	Residential Wood Combustion (C-1 - C-6)
1099	Aircraft Landing/Takeoff (LTO) - General Aviation
1189	Pulp and Paper Industry - Plywood Veneer Dryer
1313	Industry Average (circa 1990) Gasoline Exhaust
2423	Industrial Adhesives
2491	Vehicle Exhaust - Current Fleet (1989) FTP Composite, Conventional Fuel
2526	Vehicle Exhaust - Fort McHenry Tunnel Diesel - 1995
2528	Vehicle Exhaust - Van Nuys Tunnel - June 8-12, 1995
3147	Consumer Products Composite: Personal Care Products
3161	Diesel Exhaust - Farm equipment
4553	Meat charbroiling
4647	Gasoline exhaust – 1993
4674	Diesel exhaust - medium duty trucks
8746	Composite Profile - Straw Burning
8748	Composite Profile - Overall Liquid Gasoline (MTBE, Ethanol, and Non-Oxygenated)
BIOGEN**	biogenic emission profile from model

**BIOGEN is a profile developed from the GloBEIS v3.1 Model and is used the same way as other profiles.

The EPA SPECIATE database provides a breakdown of the gaseous compounds contained in the VOC emissions, which is the first step in calculating secondary organic formation. The second step is to identify those compounds in the SPECIATE gas profiles that will form organic aerosols and the fraction of those compounds that actually convert within the atmosphere. Table C.2 lists

those gaseous compounds present in the SPECIATE profiles identified in Table C.1 that also have a Fractional Aerosol Coefficient (FAC) as defined in the available literature (in particular, Grosjean & Seinfeld 1989, Grosjean 1992).

For each gaseous compound that has been identified in the SPECIATE database, and that has been further identified with a representative FAC coefficient, the following equation was used to determine the mass of Secondary Organic Aerosol produced:

$$(\text{VOC[kg]}) \text{ X } (\%\text{Weight}/100) \text{ X } (\text{FAC Coefficient}) = \text{SOA[kg]} \qquad \{\text{Equation 1}\}$$

Where %Weight is determined from the SPECIATE database. Note that this equation does not consider the amount of time that a particular compound may spend within the Grand Forks study area. As such, the production of some portion of the total mass may actually occur outside the study area.

Table C.2
Fractional Aerosol Coefficients (FAC) For the Formation of Secondary Organic Aerosols

Specie Properties Name (Gaseous Compound)	FAC (Fraction)	Specie Properties Name (Gaseous Compound)	FAC (Fraction)
Alpha-pinene	0.3	C10 aromatics	0.026
Beta-pinene	0.3	Isomers of butylbenzene	0.026
isoprene	0.3	N-butylbenzene	0.026
Orange terpenes	0.3	T-butylbenzene	0.026
Terpenes	0.18	1-Methylnaphthalene	0.025
total terpenes	0.18	Indan	0.025
1-undecene	0.12	Methylindane	0.025
1-decene	0.09	N-undecane	0.025
Cyclohexene	0.07	1,2,4-trimethylbenzene (1,3,4-trimethylbenzene)	0.02
1,2,3,4-tetramethylbenzene	0.063	1,2,4-trimethylbenzene+t-butylbenzene	0.02
1,2,4,5-tetramethylbenzene	0.063	1-heptene	0.02
1,2-diethylbenzene (ortho)	0.063	Cis-2-octene	0.02
1,3-diethylbenzene (meta)	0.063	Heptene	0.02
1,4-diethylbenzene (para)	0.063	N-decane	0.02
Tetramethylbenzene	0.063	N-propylbenzene	0.016
1-nonene	0.06	P-xylene	0.016
Hexylcyclohexane	0.06	N-nonane	0.015
1-Methyl-2-ethylbenzene	0.056	1-octene	0.01
1-Methyl-3-ethylbenzene	0.056	C7 Olefins (terminal alkenes)	0.01
1-Methyl-4-ethylbenzene	0.056	Isomers of dodecane	0.01
Ethyltoluenes (methylethylbenzenes)	0.056	2,2,3-trimethylpentane	0.0073
Ethylbenzene	0.054	2,2,4-trimethylpentane	0.0073
Toluene	0.054	2,3,4-trimethylpentane	0.0073
1-Methylcyclopentene	0.05	2,2-dimethylheptane	0.0065
2-methylnaphthalene	0.05	2,4-dimethylheptane	0.0065
3-methylcyclopentene	0.05	2,5-dimethylheptane	0.0065
O-xylene	0.05	2,6-dimethylheptane	0.0065

Specie Properties Name (Gaseous Compound)	FAC (Fraction)	Specie Properties Name (Gaseous Compound)	FAC (Fraction)
Pentadecane	0.05	3,5-dimethylheptane	0.0065
Pentylcyclohexane	0.05	4,4-dimethylheptane	0.0065
Phenol (carbolic acid)	0.05	2,2,5-trimethylhexane	0.005
2,4,4-trimethyl-1-pentene	0.049	2-methylheptane	0.005
M-xylene	0.047	3-methylheptane	0.005
C16 Branched alkane	0.0466	C7-C16 Paraffins	0.0045
Butylcyclohexane	0.04	Isomers of pentadecane	0.0019
Cyclopentane	0.04	Isomers of tetradecane	0.0019
Cyclopentene	0.04	C2-Naphthalenes	0.0017
Isopropylbenzene (cumene)	0.04	C3-naphthalenes	0.0017
Naphthalene	0.04	C4-naphthalenes	0.0017
Tetradecane	0.04	Cyclohexane	0.0017
Isomers of xylene	0.0393	Cyclohexanone	0.0017
1,2,3-trimethylbenzene	0.036	Methylcyclopentane	0.0017
N-tridecane	0.035	Heptanal	0.0012
1,1,2-trimethylcyclohexane	0.03	2,2-dimethylhexane	0.0006
1,1,3-trimethylcyclohexane	0.03	2,2-dimethylpentane	0.0006
1,1,4-trimethylcyclohexane	0.03	2,3-dimethylhexane	0.0006
Cis,trans-1,2,4-trimethylcyclohexane	0.03	2,3-dimethylpentane	0.0006
Cis-1,trans-2,trans-4-trimethylcyclohexane	0.03	2,4-dimethylhexane	0.0006
Isopropylcyclohexane	0.03	2,4-dimethylpentane	0.0006
M & p-xylene	0.03	2,5-dimethylhexane	0.0006
N-dodecane	0.03	2-methylhexane	0.0006
Propylcyclohexane	0.03	3,3-dimethylhexane	0.0006
1,3,5-trimethylbenzene	0.029	3,3-dimethylpentane	0.0006
1,1-dimethylcyclohexane	0.027	3,4-dimethylhexane	0.0006
Cis-1,2-dimethylcyclohexane	0.027	3-methylhexane	0.0006
Dimethylcyclohexane	0.027	Cyclopentane, (1-methylethyl)-	0.0006
Ethylcyclopentane	0.027	Dimethylhexanes	0.0006
Methylcyclohexane	0.027	Dimethylpentane	0.0006
Trans-1,2-dimethylcyclohexane	0.027	N-heptane	0.0006
Trans-1,4-dimethylcyclohexane	0.027	N-octane	0.0006

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