Analysis of Best Management Practices and Emission Inventory of Agricultural Sources in the Lower Fraser Valley

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EXECUTIVE SUMMARY

Air quality management programs, including those in the Lower Fraser Valley (LFV), have focused largely on motor vehicle and major industrial sources of emissions, and to a lesser extent on light industrial, commercial, institutional and residential sources. Compared to air quality management initiatives for these other sources, emissions from agricultural operations have been relatively untouched. However, within the Lower Fraser Valley airshed, emission inventory studies show that, as emissions from vehicles, fuels and industrial sources are reduced through regulations, agreements and other programs, the impact of agricultural operations along with marine vessels and non-road engines become increasingly important.

This study has been commissioned to:

- Develop an updated and comprehensive emissions inventory for the agricultural sector in the Lower Fraser Valley; and
- Review existing best management practices (BMPs) for agricultural sources of emissions and identify the preferred BMPs for application in the Lower Fraser Valley

The two pollutants of primary concern in the LFV airshed are ozone and fine particulate matter ($PM_{2.5}$), both of which contribute to smog formation. Ground-level ozone is a secondary pollutant formed in the atmosphere, through reactions involving “precursor” pollutants, including primarily nitrogen oxides (NOx) and volatile organic compounds (VOC), and to a much lesser degree, carbon monoxide (CO). $PM_{2.5}$ arises both from primary emissions and secondary formation. Primary particulate matter is emitted directly to the atmosphere from various sources, such as industrial stacks, motor vehicle exhaust and burning. Fine particulate can also be formed secondarily, by reaction of NOx, SOx, VOCs, ammonia (NH_3) and other gases in the atmosphere.

Light duty motor vehicles currently remain major sources of smog precursor emissions, but their contribution has declined due to the combined effect of tighter emission standards and the beneficial effects of the AirCare vehicle inspection and maintenance program. New Tier 2 emission standards for light duty vehicles that came into effect in 2004 model year vehicles will further reduce emissions from light duty vehicles in the future, off-set somewhat by the growth in number of vehicles and distances driven annually. Emission forecasts prepared by the Greater Vancouver Regional District (GVRD) show that emissions from marine vessels, agricultural sources and non-road engines become increasingly important in the years beyond 2015. The non-road engines category includes emissions from agricultural equipment.

The updated emission inventory prepared for this study (summarized in Table S-1) confirms the significance of the agricultural sector in terms of regional emissions of ammonia, particulate matter and greenhouse gases. Using the 2000 Lower Fraser Valley emission inventory and forecasts (GVRD, 2002 and 2003a, 2003b) as the basis, the main revisions made include:

- Updating of the base quantities used for animal emissions, with more recent information from the 2001 Census of Agriculture.
- Application of revised methodologies for calculating ammonia emissions from management of manure.

- Incorporation of new estimates for agricultural non-road engines and equipment using the new version of the U.S. EPA NONROAD model released in 2004.

In order to improve future agricultural emission inventories, a number of recommended refinements, or developments which should be monitored were noted:

- Emissions from fuel combustion in boilers used to heat greenhouses are not presently included in agricultural emission inventory totals, nor are they quantified. It is estimated that greenhouse boilers account for about 11% of the heat input capacity of all boilers in the Lower Mainland (Levelton, 2004), and that emissions could be of the same order of magnitude. However, more detailed assessment of emissions from greenhouse boilers may be warranted, particularly in light of fuel switching issues, such as the conversion from natural gas to distillate oil or solid fuels such as wood waste, which have different emission impacts.

- The GVRD could be approached to consider separating out agricultural sources in future emission inventory compilations. While there is an agricultural sources category, the burning, space heating, non-road engine, miscellaneous area source and solvent evaporation categories also include certain agricultural source emissions.

- Emissions of greenhouse gases and ammonia from agricultural operations are increasingly being studied by government agencies and agricultural research organizations, and these studies should be monitored.

A second objective of this project was to review existing best management practices in the Lower Fraser Valley and other jurisdictions, and develop a list of preferred BMPs for application in this airshed. Research conducted for this study showed that many jurisdictions use BMP compilations and programs for the agricultural sector. Although many of these BMPs focus on water quality and soil, most also have associated air quality benefits.

Initially, the intent of this study was to develop a list of preferred BMPs based on an assessment of costs and benefits associated with the measures. However, it was found that reliable data on the costs of implementing agricultural BMPs is lacking. The lack of economic data is due to the fact that agricultural BMPs have not typically been required as part of regulatory programs, and information on costs and benefits has not been needed to justify their implementation. In addition, many of the BMPs have low cost implications, or even represent a cost savings to the agricultural sector.

As a result, a more qualitative approach was used to select a list of the most promising BMPs for application in the Lower Fraser Valley. The parameters used in this assessment included: a qualitative ranking of BMPs as being of high, medium, low or negative cost; a review of barriers to implementation; discussion with industry and government representatives; and consistency with direction being provided to agriculture sources under federal and provincial environmental programs.

From the long list of BMPs reviewed, a short list of preferred BMPs was prepared, consisting of:

- Reduced tillage and cover cropping;
- Relay cropping;
- Management of riparian areas and field margins;
- Changing feed rations for both dairy and poultry operations;
- Improved application of manure to grass land and corn land;
- Improved manure storage systems and practices;

- Nutrient management programs and plans;
- Improved fuel storage; and
- Dust control.

A regulatory approach is not recommended for the adoption of agricultural BMPs in the Lower Fraser Valley. Command and control approaches have not historically been used for the agricultural sector, and there is even some question as to the regulatory authority of the BC MWLAP and GVRD to regulate air emissions from agricultural sources. The FVRD does not have delegated regulatory powers with respect to air pollution control.

For many of the BMPs listed above, cost is not the most significant barrier to implementation, but rather attitude and a need to overcome resistance to changing historical practices. The list of preferred BMPs has low or negative cost implications, yet provide significant opportunity for emission reductions. This combination should allow the use of voluntary, education-based approaches.

Some of the elements which should be considered in implementing the BMPs are:

- Development of communication materials which explain the low costs and emission reduction benefits of implementing BMPs, and emphasize the potential cost savings through adoption of better management practices. Another benefit is improved public perception of agricultural operations.
- Guidance documents and training materials should be developed because of the variability in the agriculture sector. These could build on BC Ministry of Agriculture, Food and Fisheries Environmental Guidelines and Environmental Farm Plan reference guides. In addition, many jurisdictions as well as academic organizations have technical assistance materials developed for agricultural BMPs, which provide a useful resource for the development of similar materials in the Lower Fraser Valley.
- Utilize the interest in environmental stewardship and sustainable agriculture from the agricultural community. By engaging the agricultural sector in the development of BMP programs and building partnerships. Agricultural advisory committees are used in many U.S. jurisdictions, and are already in place in GVRD and FVRD.
- Capitalize on the extensive body of research currently underway and anticipated for this sector, both by agricultural organizations and government agencies.
- Although regulatory programs are not recommended, there are lessons to be learned from some which have been established recently. In jurisdictions such as California and Arizona, where agricultural sources have been identified as priority sources with respect to attainment of PM_{10} standards, new regulatory programs are being implemented. These programs should be monitored as they will become sources of information on control technologies and associated economics.

Table S-1: Updated LFV Agricultural Emission Inventory for 2000

	emissions (tonnes/year)											
	CO	NO_x	particulate matter			SO_x	VOC	NH_3	greenhouse gases			
			PM	PM_{10}	$PM_{2.5}$				CO_2	CH_4	N_2O	CO_2E
Livestock Animals												
Cattle	0.0	0.0	119.8	76.7	12.0	0.0	2,256.0	0.0	0.0	9,024.0	0.0	189,503.6
Pigs	0.0	0.0	215.9	138.2	21.6	0.0	33.5	0.0	0.0	133.8	0.0	2,810.1
Sheep	0.0	0.0	23.2	14.9	2.3	0.0	21.9	0.0	0.0	87.8	0.0	1,843.6
Poultry	0.0	0.0	6.3	4.0	0.6	0.0	24.9	0.0	0.0	106.9	0.0	2,245.2
Horses	0.0	0.0	153.5	98.2	15.3	0.0	42.1	0.0	0.0	168.6	0.0	3,540.1
Miscellaneous Animals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	92.2	0.0	1,936.9
Subtotal	**0.0**	**0.0**	**518.7**	**331.9**	**51.9**	**0.0**	**2,378.4**	**0.0**	**0.0**	**9,613.3**	**0.0**	**201,879.5**
Manure Management												
Livestock wastes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10,008.6	0.0	5,893.8	127.2	163,196.3
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**10,009**	**0**	**5,894**	**127**	**163,196**
Burning												
Agricultural	1,803.4	62.2	342.0	342.0	342.0	0.0	279.8	0.0	0.0	84.0	0.0	1,763.0
Subtotal	**1,803**	**62**	**342**	**342**	**342**	**0**	**280**	**0**	**0**	**84**	**0**	**1,763**
Chemical & Nutrient Applications												
Synthetic Fertilizers	0.0	0.0	53.6	26.3	7.5	0.0	0.0	891.2	0.0	0.0	115.5	35,790.7
Organic Fertilizers [a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	146.3	45,361.9
Pesticides	0.0	0.0	106.9	52.5	14.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Limestone/Dolomite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4,394.2	0.0	0.0	4,394.2
Subtotal	**0**	**0**	**160**	**79**	**22**	**0**	**0**	**891**	**4,394**	**0**	**262**	**85,547**
Fugitive Dust												
Wind Erosion	0.0	0.0	910.7	455.4	100.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tilling	0.0	0.0	1,220.2	256.3	51.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**0**	**0**	**2,131**	**712**	**152**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines												
Agricultural Equipment	1,922.3	1,737.1	246.8	246.8	239.4	47.5	306.1	1.1	135,043.7	14.0	54.5	152,219.8
Subtotal	**1,922**	**1,737**	**247**	**247**	**239**	**47**	**306**	**1**	**135,044**	**14**	**54**	**152,220**
LFV Total	**3,726**	**1,799**	**3,399**	**1,711**	**808**	**47**	**2,964**	**10,901**	**139,438**	**15,605**	**443**	**604,605**

[a] **emissions of NH3 of organic fertilizers are quantified under manure management**

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

AAFC	Agriculture and Agri-Food Canada
AEI	agricultural emissions inventory
AFOs	animal feeding operations
AQMP	Air Quality Management Plan
BAU	business as usual
BC	British Columbia
BCAC	British Columbia Agricultural Council
BCMAFF	British Columbia Ministry of Agriculture, Food and Fisheries
BCMWLAP	British Columbia Ministry of Water, Land and Air Protection
BMPs	best management practices
BQ	base quantities
CAC	criteria air contaminants (CO, VOC, NOx, SOx, total particulate matter)
CEEMA	Canadian Economic and Emissions Model for Agriculture
CH_4	methane
CMP	conservation management practice
CO	carbon monoxide
CO_2	carbon dioxide
EC	Environment Canada
EF	emission factor
EFPs	environmental farm plans
EIIP	Emission Inventory Improvement Program
EPA	United States Environmental Protection Agency
ERM	emission reduction measure
FVRD	Fraser Valley Regional District
GHG	greenhouse gases
GIS	Geographical Information Systems
GVRD	Greater Vancouver Regional District
H_2S	hydrogen sulphide
IPM	integrated pest management
IPCC	Intergovernmental Panel on Climate Change
LFV	Lower Fraser Valley
N	nitrogen
NCCP	Canada's National Climate Change Process
NH_3	ammonia
NH_4^+	ammonium

NO_x	nitrogen oxides
NO	nitric oxide
NO_2	nitrogen dioxide
NO_3^-	nitrate
NPV	net present value
N_2O	nitrous oxide
PM	particulate matter
PM_{10}	inhalable particulate matter, particles smaller than 10 microns in diameter
$PM_{2.5}$	fine particulate matter, particles smaller than 2.5 microns in diameter
PV0	present value, 0% discount rate
PV5	present value, 5% discount rate
PV10	present value, 10% discount rate
SCAQMD	South Coast Air Quality Management District
SJVUAPCD	San Joaquin Valley Unified Air Pollution Control District
SOx	sulphur oxides
SO_2	sulphur dioxide
SO_4^{2-}	sulphate
SPFG	Sustainable Poultry Farming Group
USDA	United States Department of Agriculture
US EPA	United States Environmental Protection Agency
VOC	volatile organic compounds
WRAP	Western Regional Air Partnership

1. INTRODUCTION

In October 2002, the Greater Vancouver Regional District (GVRD) published an emissions inventory for the Lower Fraser Valley (LFV) for the year 2000 (GVRD, 2002). In this inventory, agricultural sources were identified as significant contributors of several contaminants, including ammonia, methane and particulate. Some of these contaminants, such as ammonia, react chemically with other gases and particles in the air to form secondary particulate such as nitrates or sulphates. These fine secondary particles, with diameters less than 2.5 µm ($PM_{2.5}$), are of great concern to human health as they can lodge deep in the respiratory tract causing irritation and possibly lung disease. Particulate and secondary particulate also impact on visibility. Other gases such as methane are greenhouse gases that contribute to global warming.

Given the adverse impacts of these contaminants on human health and the environment in the forms of secondary particulate, ground level ozone, greenhouse gases, and others, the Fraser Valley Regional District (FVRD), in conjunction with Environment Canada (EC), wish to verify the magnitude of agricultural emissions in the Lower Fraser Valley and to identify best management practices to reduce these emissions from the agriculture sector.

This report provides an updated and comprehensive air emissions inventory for the agricultural sector in the LFV and summarizes existing best management practices (BMPs) for this sector in the study area. Based on limited information on costs and benefits of BMPs, combined with qualitative analysis of opportunities and barriers, a list of preferred best management practices are identified. The following sections outline the findings of this project.

1.1 SCOPE OF WORK

The main objectives of the project are as follows:

- Develop an updated and comprehensive emissions inventory for the agricultural sector in the LFV; and
- Determine existing and preferred best management practices to reduce agricultural air emissions.

For the updated inventory, the following sources have been reviewed and updated, as appropriate.

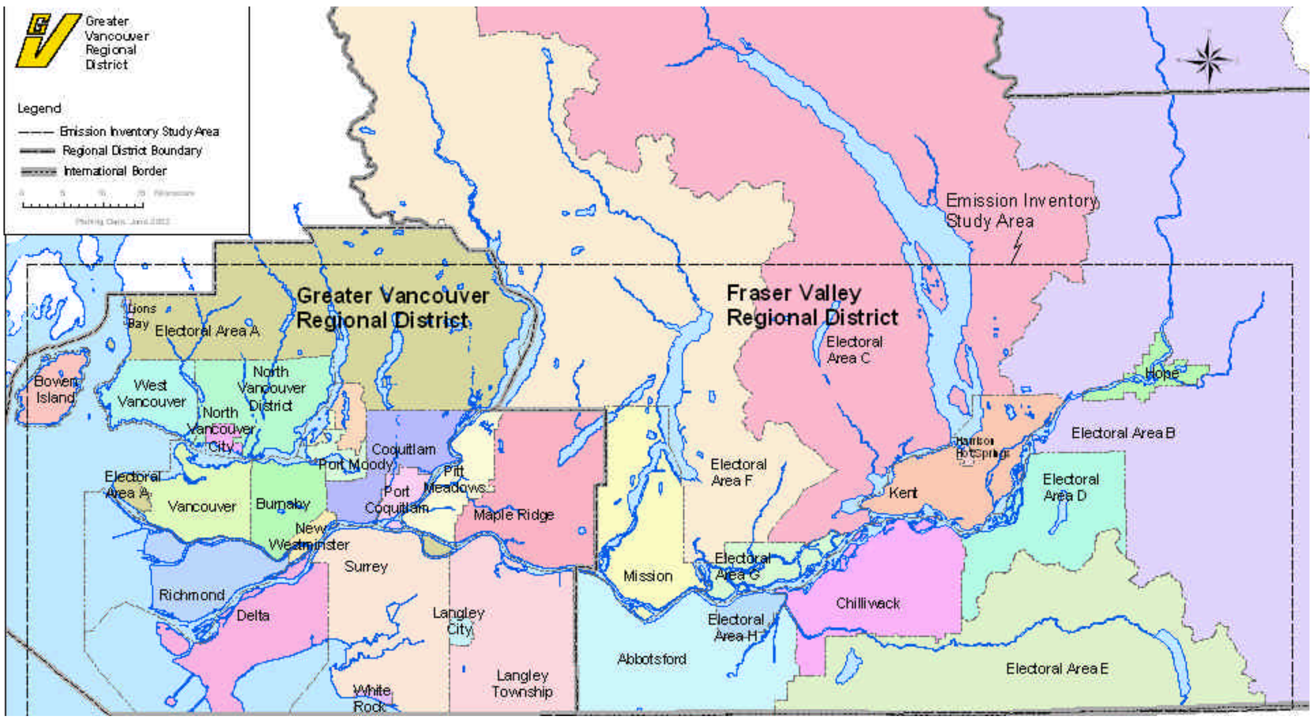
- Domesticated animals & wildlife
- Tilling operations
- Fertilizer applications
- Pesticide Use
- Agricultural burning
- Manure and manure application
- Lime and agricultural chemical applications
- Off-road vehicles
- Wind erosion

The updated inventory has been prepared for the following pollutants of interest.

- Common air contaminants – NO_X, SO_X, CO, VOC and total particulate matter (PM)
- Primary inhalable particulate (PM_{10}) and fine particulate ($PM_{2.5}$)
- Greenhouse gases – CO_2, CH_4 and N_2O (also reported on CO_2 equivalent basis)
- Ammonia (NH_3)

As shown in Figure 1-1, the inventory study area is the Canadian portion of the LFV, as defined in the 2000 GVRD inventory, and it consists of the GVRD and the southwestern portion of the FVRD which is referred to as the "FVRD" in this report.

Figure 1-1: Lower Fraser Valley Study Area



Source: GVRD, 2003a

2. AGRICULTURAL EMISSIONS IN THE LOWER FRASER VALLEY

2.1 CONTEXT

The Lower Fraser Valley (LFV) airshed is situated within what is known as the Georgia Basin ecosystem – one of the most diverse regions of North America in terms of ecology, landscape and people. The Georgia Basin is a region of rapid growth, having seen a doubling in population in the past 25 years, with the potential for similar growth in the next 15 years.

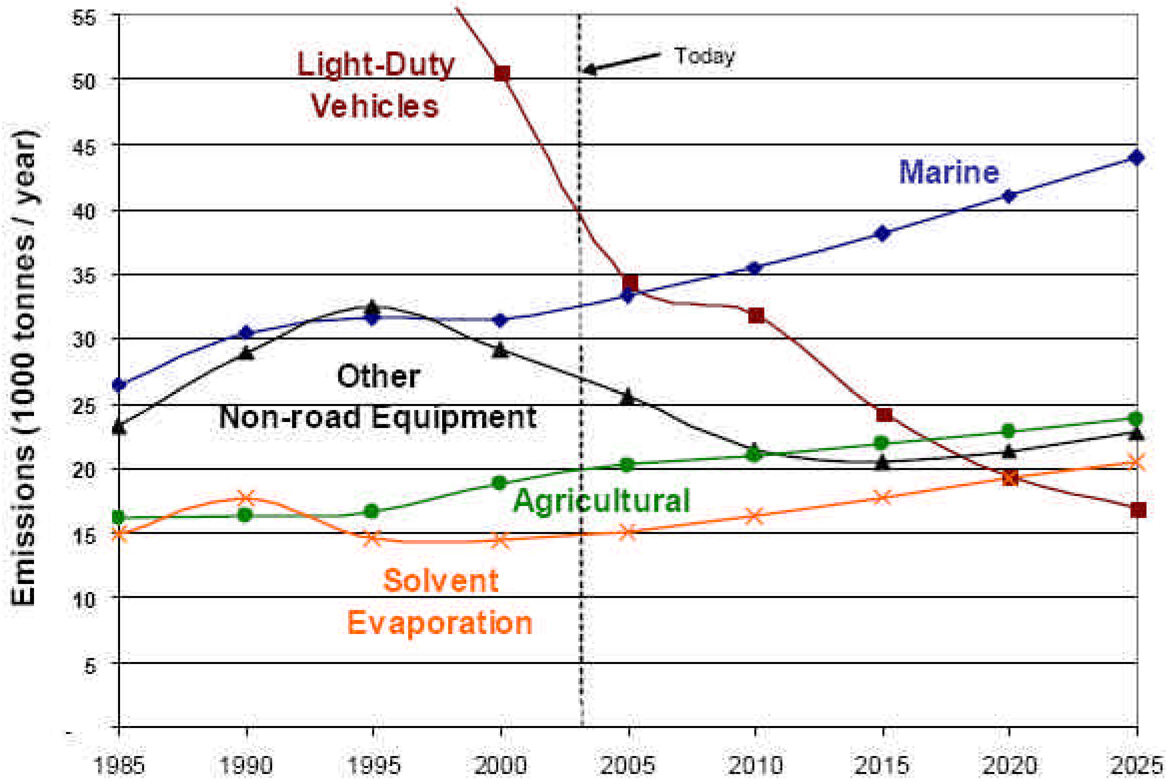
The airshed includes the Greater Vancouver Regional District and southwest portion of the Fraser Valley Regional District in Canada, and Whatcom County in the State of Washington. The population growth, meteorology and topography of the LFV airshed combine to make it a region of high air pollution potential. The regional population growth increases human activities that result in emissions of air pollutants, such as the use of on-road motor vehicles and the distances they travel. Air movement is restricted by the Coast and Cascade mountains which form a barrier to the north and southeast. Together with water to the west, these natural features form a triangular basin where air contaminants can be trapped and build up over several days during stagnant weather conditions. This effect can be worse during "inversion" conditions when a mass of warmer air forms a lid over a layer of cooler air (and its loading of air contaminants).

The two pollutants of primary concern in the LFV airshed are ozone and fine particulate matter ($PM_{2.5}$), both of which contribute to smog formation. Ground-level ozone is a secondary pollutant formed in the atmosphere, through reactions involving "precursor" pollutants, including primarily nitrogen oxides (NOx) and volatile organic compounds (VOC), and to a much lesser degree, carbon monoxide (CO). $PM_{2.5}$ arises both from primary emissions and secondary formation. Primary particulate matter is emitted directly to the atmosphere from various sources, such as industrial stacks, motor vehicle exhaust and burning. Fine particulate can also be formed secondarily, by reaction of NOx, SOx, VOCs, NH_3 and other gases in the atmosphere.

Recent studies sponsored by the GVRD and other government agencies and organizations provide a forecast of future emissions from stationary and mobile sources (with allowances for the effects of commitments that have been made to implement new emission standards and control technologies) and information on the current understanding of the effects of emissions on air quality and human health in the Canadian and United States areas of the Lower Fraser Valley airshed. Studies of the effects of pollution on human health and the environment have generally encouraged long-term efforts to reduce air pollution and prevent degradation of regional air quality.

Figure 2-1 shows the contribution of major source categories to the regional emissions total for smog-forming pollutants, past, present and future. Light duty motor vehicles currently remain major sources of smog precursor emissions, but their contribution has declined due to the combined effect of tighter emission standards and the beneficial effects of the AirCare vehicle inspection and maintenance program. New Tier 2 emission standards for light duty vehicles that came into effect for 2004 model year vehicles will further reduce emissions from light duty vehicles in the future, off-set somewhat by the growth in number of vehicles and distances driven annually. The GVRD forecasts show that emissions from marine vessels, agricultural sources and non-road engines become increasingly important in the years beyond 2015. It is important to note that the non-road engine category also includes agricultural non-road equipment. In the GVRD's 2000 LFV emission inventory, agricultural non-road equipment represents 16% of the total non-road emissions of smog-forming pollutants.

Figure 2-1: Top Five Sources of Smog-Forming* Emissions in the LFV



* smog forming pollutants include nitrogen oxides, sulphur oxides, volatile organic compounds, fine particulate matter and ammonia

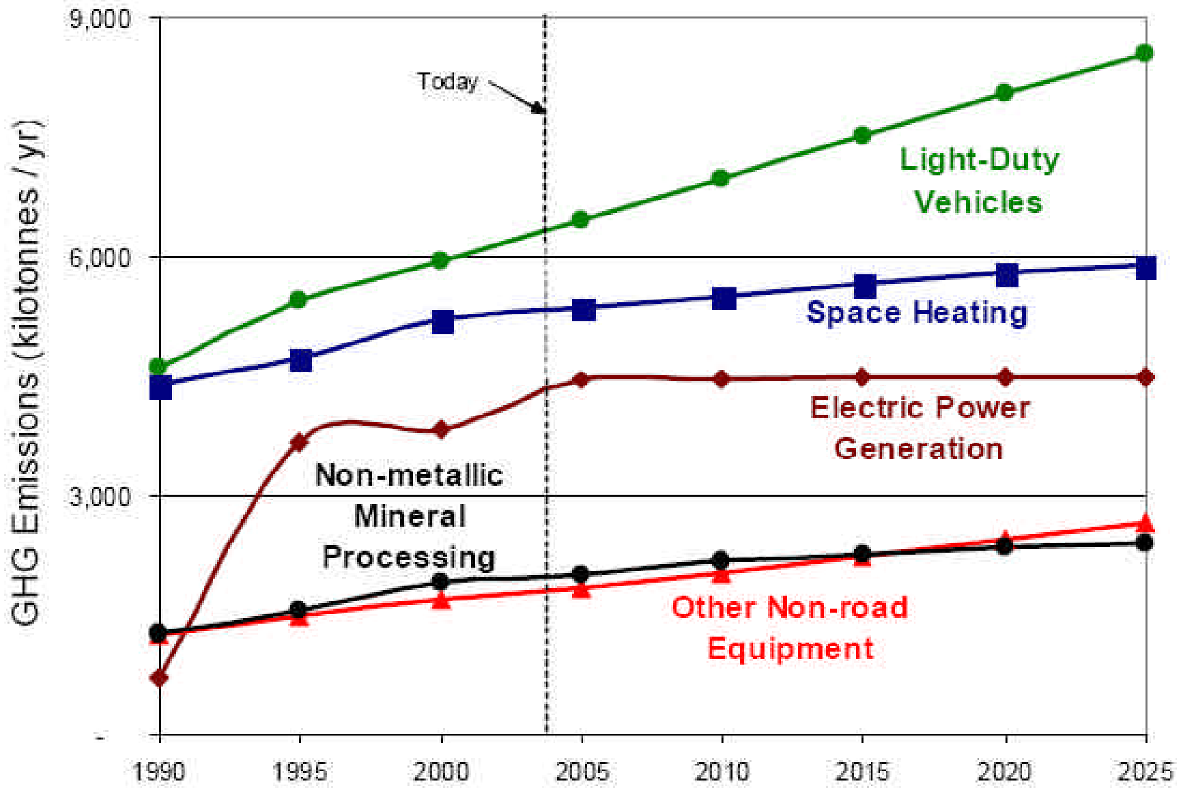
source: GVRD, 2004

Ammonia is an important pollutant from an agricultural perspective. The most recent GVRD inventory report (GVRD, 2003a) ranks agriculture as the largest source of NH_3 in the region, with cattle, pig, and poultry housing, manure land-spreading and storage, and inorganic fertilizer application accounting for 75% of the total NH_3 emissions in 2000. These numbers are reviewed and updated in Sections 3 and 4 of this report.

Figure 2-2 shows emissions and projections for greenhouse gas emissions [GHGs – including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O)] in the Lower Fraser Valley. As for smog-forming pollutants in the previous table, agricultural equipment is included in the “other non-road equipment” total. It should also be noted that the “space heating” category includes space heating for agricultural operations, including boilers used for heating in greenhouses. Space heating emissions in the GVRD are sub-categorized into residential, and industrial/commercial/institutional sectors, but there is no separate quantification of emissions from agricultural or greenhouse boilers.

In order to provide an estimate, data from the provincial Boiler and Pressure Vessel Safety Program, operated by the BC Safety Authority, was reviewed. This data was obtained by Levelton in a separate study on external combustion sources in the GVRD (Levelton, 2004). Out of a total of nearly 11,000 boilers in the boiler branch database, just over 10%, or 1100 boilers were used at greenhouse operations. Moreover, out of a total rated heat input capacity of 29,000 gigajoules per hour for all boilers, close to 11% of the capacity (3000 GJ/hr) is from greenhouse boilers. While the emissions from greenhouse boilers cannot be estimated, it would be expected that they would contribute roughly 11% of the total emissions in the space heating category.

Figure 2-2: Top Five Sources of Greenhouse Gas Emissions in the LFV



source: GVRD, 2004

3. METHODOLOGY FOR EMISSIONS INVENTORY UPDATE

In October 2002, the Greater Vancouver Regional District (GVRD) published an emissions inventory for the LFV for the year 2000 which included emission estimates of common air contaminants (CACs), greenhouse gases (GHGs) and ammonia from agricultural sources (GVRD, 2002). These original GVRD estimates for the LFV agriculture sector are summarized in Appendix A. The GVRD inventory was based on data and methodologies that were current at the time. For the current project, the GVRD estimates were obtained and the base quantity data and estimation methodologies used to derive these agricultural emissions were reviewed in detail to assess data quality, review estimation methodologies and identify areas where updates or revisions could be needed.

A literature search was conducted in parallel with the review of the GVRD inventory data. This literature search served to identify updated agricultural statistics for the LFV for 2000 and the most current estimation methodologies for agricultural sources. The U.S. Environmental Protection Agency (EPA) and Environment Canada were the main focus for this literature research. Other sources of information, such as the GVRD, Intergovernmental Panel on Climate Change (IPCC) and Statistics Canada were also accessed when needed in order to refine and complete our search.

There are two areas to consider when updating an emissions inventory. The first is the update of the emission factors (EF) and other methodologies used to calculate the pollutant emissions. The second area is the update of the activity data on which estimates are based, sometimes referred to as base quantities (BQ). These are values such as the number of animals, types of crops and areas of cropland. Since the GVRD 2000 emissions inventory was completed recently, changes to the emission factors or the methodologies for many of the sources were not required. However, there is new information available for some sources, specifically, for emissions generated by wind erosion and manure management systems. In these cases, the calculations were updated and the new values are presented in the respective sections.

The following sections summarize the methodologies used in updating the 2000 emissions from agricultural sectors in the LFV.

3.1 DOMESTICATED ANIMALS AND WILDLIFE

For this study, the animals included in this category are consistent with those in the 2000 LFV inventory:

- Livestock - cattle, pigs, sheep, poultry, turkey and horses
- Miscellaneous animals (rabbits, mink, fox and goats)

In each animal category, emissions were generally estimated by applying appropriate pollutant specific emission factors to the number of animals. A description of the updates made to the emission factors and/or animal counts for each animal category is given in the following sections.

Previous emission inventories have included the emissions produced by animals like cats, dogs, ducks and wildlife in the agricultural category. However, in the 2000 LFV inventory these animals were instead included under miscellaneous area sources since they are not directly related to farming or agricultural practices. In the present study the same assumption was followed.

3.1.1 Livestock Emissions

The most significant pollutants found in this category were volatile organic compounds (VOC), particulate matter (PM), methane (CH_4) nitrous oxide (N_2O) and ammonia (NH_3). PM emissions are generated from feed, bedding materials, dry manure, unpaved soil surfaces, animal dander and poultry feathers. Therefore, sites of animal confinement, dry manure storage, and land application are potential PM sources.

CH_4 is also produced as a result of "enteric fermentation", which is a digestive process in herbivores when microorganisms that reside in the digestive system break down feed consumed by the animal. Ruminants such as cattle, sheep and goats are the predominant source of methane because of their digestive system, called rumen or large "fore-stomach". However, some non-ruminants such as pigs and horses can also produce methane due to the fermentation that takes place in their digestive system. Some of the factors affecting the amount of emissions released by enteric fermentation are the type, age, live weight of the animal as well as feed intake and energy expenditure. Methane emitted can also be affected by the climate (Levelton, 1996).

Ammonia is produced as a by-product of the decomposition of the organic nitrogen compounds present in manure. Nitrogen occurs as both unabsorbed nutrients in manure and as either urea (mammals) or uric acid (poultry) in urine. Urea and uric acid will hydrolyze rapidly to form NH_3 and will be emitted soon after excretion. The formation of NH_3 will continue with the microbial breakdown of manure under both aerobic and anaerobic conditions. Because NH_3 is highly soluble in water, it will accumulate in manures handled as liquids and semi-solids or slurries, but will volatilize rapidly with drying from manures handled as solids. Therefore, the potential for NH_3 volatilization occurs whenever manure is present, and it will be emitted from confinement buildings, open lots, stockpiles, anaerobic lagoons and land applications from both wet and dry handling systems.

Nitrous oxide is also produced by the microbial decomposition of organic nitrogen compounds found in manure. However, N_2O emissions will only occur if nitrification occurs and is followed by denitrification. The nitrification process is the oxidation of ammonia to nitrites and nitrates, and requires an aerobic environment. Denitrification occurs when nitrites and nitrates are reduced under anaerobic conditions. Therefore, for nitrous oxide emissions to occur, the manure must first be handled aerobically (i.e. dry) and then anaerobically (i.e. wet). Nitrous oxide emissions are most likely to occur from unpaved drylots for dairy and beef cattle and at land application sites (EPA, 2001).

While reviewing the data from the 2000 LFV inventory, it was observed that in some calculations the base quantities used (i.e. numbers of animals) were from the year 2000, whereas in other cases they were from 2001. After careful consideration, it was decided that in this section all the base quantities from 2000 would be updated to 2001. The 2001 numbers are actual census values and they were considered to be close enough to the base year of the inventory, whereas the 2000 data was calculated by interpolating the 1995 and 2001 Census values. The base quantities remained the same only when there was no new information available. Those cases are discussed in the respective sections. All the updates made to the GVRD 2000 LFV Emissions Inventory are summarized in Appendix C.

In regards to the emission factors, they are based on the best available data. A list of the factors adopted in this inventory is shown in Table 3-1. The factors in Table 3-1 are aggregate values for each animal class. They were "rolled up" in order to show a representative value, by class, for the Lower Fraser Valley. For some of the pollutants, specifically CH_4, N_2O and NH_3, the emission factors are "back calculated" using the final emissions result and the numbers of animals as variables. A complete table with the emission factors derived for all animal classes and sub-classes (e.g. dairy and non-dairy cattle) can be found in Appendix C.

It is also important to note that the emission factors utilized in this study are specific to the Lower Fraser Valley since they were derived from variables specific to the region such as, animal weights, types and manure management practices.

3.1.1.1 Cattle

There were no updates available to the methodology to calculate the emission factors of PM, PM_{10}, $PM_{2.5}$ and VOC. Thus, the methodology followed in the GVRD study was retained. However, as previously discussed, the base quantities, i.e. heads of animals, were brought forward from the year 2000 to 2001 using data from the 2001 Agricultural community profile Census (Statistics Canada, 2001).

The emission factors for PM, 15.07 kg/head, includes a correction based on the amount of rainfall measured for the LFV. The PM_{10} and $PM_{2.5}$ emission factors, 9.64 kg/head and 1.51 kg/head respectively, were calculated based on a percentage of total PM emissions, such as 64% for PM_{10} and 10% for $PM_{2.5}$. The VOC emission factor, 18.34 kg/head was 25% of CH_4 produced by enteric fermentation (GVRD, 2003a).

Methane production by enteric fermentation is dependent on many factors such as, feed characteristics, feed intake and the rate of energy conversion present in the feed to CH_4. For livestock the energy intake is used for maintenance, growth, lactation, work and gestation. Since the CH_4 emission factor previously used was developed specifically for B. C. livestock and was comparable to IPCC, AP-42 and EC factors (GVRD, 2003a), they were adopted again for this inventory. The emission factor for cattle was 73.35 kg of CH_4/head.

The emission factor mentioned above is an average of the different sub-categories included in cattle. The sub-categories are dairy cattle (lactating, dry, replacements and calves) and non dairy cattle (brood cows, bulls, replacements, feedlot and calves).

The emissions generated by the production and handling of manure will be addressed in Section 3.1.2.

3.1.1.2 Pigs

The methodologies described for cattle, in the previous section, were adopted for all the other types of livestock. Under the pigs category, sows and boars were considered. The emission factors adopted for pigs were 1.51 kg of PM, 0.96 kg of PM_{10}, 0.15 kg of $PM_{2.5}$, 0.23 kg of VOC and 0.93 kg of CH_4 released by enteric fermentation, all per head of animal.

As previously stated, the emissions generated by the production and handling of manure will be addressed in Section 3.1.2.

3.1.1.3 Sheep

Under the Sheep category, ewes, rams, animals for replacement and for market were considered. The emission factors adopted were 1.51 kg of PM, 0.96 kg of PM_{10}, 0.15 kg of $PM_{2.5}$, 1.42 kg of VOC and 5.70 kg of CH_4 produced by enteric fermentation, all per head of animal.

Table 3-1: List of Annual Emission Factors Adopted for Livestock on the 2000 LFV Agricultural Emissions Inventory Update

		Emission Factors						
Sources	**Units**	**VOC**	**PM**	**PM_{10}**	**$PM_{2.5}$**	**CH_4**	**N_2O**	**NH_3**
Cattle	Kg/head	18.34	15.07[b]	9.64[b]	1.51[b]	73.35/19.68[a]	0.06	14.40
Pigs	Kg/head	0.23	1.51	0.96	0.15	0.93/3.46[a]	0.04	7.24
Sheep	Kg/head	1.42	1.51	0.96	0.15	5.70/0.32[a]	-	2.01
Poultry	Kg/1000head	1.57	0.40	0.26	0.04	0.01/0.17[a,c]	0.01[c]	0.38[c]
Horses	Kg/head	4.14	15.07	9.64	1.51	16.55/3.63[a]	-	8.70
Miscellaneous Animals	Kg/head	-	-	-	-	11.41/0.18[a]	-	0.83

[a] values from enteric digestion/ values from manure;
[b] EF apply to beef cattle only;
[c] Value is in kg/head;

3.1.1.4 Poultry

Under Poultry, laying hens, laying pullets, broilers and roasters for market, broiler breeders, breeder replacements and turkeys were considered. The emission factors adopted were 0.40 kg of PM, 0.26 kg of PM_{10}, 0.04 kg of $PM_{2.5}$, 1.57 kg of VOC and 6.30 kg of CH_4 produced by enteric fermentation, all per 1000 heads of animals. Turkeys have a specific emission factor for CH_4 which is 10.06 kg per 1000 heads of animals.

3.1.1.5 Horses

The emission factors adopted for horses were 15.07 kg of PM, 9.64 kg of PM_{10}, 1.51 kg of $PM_{2.5}$, 4.14 kg of VOC and 16.55 kg of CH_4, all per head of animal.

3.1.1.6 Miscellaneous animals

For this category the 2000 LFV inventory only included methane emissions from goats. Since there was no recent update on this matter, a similar approach was taken. Therefore, the emissions factor for enteric fermentation from goats was 11.41 kg of CH_4 per head.

3.1.2 Manure Production and Management

The main pollutants associated with the production and handling of manure are methane (CH_4), ammonia (NH_3) and nitrous oxide (N_2O).

VOCs are formed when organic matter in manure begins to degrade. Under aerobic conditions, any VOCs formed are rapidly oxidized to carbon dioxide (CO_2) and water. Under anaerobic conditions, the degradation of complex organic compounds forms VOC, which in turn are converted to CH_4 and CO_2.

Methane is a product of microbial degradation of organic compounds under anaerobic conditions. The microorganisms decompose the carbon (cellulose, sugars, proteins, fats) in manure and bedding materials into CH_4 and CO_2. Because anaerobic conditions are necessary, manures handled as a liquid or slurry will emit CH_4. Manures handled as solids have a lower moisture content and therefore permit the oxidation of any CH_4 generated.

Ammonia is produced as a by-product of the decomposition of organic nitrogen compounds. Nitrogen occurs as both unabsorbed nutrients in manure and as either urea (mammals) or uric acid (poultry) in urine. Urea and uric acid will hydrolyze rapidly to form NH_3 and will be emitted soon after excretion. The formation of NH_3 will continue with the microbial breakdown of manure under both aerobic and anaerobic conditions. N_2O is also produced by the microbial decomposition of organic nitrogen compounds. However, for N_2O emissions to occur, the manure must first be handled aerobically (i.e. dry) and then anaerobically (i.e. wet) as previously explained.

Although the EPA has recently published manure emission factors for North American conditions, state by state (EPA, 2003a, 2003b), these factors were not used since the manure management systems assumed in the calculations differ from the current management practices in Canada. Hence, the methodologies used in the previous inventory were again adopted.

In generic terms, the methodologies are based on the number of animals, the amount of manure produced and the manure handling process, for each type of animal. Different manure practices are associated with different percentages of pollutants emitted.

In order to refine the estimates, the manure handling practices used in BC were updated based on discussions with BCMAFF officials (Brisbin, 2004). The updated percentages can be seen in Table 3-2.

In an attempt to update the NH_3 calculations, two methodologies were reviewed, one methodology published by the US EPA (EPA, 2004a) and another developed by Environment Canada (EC, 2004).

The Environment Canada methodology is similar to its previous version published in 1995, except for some minor alterations introduced when the work was revised in 2004. The revised version has not yet been officially released.

Table 3-2: Updated Manure Management Practices in BC

Livestock Type	Manure System	GVRD Inv. Waste System Distribution [a]	Updated Waste System Distribution [b]
Dairy	Anaerobic lagoon	0%	0%
	Liquid/slurry	88%	90%
	Solid storage	12%	10%
Beef	Drylot	15%	15%
	Pasture	85%	85%
Sheep	Pasture	100%	100%
Goats	Pasture	100%	100%
Swine	Anaerobic lagoon	0%	0%
	Drylot	5%	10%
	Pit storage covered	48%	55%
	Pit storage uncovered	48%	35%
Lay	Solid	27%	100%
	Deep pit	37%	0%
	Liquid/slurry	37%	0%
Broilers	Litter	100%	100%
Turkeys	Litter	100%	100%
Horses	Paddock	50%	50%
	Pasture	50%	50%

[a] (GVRD, 2003c); [b] (Brisbin, 2004)

In order to choose the best available methodology, several factors were taken into consideration. While the EPA methodology is the most recent study, it did not include emissions produced by grazing animals.

The Environment Canada (EC) method was more comprehensive. It included emission factors from grazing, housing, storage and landspreading. This methodology was also reviewed this year and it takes into account Canadian manure management practices.

For the above reasons the Environment Canada methodology was considered the most suitable given the context of this study.

Again, in order to further refine the estimates, the percentage of distribution of each waste management practice in BC was updated based on discussions with British Columbia Ministry of Agriculture, Food and Fisheries (BCMAFF) officials (Brisbin, 2004).

3.1.2.1 Livestock Manure

In the case of N_2O, due to the methodology followed, the emissions from manure applied directly to soils (i.e. manure used as a daily spread or excreted directly on pasture, range or paddock) are treated as an organic fertilizer and, as such, are included in Section 3.3.1. For CH_4 and NH_3 all the emissions related with animal waste are discussed in this section.

The emission factors used in the calculation of CH_4 and N_2O are a function of the animal mass and the manure management technique used. For NH_3 the methodology adopted divides the calculations into four stages - grazing, housing, storing and landspreading. Each operation has a specific rate of nitrogen (N) release, changing the amount of emissions generated.

As described earlier, the manure techniques were updated through discussions with officials from BCMAFF, and the landspreading techniques were updated from data gathered in the 2001 Agricultural Community Census (Statistics Canada, 2001). The NH_3 methodology was also updated by introducing the changes proposed by Environment Canada in their revised version. The changes were specific to the “Laying hens in hatchery supply flocks” which were removed in order to avoid double counting. The total population was then redistributed through the remaining categories.

As presented in Table 3-1, the emission factors for CH_4 resulting from manure management were 19.68 kg for cattle, 0.32 kg for sheep, 0.18 kg for goats (included under the category of miscellaneous animals), 3.46 kg for pigs, 0.17 kg for poultry, 0.27 kg for turkeys and 3.63 kg for horses. All the emission factors are measured in kg per head of animal.

For N_2O the emissions factors are 0.06 kg for cattle, 0.04 kg for pigs, 0.01 kg for poultry and 0.02 kg for turkeys. As previously explained horses, goats and sheep are considered grazing animals and therefore were not included in the calculations. Their manure emissions are under the fertilizers section. Similarly to CH_4, all the emission factors are measured in kg per head of animal.

For NH_3 the emissions factors are 14.40 kg for cattle, 7.24 kg for pigs, 0.38 kg for poultry, 2.01 kg for sheep, 8.70 kg for horses and 0.83 for miscellaneous animals. All the emission factors are measured in kg per head of animal.

3.1.3 Odours

The main compounds responsible for noxious odours in animal feeding operations are hydrogen sulphide (H_2S), NH_3, and VOC. The VOC that contribute to odours are volatile acids (acetic, propionic, formic, butyric, and valeric), indole, phenols, volatile amines, methyl mercaptan, and skatole.

Most of these compounds are products of anaerobic digestion of organic matter. Therefore, the potential for odours is greater at operations with liquid manure management systems. In liquid systems, odours can be produced from storage pits, ponds, and land application. Furthermore, odours can also be produced when in the spring and fall there are sudden temperature changes that upset the microbial balance, or if the liquid manure system is overloaded with volatile solids. Drylots can produce odours whenever warm, wet conditions produce transient anaerobic conditions. Odours also can be caused by decaying animals, if the carcasses are stored too long prior to disposal (EPA, 2001).

Information on hydrogen sulphide emission factors was not available from the literature search and therefore no estimate was made in the study. Information on the emission factors of the other main odour-causing pollutants, namely NH_3 and VOC are described in Table 3-1.

3.2 AGRICULTURAL BURNING

Since the original emission estimates were based on actual permitted burns and emission factors that are still current, no changes were made to the GVRD estimates for this source.

3.3 CHEMICAL AND NUTRIENT APPLICATIONS

3.3.1 Fertilizer Application

The role of fertilizers in the agriculture industry is to supply the essential elements to the soils in order to insure healthy plant growth. There are 16 essential nutrients, three of which (carbon, hydrogen and oxygen) are supplied from the atmosphere or water. The other 13 elements (nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, copper, zinc, boron, manganese, iron, chlorine, and molybdenum) are principally supplied through the soil medium. However, some soils have low concentrations of some of these elements, and therefore need to be supplemented by fertilizers (EPA, 1999).

In the literature review carried out for this section there was no update found on either new methodologies or emission factors. Therefore all the base quantities, emission factors and methodologies used in the GVRD Inventory were adopted again, as described below.

3.3.1.1 Particulate emissions

During the application of fertilizers, PM emissions can occur, so the estimates of the emissions are based either on the amount of fertilizer applied or the land area affected. The amount of fertilizer applied in the LFV was estimated from 2001 data published by the Canadian Fertilizer Institute. For the development of the emission factors, the size speciation of total particulate was based on EPA data which resulted in PM, PM_{10} and $PM_{2.5}$ EF of 2.23, 1.09 and 0.31 kg/tonne of fertilizer, respectively.

3.3.1.2 Nitrous Oxide emissions

N_2O emissions are estimated as a result of nitrogen volatilized after the application of fertilizer or manure to soils through landspreading and grazing animals. Table 3-3 shows a summary of the base quantities, emission factors and final emissions for this pollutant.

Table 3-3: Results for N_2O Emissions from Chemical and Nutrient Application

	BQ (Kg of N)	EF (kg N_2O/ head of animal)	N_2O emissions (tonnes)
Synthetic fertilizer	6,530	18.4	120.07
Manure from Livestock:	5,429	0.39	61.03
Cattle		0.36	44.20
Sheep		0.19	2.94
Goats		0.28	2.24
Swine[a]		-	-
Poultry[a]		-	-
Horses		1.14	11.65

[a] Swine and Poultry are not considered grazing animals.

The aforementioned base quantities were gathered from estimates of fertilizer and manure applied in the LFV, published by the Environment Canada in 2000. The remaining values included in the development of the methodology came from various sources, such as, Emission Inventory Improvement Program (EIIP) and Environment Canada (GVRD, 2003a).

3.3.1.3 Ammonia emissions

The NH_3 emissions resulting from the application of fertilizers are dependent on the quantity of fertilizers used in the area, which type and the nitrogen content of each one. With respect to the update of methodologies and emission factors, there were none found in the literature review. Therefore the methodology and the base quantities utilized in the GVRD study were again adopted.

Fertilizer nitrogen applied in the LFV was estimated at 6,531 tonnes based on Environment Canada estimates for the year 2000 (GVRD, 2003a) and the EF applied was 136.45 kg of NH_3/tonne of N contained in the fertilizers. The EF was back-calculated and is an average of the different types of fertilizers used.

Emissions of NH_3 from the direct application of manure and grazing animals were calculated as part of the methodology of manure production and management in Section 3.1.3.1.

3.3.2 Pesticide Application

In the GVRD inventory, particulate emissions from pesticides application were based on applying published emission factors to the cropland areas. No new emission factors were found from the literature search and therefore no changes were made to the factors used in the original inventory. Cropland areas were updated based on the 2001 Agriculture Census data from the 1996 values that were used in the GVRD inventory.

VOC emissions are dependent on the volatility of the active ingredients in the formulation, VOC content of the inert ingredients, the type of formulation, the method of application, meteorology conditions and soil adsorption. VOC emission factors are available from the U.S. EPA (AP42) as functions of application method and vapor pressure of the pesticide active ingredient. Depending on the formulation type, including powder, emulsion and oil, the EPA also provided an estimate of the average VOC content of the inert ingredient. In order to utilize this EPA methodology, pertinent data on pesticide usage in the study area is required. A recent survey of pesticide use in BC for 1999 was completed as part of the Georgia Basin Ecosystem Initiative (Enkon Env., 2001). This survey estimated that a total of 86.6 tonnes of pesticide active ingredients was used by Lower Mainland pest control licensees for agriculture. However, other pertinent information for VOC estimation, such as ingredient volatility and formulation type, was not readily available from this report. Although it is conceivable that the database developed for the above survey may contain the missing data, considerable effort is anticipated and is not warranted given the relatively small contribution of VOC emissions from pesticide applications in the study area. Hence, no changes were made to the 2000 GVRD estimates of VOC emissions from pesticide applications.

Due to work on a concurrent project regarding air toxics emissions in the LFV, the methodology for the calculation of emissions from pesticides was revisited and the VOC estimation was changed. However, in the GVRD 2000 inventory, the VOC emissions resulting from the application of agricultural pesticides are included under the “solvent evaporation” category, rather than agricultural. Therefore, to maintain consistency, the new estimation of VOC emissions will not be reported in this study within the agricultural category.

3.3.3 Limestone/Dolomite Application

Agricultural use of soils can lead to a depletion of the soil essential components and to an eventual unbalance in the pH values. The most common and inexpensive method to restore the soil pH is liming, which decreases the acidity. Both limestone and dolomite are products frequently used in this process and can be generically considered to react according to:

$$CaCO_3 + CO_2 + H_2O \rightarrow Ca^{2+} + 2\,HCO_3^- \rightarrow Ca^{2+} + 2\,OH^- + 2\,CO_2,$$

As seen in the equation above, the application of these substances lead to emissions of CO_2 which are released to the atmosphere. The emissions release can be calculated by multiplying the quantity of the limestone-dolomite applied to the soils by the carbon content found on each of the components.

According to the literature review no update to the methodology was needed. The base quantities used in the GVRD study were also accepted since they were actual values for the base year 2000. For the LFV the quantity of limestone and dolomite used was estimated at 9,910 tonnes.

3.4 FUGITIVE DUST

3.4.1 Agricultural Tilling

In the 2000 GVRD inventory for the LFV, fugitive dust emissions from tilling operations were estimated based on the area tilled, the number of tillings per year and a particulate emission factor correlation developed by the EPA from field measurements. The area of tilled land, including those using conventional and conservative tilling practices, was previously based on the 1996 census data. For this study, the area of tilled land has been updated to reflect the 2001 census data. Since the emission factor correlation is still current, no change was made.

The number of tillings is dependent on the crop type and tilling practice (conventional or conservation). In the 2000 GVRD inventory, an averaged value of 4 tillings/year was assumed for all crop types and was applied to all tilling practices. For this study, the number of tillings was refined to reflect the major crop types in the GVRD and FVRD. Table 3-4 below shows the acreage breakout of major crops in the GVRD and FVRD, as reported in the 2001 Census, and the number of estimated tillings by crop type, as published in the literature (EPA, 2004b). Although the number of tillings is dependent on the chosen tilling practice, this update assumes conservatively that conventional tilling was applied to all crops in the study area as the split between conventional and conservation tilling practices for a given crop is not readily available. The assumption is believed to be reasonable since the 2001 Census data indicated that of the land areas tilled in the GVRD and FVRD, conventional tilling accounted for about 87% of the total in each region.

To estimate the average number of tillings/year for crops in each regional district, a weighted approach was used. By dividing the sum of the product of each major crop acreage and its corresponding number of tillings/year with the total area under major crops in a given regional district, weighted averages of 3 and 4 tillings/year were estimated for GVRD and FVRD crops, respectively. These averages were then applied to all tilled land in the respective regional district.

Table 3-4 Area Planted and Number of Tillings by Crop Type

Major crops	Area planted (ha)		# tillings *
	GVRD	FVRD	
Corn		6,999	6
Forage/hay	8,733	15,081	3
Pasture	2,672	3,469	1
Alfalfa		1,305	3
Potatoes	2,085		3
Total, major crops	13,490	26,854	
Total land in crops	22,965	31,799	
% land in major crops	58.7	84.4	

* for conventional tilling

3.4.2 Wind erosion

The wind erosion process involves detaching, transporting, sorting, abrading, avalanching, and depositing of soil particles. Turbulent winds blowing over erodible soils can cause wind erosion. The soil conditions that favor wind erosion include: (i) loose, dry and finely granulated soil, (ii) smooth soil surface that has little or no vegetation, (iii) sufficiently large area susceptible to erosion, and (iv) sufficient wind velocity to move soil. Winds are considered erosive when they reach 21 km/h at 0.3 meters above ground (13 miles per hour at 1 foot above the ground) or 29 km/h at 9 meters height (18 miles per hour at a 30 foot height), (USDA, 2001).

The calculation of emissions generated by wind erosion was performed using the Wind Erosion Equation. This equation includes factors, such as, soil erodibility index, soil surface roughness factor, climatic factor, the unsheltered distance and the vegetative cover factor. This methodology, previously used by the GVRD, has not been updated. However, according to EPA officials, a new methodology is currently under development by the Western Regional Air Partnership (WRAP) Dust Forum (WRAP, 2004). Since research on this new methodology was still ongoing at the time of writing of this report, it was not available for use in this project. Hence, the only factors updated were the base quantities, i.e. the hectares of each type of crop, gathered from the 2001 Census data.

Therefore, the emission factors remain as 7.49 kg/hectare for PM, 3.75 kg/hectare for PM_{10} and 0.08 kg/hectare for $PM_{2.5}$.

3.5 NONROAD AGRICULTURAL EQUIPMENT

Agricultural equipment is a significant source within the agricultural sector. For this study, the resulting emissions were updated based on recent revised estimates provided by the GVRD. These new estimates reflect the use of the 2004 version of the U.S. EPA NONROAD model and updated base quantities from Environment Canada and the GVRD. The new GVRD estimates for nonroad engines, including agricultural equipment, were generated in support of a multi-agency study on emissions reduction measures (ERMs) for nonroad diesel sources.

4. UPDATED LFV AGRICULTURAL EMISSION RESULTS

4.1 OVERALL EMISSIONS IN THE LFV FOR 2000

4.1.1 Discussion of Results from Livestock

Due to the update of the base quantities in the livestock category, the emissions values changed accordingly. In the cases where the base quantities increased from the year 2000 to 2001 (sheep, pigs, poultry and horses) the emissions increased proportionately. Cattle was the only type of animal for which the total number of heads decreased, and therefore, a decrease in their final emissions was observed compared to the previous work.

4.1.1.1 Discussion of Results from Livestock Manure

With the refinement of the manure management and landspreading techniques, the emission factors and final results were also adjusted. However, this change was not linear as observed with the update of the number of animals under the section of livestock emissions, where an increase in animals resulted in a direct increase in emissions.

Compared to the original 2000 LFV inventory, CH_4 final emissions decreased by about 6%, due mainly to the decrease of pigs and poultry emissions. However, the N_2O final emissions increased from 63 to 127 tonnes, again mainly due to pigs and poultry. The refinement of the manure management systems, in the case of CH_4, contributed to a decrease in the emissions of both animals. Yet, in the case of N_2O, it did not affect the emissions from pigs but it contributed to a significant increase in poultry emissions.

Finally, for NH_3 an increase of 27 tonnes (± 0.3%) was observed, mainly due to the increase of poultry and cattle emissions. As expected, for NH_3, the only sections which required an adjustment were storage of manure and landspreading with the increase in storage emissions offsetting somewhat the decrease in landspreading.

4.2 UPDATED AGRICULTURAL EMISSIONS FOR LFV, GVRD AND FVRD FOR 2000

Tables and Figures 4-1, 4-2 and 4-3 show the updated agricultural emission inventory results for the Lower Fraser Valley, GVRD and FVRD (southwestern portion within the LFV). Table 4-4 shows a further breakdown of the results for the categories of manure management and nonroad engine emissions, for the LFV. For the GVRD and FVRD breakdowns, refer to Appendix B.

Table 4-1: Updated LFV Agricultural Emissions Inventory for 2000

	emissions (tonnes/year)											
	CO	NO_x	particulate matter			SO_x	VOC	NH_3	greenhouse gases			
			PM	PM_{10}	$PM_{2.5}$				CO_2	CH_4	N_2O	CO_2E
Livestock Animals												
Cattle	0.0	0.0	119.8	76.7	12.0	0.0	2,256.0	0.0	0.0	9,024.0	0.0	189,503.6
Pigs	0.0	0.0	215.9	138.2	21.6	0.0	33.5	0.0	0.0	133.8	0.0	2,810.1
Sheep	0.0	0.0	23.2	14.9	2.3	0.0	21.9	0.0	0.0	87.8	0.0	1,843.6
Poultry	0.0	0.0	6.3	4.0	0.6	0.0	24.9	0.0	0.0	106.9	0.0	2,245.2
Horses	0.0	0.0	153.5	98.2	15.3	0.0	42.1	0.0	0.0	168.6	0.0	3,540.1
Miscellaneous Animals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	92.2	0.0	1,936.9
Subtotal	**0.0**	**0.0**	**518.7**	**331.9**	**51.9**	**0.0**	**2,378.4**	**0.0**	**0.0**	**9,613.3**	**0.0**	**201,879.5**
Manure Management												
Livestock wastes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10,008.6	0.0	5,893.8	127.2	163,196.3
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**10,009**	**0**	**5,894**	**127**	**163,196**
Burning												
Agricultural	1,803.4	62.2	342.0	342.0	342.0	0.0	279.8	0.0	0.0	84.0	0.0	1,763.0
Subtotal	**1,803**	**62**	**342**	**342**	**342**	**0**	**280**	**0**	**0**	**84**	**0**	**1,763**
Chemical & Nutrient Applications												
Synthetic Fertilizers	0.0	0.0	53.6	26.3	7.5	0.0	0.0	891.2	0.0	0.0	115.5	35,790.7
Organic Fertilizers [a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	146.3	45,361.9
Pesticides	0.0	0.0	106.9	52.5	14.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Limestone/Dolomite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4,394.2	0.0	0.0	4,394.2
Subtotal	**0**	**0**	**160**	**79**	**22**	**0**	**0**	**891**	**4,394**	**0**	**262**	**85,547**
Fugitive Dust												
Wind Erosion	0.0	0.0	910.7	455.4	100.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tilling	0.0	0.0	1,220.2	256.3	51.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**0**	**0**	**2,131**	**712**	**152**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines												
Agricultural Equipment	1,922.3	1,737.1	246.8	246.8	239.4	47.5	306.1	1.1	135,043.7	14.0	54.5	152,219.8
Subtotal	**1,922**	**1,737**	**247**	**247**	**239**	**47**	**306**	**1**	**135,044**	**14**	**54**	**152,220**
LFV Total	**3,726**	**1,799**	**3,399**	**1,711**	**808**	**47**	**2,964**	**10,901**	**139,438**	**15,605**	**443**	**604,605**

[a] **emissions of NH3 of organic fertilizers are quantified under manure management**

Figure 4-1: Updated LFV Agricultural Emissions Inventory for 2000

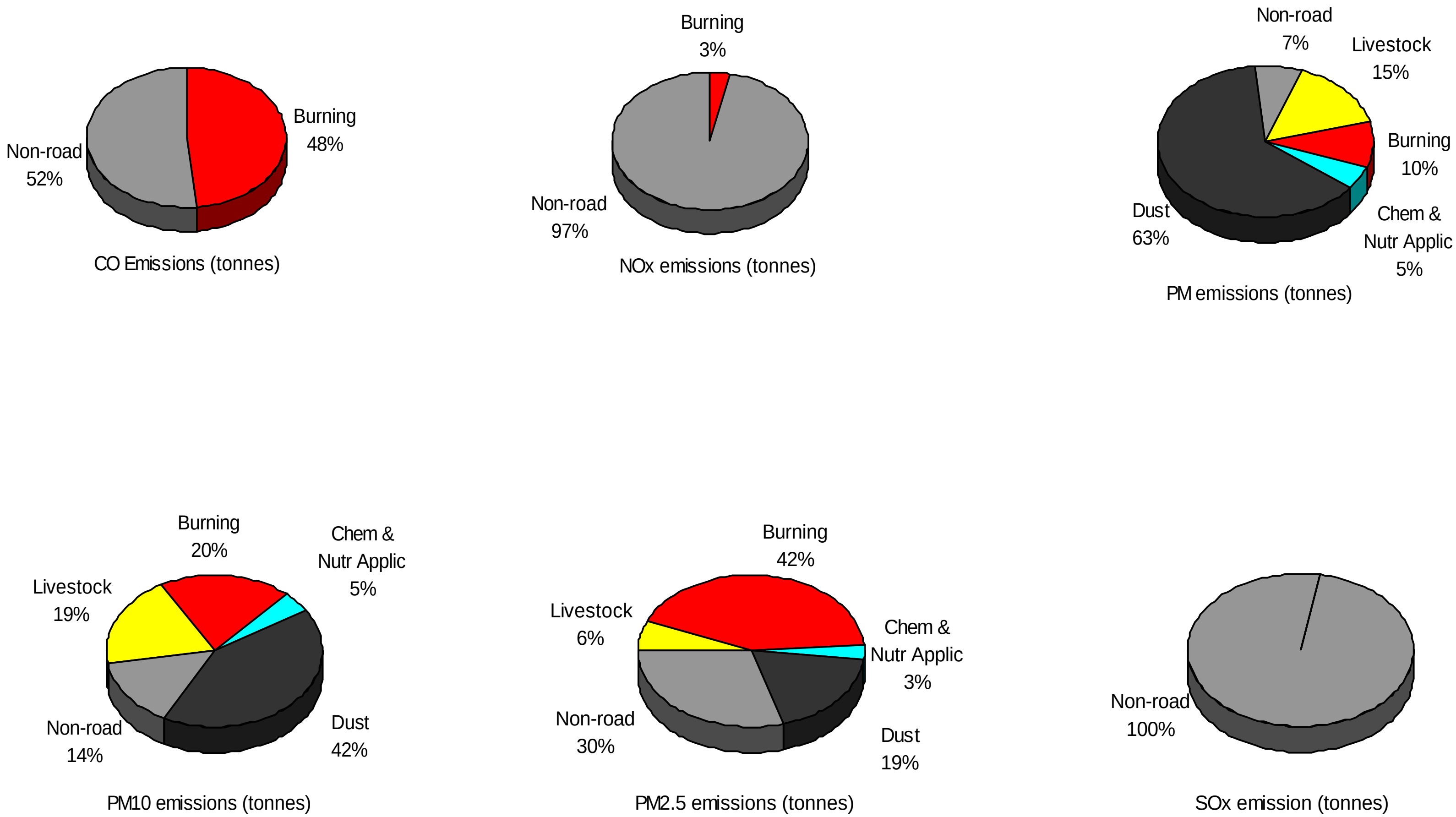


Figure 4-1 (con't): Updated LFV Agricultural Emissions Inventory for 2000

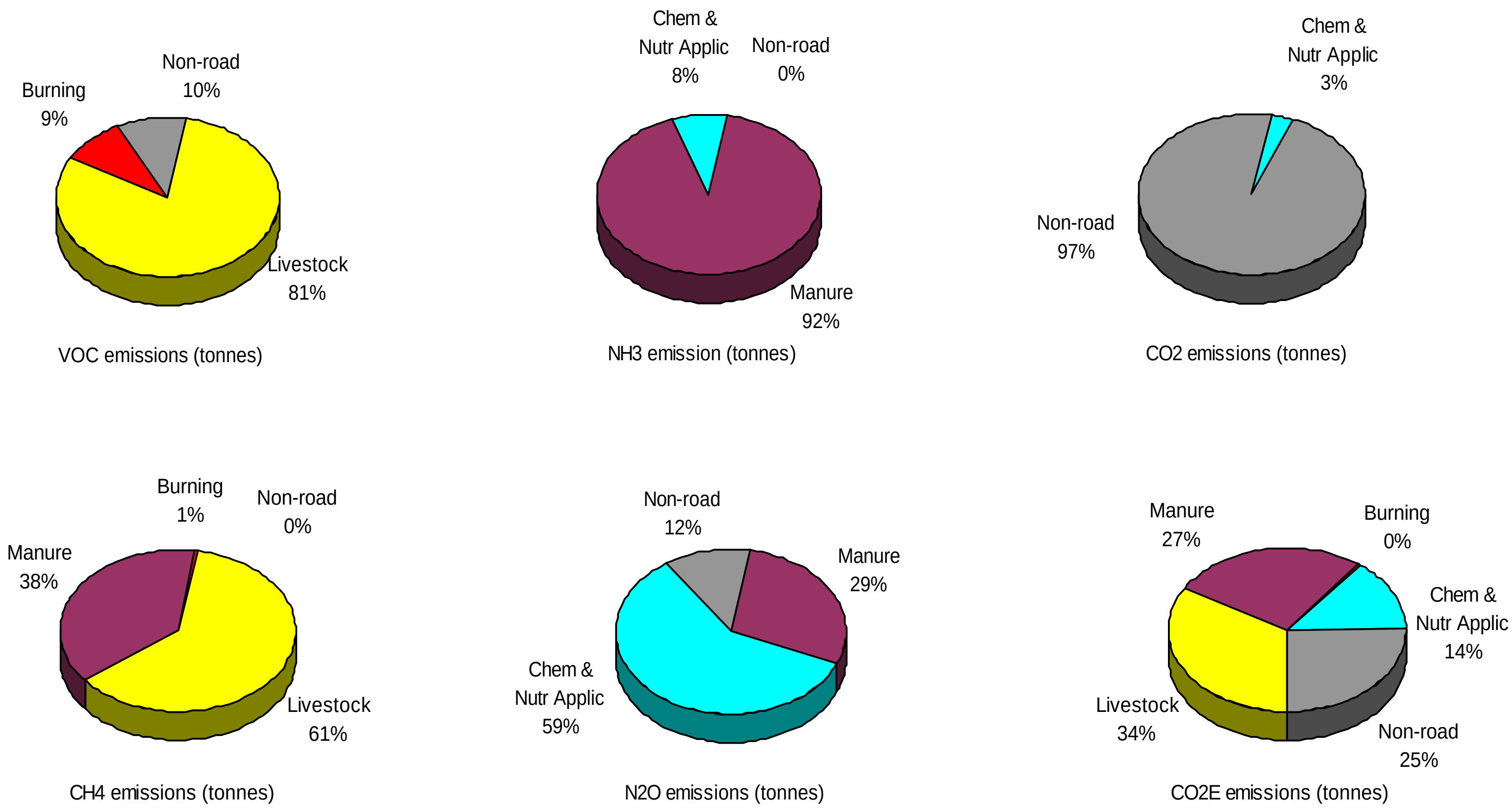


Table 4-2: Updated GVRD Agricultural Emissions Inventory for 2000

	emissions (tonnes/year)											
	CO	NO_x	particulate matter			SO_x	VOC	NH_3	greenhouse gases			
			PM	PM_{10}	$PM_{2.5}$				CO_2	CH_4	N_2O	CO_2E
Livestock Animals												
Cattle	0.0	0.0	62.6	40.1	6.3	0.0	585.3	0.0	0.0	2,057.0	0.0	43,196.0
Pigs	0.0	0.0	7.3	4.7	0.7	0.0	1.1	0.0	0.0	4.5	0.0	95.0
Sheep	0.0	0.0	10.2	6.5	1.0	0.0	9.6	0.0	0.0	38.8	0.0	815.3
Poultry	0.0	0.0	2.0	1.3	0.2	0.0	7.9	0.0	0.0	27.8	0.0	584.7
Horses	0.0	0.0	111.5	71.4	11.1	0.0	30.6	0.0	0.0	122.5	0.0	2,572.0
Miscellaneous Animals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.6	0.0	412.2
Subtotal	**0**	**0**	**194**	**124**	**19**	**0**	**634**	**0**	**0**	**2,270.2**	**0**	**47,675**
Manure Management												
Livestock wastes	0	0	0	0	0	0	0	2,786.9	0	1,670.0	43.3	48,502.8
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2,787**	**0**	**1,670**	**43**	**48,503**
Burning												
Agricultural	1,249	43.1	237	237	237	0	193.9	0	0	58.2	0.0	1,221.4
Subtotal	**1,249**	**43**	**237**	**237**	**237**	**0**	**194**	**0**	**0**	**58**	**0**	**1,221**
Chemical & Nutrient Applications												
Synthetic Fertilizers	0.0	0.0	18.4	9.0	2.6	0.0	0.0	305.0	0.0	0.0	39.5	12,249.4
Organic Fertilizers [a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.5	14,722.1
Pesticides	0.0	0.0	35.2	17.3	4.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Limestone/Dolomite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,963.3	0.0	0.0	1,963.3
Subtotal	**0.0**	**0.0**	**53.6**	**26.3**	**7.4**	**0.0**	**0.0**	**305.0**	**1,963.3**	**0.0**	**87.0**	**28,934.8**
Fugitive Dust												
Wind Erosion	0	0	256.3	128	28.4	0	0	0	0	0	0	0
Tilling	0.0	0.0	443.4	93.1	18.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**0**	**0**	**700**	**221**	**47**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines												
Agricultural Equipment	870	787	112	112	109	22	139	1	61,159	6	25	68,927.7
Subtotal	**870**	**787**	**112**	**112**	**109**	**22**	**139**	**1**	**61,159**	**6**	**25**	**68,928**
GVRD Total	**2,120**	**830**	**1,296**	**720**	**419**	**22**	**967**	**3,092**	**63,123**	**4,004**	**155**	**195,262**

[a] **emissions of NH3 of organic fertilizers are quantified under manure management**

Figure 4-2: Updated GVRD Agricultural Emissions Inventory for 2000

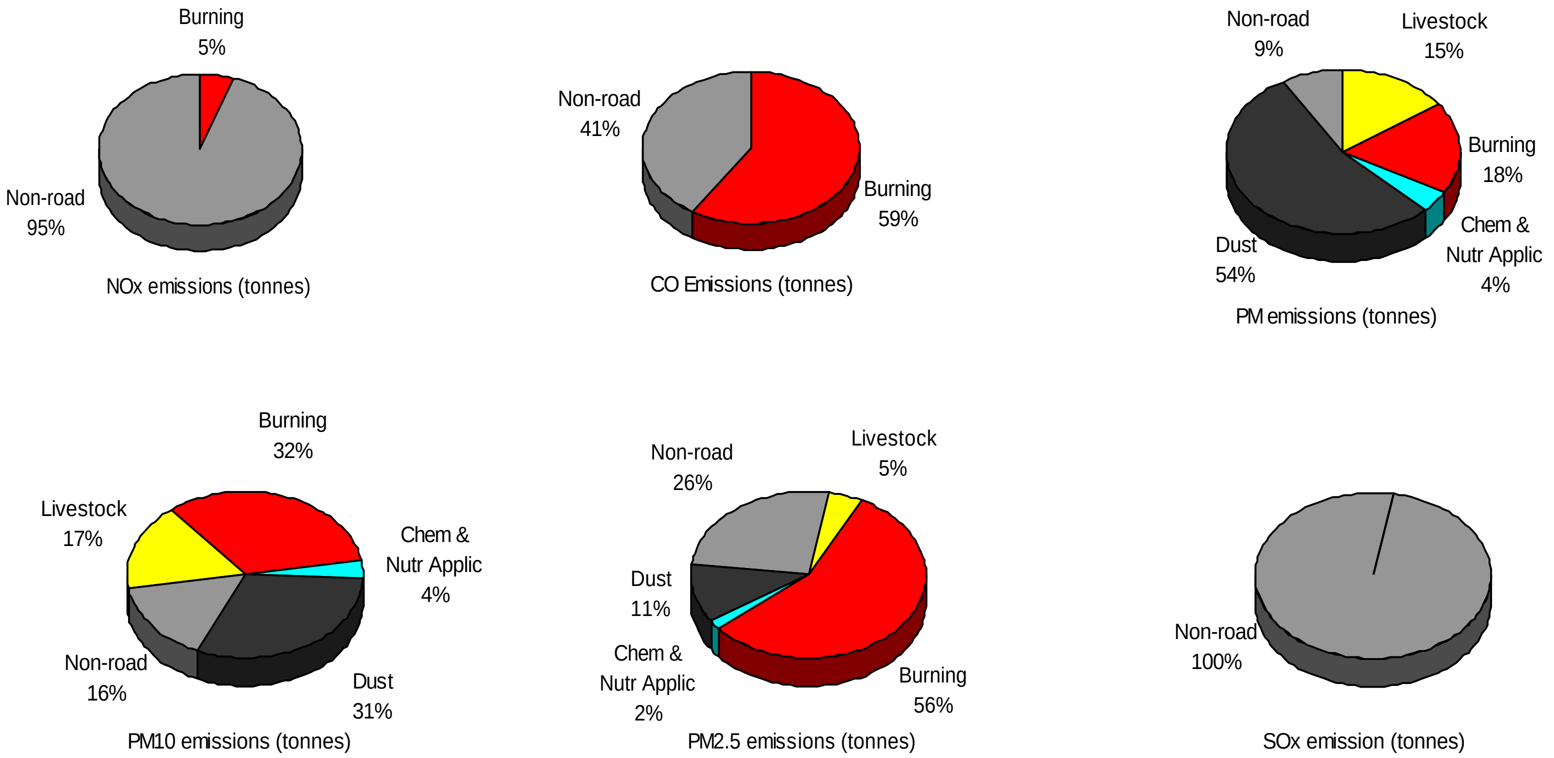


Figure 4-2 (con't): Updated GVRD Agricultural Emissions Inventory for 2000

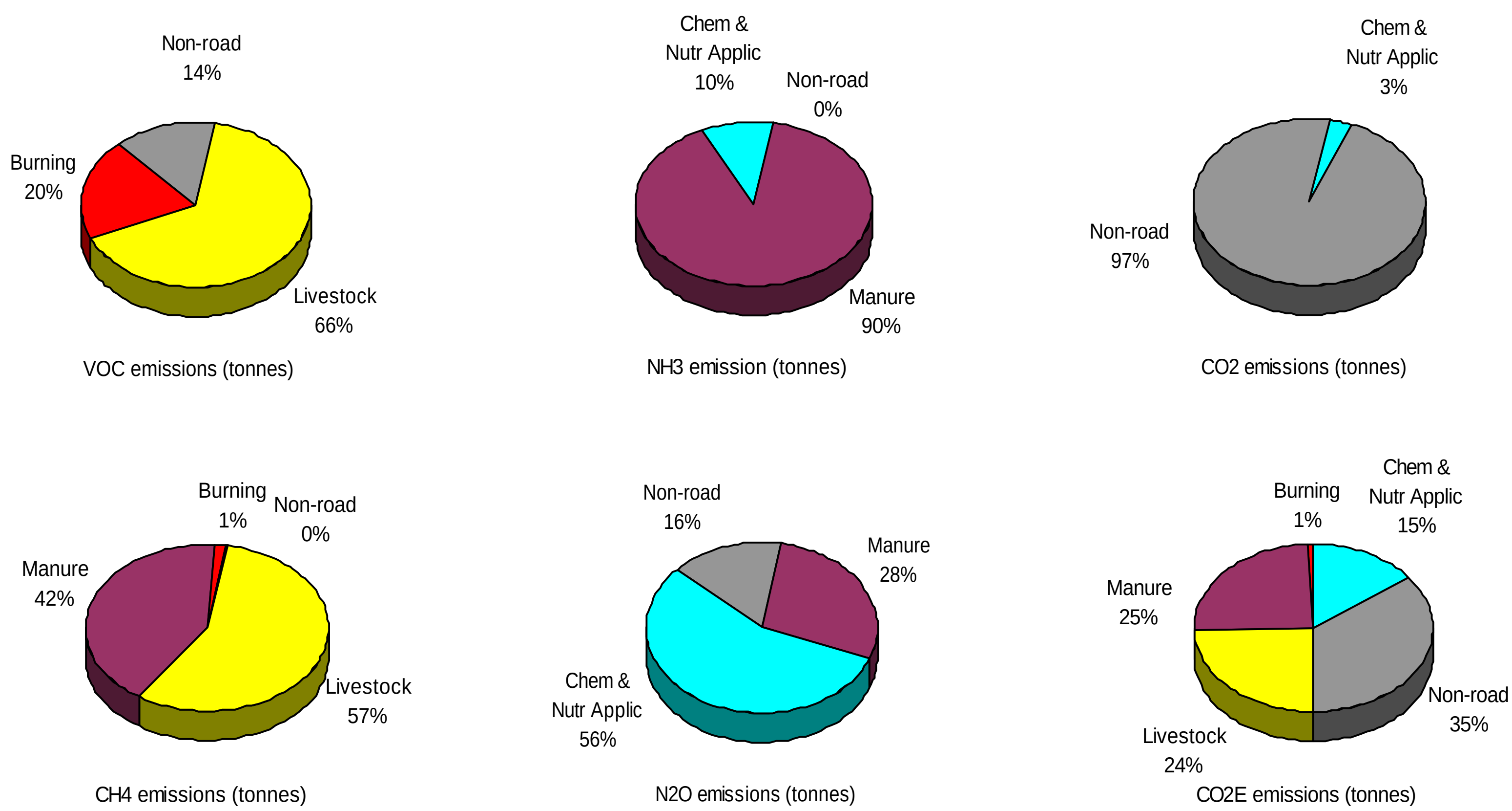


Table 4-3: Updated FVRD Agricultural Emissions Inventory for 2000

	emissions (tonnes/year)											
	CO	NO_x	particulate matter			SO_x	VOC	NH_3	greenhouse gases			
			PM	PM_{10}	$PM_{2.5}$				CO_2	CH_4	N_2O	CO_2E
Livestock Animals												
Cattle	0.0	0.0	57.2	36.6	5.7	0.0	1,670.7	0.0	0.0	6,967.0	0.0	146,307.6
Pigs	0.0	0.0	208.6	133.5	20.9	0.0	32.3	0.0	0.0	129.3	0.0	2,715.1
Sheep	0.0	0.0	13.1	8.4	1.3	0.0	12.3	0.0	0.0	49.0	0.0	1,028.3
Poultry	0.0	0.0	4.3	2.8	0.4	0.0	17.0	0.0	0.0	79.1	0.0	1,660.5
Horses	0.0	0.0	42.0	26.9	4.2	0.0	11.5	0.0	0.0	46.1	0.0	968.1
Miscellaneous Animals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	72.6	0.0	1,524.7
Subtotal	**0**	**0**	**325**	**208**	**33**	**0**	**1,744**	**0**	**0**	**7,343**	**0**	**154,204**
Manure Management												
Livestock wastes	0	0	0	0	0	0	0	7,221.6	0	4,223.8	83.9	114,693.4
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**7,222**	**0**	**4,224**	**84**	**114,693**
Burning												
Agricultural	554	19.1	105	105	105	0	86.0	0	0	25.8	0.0	541.6
Subtotal	**554**	**19**	**105**	**105**	**105**	**0**	**86**	**0**	**0**	**26**	**0**	**542**
Chemical & Nutrient Applications												
Synthetic Fertilizers	0.0	0.0	35.3	17.3	4.9	0.0	0.0	586.2	0.0	0.0	75.9	23,541.3
Organic Fertilizers [a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	98.8	30,639.8
Pesticides	0.0	0.0	71.6	35.2	9.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Limestone/Dolomite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2,431.0	0.0	0.0	2,431.0
Subtotal	**0**	**0**	**107**	**52**	**15**	**0**	**0**	**586**	**2,431**	**0**	**175**	**56,612**
Fugitive Dust												
Wind Erosion	0	0	654.5	327	72.5	0	0	0	0	0	0	0
Tilling	0.0	0.0	776.8	163	32.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**0**	**0**	**1,431**	**490**	**105**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines												
Agricultural Equipment	1,052	950	135	135	131	26	168	1	73,884	8	30	83,292.1
Subtotal	**1,052**	**950**	**135**	**135**	**131**	**26**	**168**	**1**	**73,884**	**8**	**30**	**83,292**
FVRD Total	**1,606**	**969**	**2,103**	**991**	**388**	**26**	**1,997**	**7,808**	**76,315**	**11,601**	**288**	**409,343**

[a] **emissions of NH3 of organic fertilizers are quantified under manure management**

Figure 4-3: Updated FVRD Agricultural Emissions Inventory for 2000

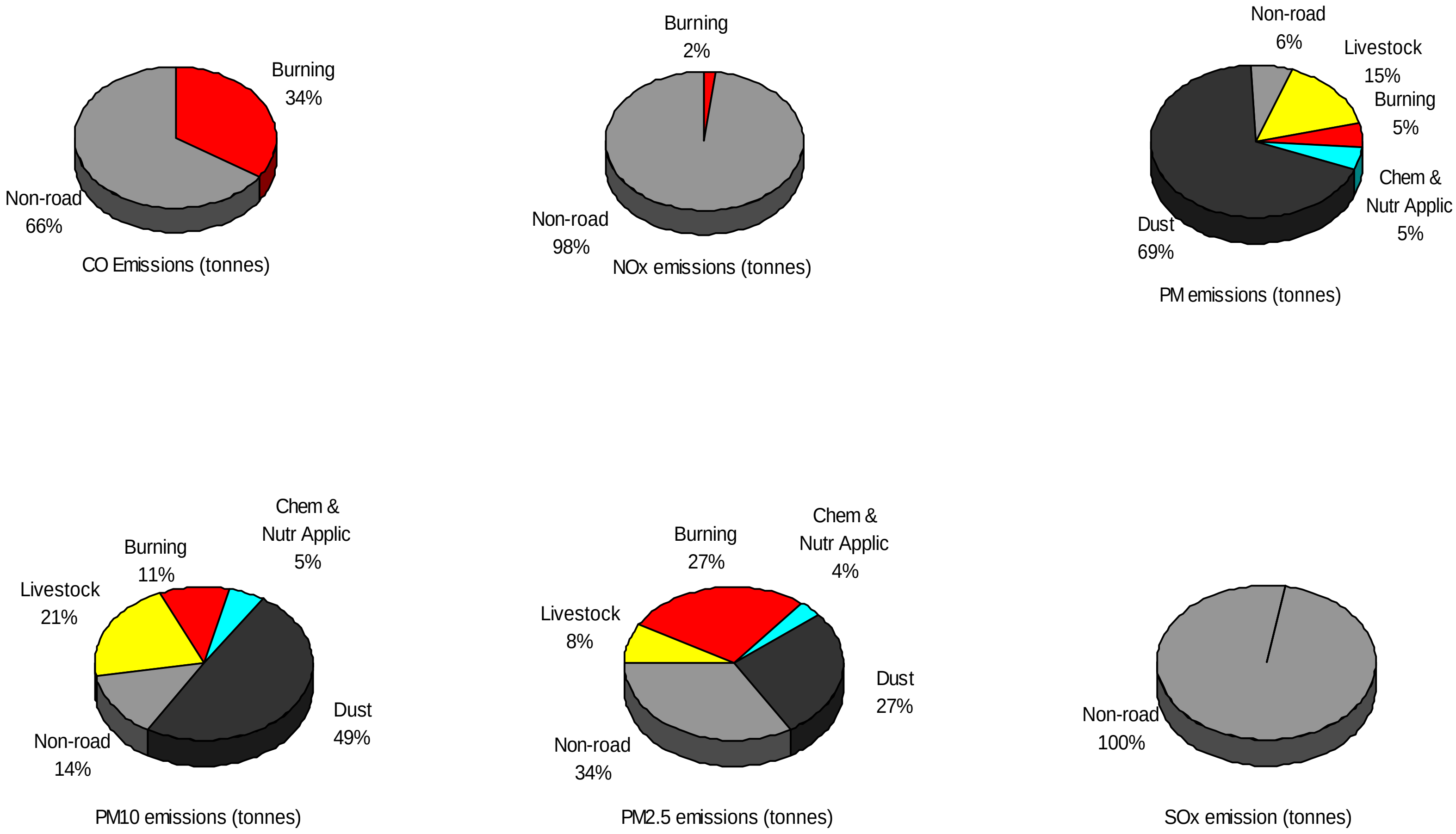


Figure 4-3 (con't) : Updated FVRD Agricultural Emissions Inventory for 2000

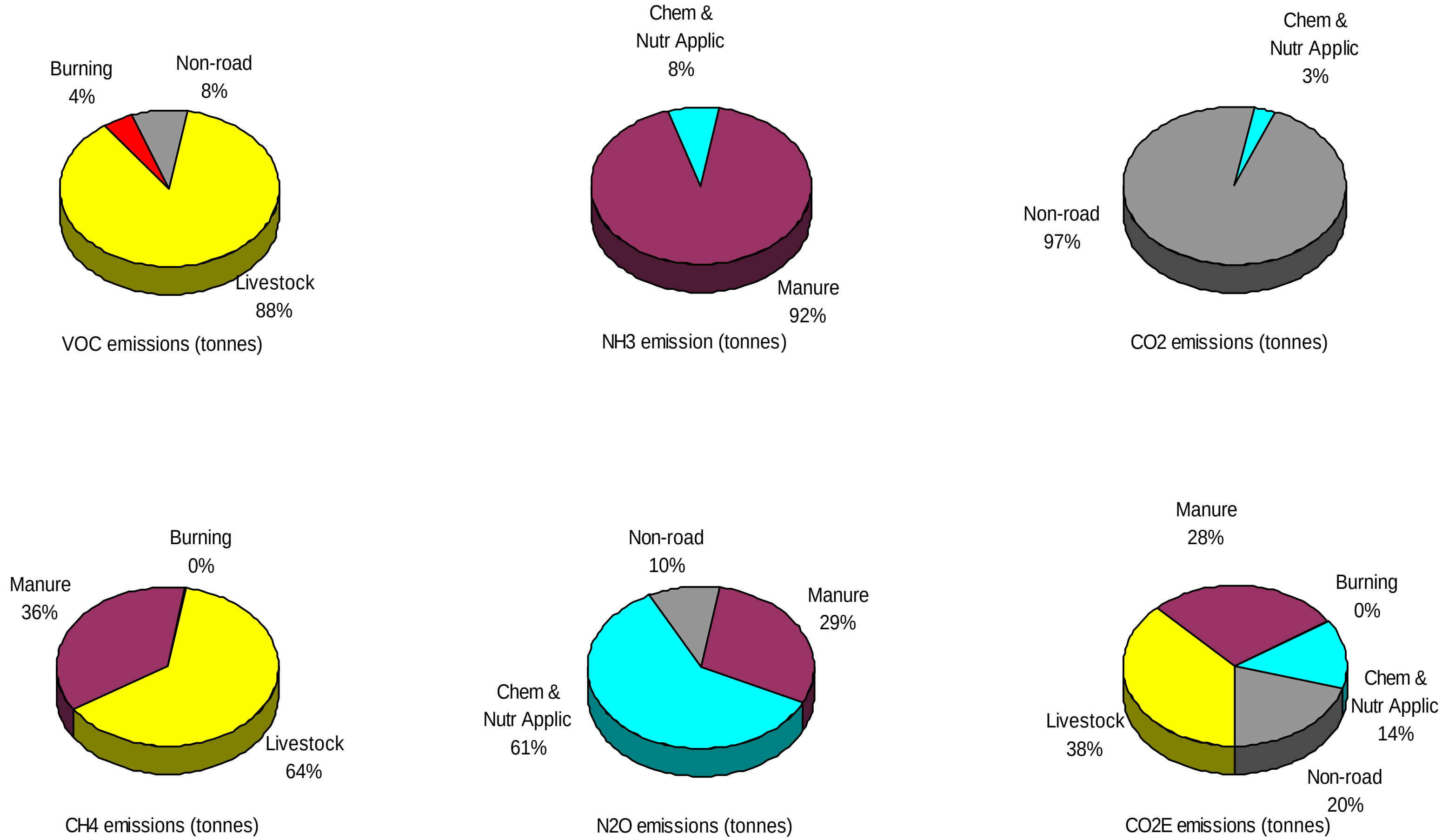


Table 4-4: Breakdown of manure management and nonroad engine emissions for the LFV Agricultural Emissions Inventory for the year 2000

	emissions (tonnes/year)											
	CO	NO_x	particulate matter			SO_x	VOC	NH_3	greenhouse gases			
			PM	PM_{10}	$PM_{2.5}$				CO_2	CH_4	N_2O	CO_2E
Manure Management												
Dairy Cattle	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,371.8	0.0	2,384.6	2.8	50,935.0
Non Dairy Cattle	0.0	0.0	0.0	0.0	0.0	0.0	0.0	399.1	0.0	36.3	4.2	2,070.5
Pigs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,037.2	0.0	495.0	5.1	11,970.2
Sheep	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.9	0.0	5.0	0.0	104.4
Poultry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6,844.3	0.0	2,934.4	115.1	97,309.0
Horses	0.0	0.0	0.0	0.0	0.0	0.0	0.0	88.6	0.0	37.0	0.0	776.0
Miscellaneous Animals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	236.7	0.0	1.5	0.0	31.2
Subtotal	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**10,008.6**	**0.0**	**5,893.8**	**127.2**	**163,196.3**
Non-road Engines												
2-Wheel Tractors	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agricultural Mowers	5.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	13.9	0.0	0.0	14.7
Agricultural Tractors	1,466.4	1,691.9	240.1	240.1	232.9	45.3	285.2	1.1	131,673.8	4.8	53.5	148,357.9
Balers	7.5	0.7	0.1	0.1	0.1	0.0	0.5	0.0	54.1	0.0	0.0	57.5
Combines	9.3	26.5	4.6	4.6	4.5	0.5	2.5	0.0	1,442.7	0.0	0.6	1,625.6
Hydro Power Units	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irrigation Sets	27.7	8.2	0.6	0.6	0.6	0.2	1.6	0.0	573.9	7.6	0.2	785.4
Sprayers	41.7	3.3	0.7	0.7	0.6	0.1	3.3	0.0	297.5	0.2	0.1	328.1
Swathers	11.6	4.5	0.7	0.7	0.7	0.1	0.9	0.0	279.2	0.1	0.1	309.8
Tillers > 6 HP	353.1	1.8	0.1	0.1	0.1	0.1	12.1	0.0	708.7	1.3	0.0	740.7
Other Agricultural Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**1,922.3**	**1,737.1**	**246.8**	**246.8**	**239.4**	**46.3**	**306.1**	**1.1**	**135,043.7**	**14.0**	**54.5**	**152,219.8**
LFV Total	**1,922.3**	**1,737.1**	**246.8**	**246.8**	**239.4**	**46.3**	**306.1**	**10,009.7**	**135,043.7**	**5,907.8**	**181.6**	**315,416.1**

4.3 EMISSIONS BACKCAST AND FORECAST 1990 - 2020

The updated 2000 agricultural emissions have been forecast to the year 2020 in five year increments and, where information is available, backcast to 1990. The selection of appropriate socio-economic parameters and the subsequent development of growth factors for each agricultural source category was based on a review of the GVRD report entitled "Forecast and Backcast of the 2000 Emission Inventory for the Lower Fraser Valley Airshed 1985-2025" (GVRD, 2003b). A summary of all the growth factors applied to each source can be found in Appendix C.

Table 3-5 summarizes emission trends for the LFV. Additional detail on individual source forecasts for the LFV, GVRD and FVRD is provided in Appendix B.

It should be noted that GVRD staff have provided updated emission estimates and forecasts for agricultural equipment, reflecting the use of the 2004 version of the U.S. EPA NONROAD model and updated base quantities from Environment Canada.

Table 4-5: Emission Trends for the LFV (1990-2020)

Sources	CO emissions (tonnes/year)							
	1990	1995	2000	2005	2010	2015	2020	Growth 2000-2020 (%)
Livestock Animals	0	0	0	0	0	0	0	-
Manure Management	0	0	0	0	0	0	0	-
Burning	1,857	1,830	1,803	1,803	1,803	1,803	1,803	0
Chemical & Nutrient Applications	0	0	0	0	0	0	0	-
Fugitive Dust	0	0	0	0	0	0	0	-
Non-road Engines	1,822	1,936	1,922	1,731	1,526	1,280	1,080	-44
LFV Total	**3,679**	**3,766**	**3,726**	**3,535**	**3,329**	**3,083**	**2,883**	**-23**

Sources	NO_X emissions (tonnes/year)							
	1990	1995	2000	2005	2010	2015	2020	Growth 2000-2020 (%)
Livestock Animals	0	0	0	0	0	0	0	-
Manure Management	0	0	0	0	0	0	0	-
Burning	64	63	62	62	62	62	62	0
Chemical & Nutrient Applications	0	0	0	0	0	0	0	-
Fugitive Dust	0	0	0	0	0	0	0	-
Non-road Engines	1,637	1,799	1,737	1,628	1,490	1,237	943	-46
LFV Total	**1,701**	**1,863**	**1,799**	**1,690**	**1,552**	**1,299**	**1,005**	**-44**

Sources	PM emissions (tonnes/year)							
	1990	1995	2000	2005	2010	2015	2020	Growth 2000-2020 (%)
Livestock Animals	517	516	519	540	551	561	573	10
Manure Management	0	0	0	0	0	0	0	-
Burning	352	347	342	342	342	342	342	0
Chemical & Nutrient Applications	160	160	160	160	160	160	160	0
Fugitive Dust	2,131	2,131	2,131	2,131	2,131	2,131	2,131	0
Non-road Engines	375	349	247	194	153	106	65	-74
LFV Total	**3,536**	**3,503**	**3,399**	**3,368**	**3,337**	**3,300**	**3,271**	**-4**

Sources	PM_{10} emissions (tonnes/year)							
	1990	1995	2000	2005	2010	2015	2020	Growth 2000-2020 (%)
Livestock Animals	331	330	332	346	352	359	367	10
Manure Management	0	0	0	0	0	0	0	-
Burning	352	347	342	342	342	342	342	0
Chemical & Nutrient Applications	79	79	79	79	79	79	79	0
Fugitive Dust	712	712	712	712	712	712	712	0
Non-road Engines	375	349	247	194	153	106	65	-74
LFV Total	**1,849**	**1,816**	**1,711**	**1,673**	**1,638**	**1,597**	**1,563**	**-9**

Sources	$PM_{2.5}$ emissions (tonnes/year)							
	1990	1995	2000	2005	2010	2015	2020	Growth 2000-2020 (%)
Livestock Animals	52	52	52	54	55	56	57	10
Manure Management	0	0	0	0	0	0	0	-
Burning	352	347	342	342	342	342	342	0
Chemical & Nutrient Applications	22	22	22	22	22	22	22	0
Fugitive Dust	152	152	152	152	152	152	152	0
Non-road Engines	364	338	239	189	148	102	63	-74
LFV Total	**942**	**911**	**808**	**759**	**720**	**675**	**636**	**-21**

Sources	SO_X emissions (tonnes/year)							
	1990	1995	2000	2005	2010	2015	2020	Growth 2000-2020 (%)
Livestock Animals	0	0	0	0	0	0	0	-
Manure Management	0	0	0	0	0	0	0	-
Burning	0	0	0	0	0	0	0	-
Chemical & Nutrient Applications	0	0	0	0	0	0	0	-
Fugitive Dust	0	0	0	0	0	0	0	-
Non-road Engines	126	169	47	54	2	2	2	-97
LFV Total	**126**	**169**	**47**	**54**	**2**	**2**	**2**	**-97**

Sources	VOC emissions (tonnes/year)							
	1990	1995	2000	2005	2010	2015	2020	Growth 2000-2020 (%)
Livestock Animals	2,582	2,518	2,378	2,608	2,615	2,622	2,629	11
Manure Management	0	0	0	0	0	0	0	-
Burning	288	284	280	280	280	280	280	0
Chemical & Nutrient Applications	0	0	0	0	0	0	0	-
Fugitive Dust	0	0	0	0	0	0	0	-
Non-road Engines	386	376	306	229	168	123	93	-70
LFV Total	**3,256**	**3,178**	**2,964**	**3,117**	**3,063**	**3,024**	**3,002**	**1**

Sources	NH_3 emissions (tonnes/year)							
	1990	1995	2000	2005	2010	2015	2020	Growth 2000-2020 (%)
Livestock Animals	0	0	0	0	0	0	0	-
Manure Management	7,445	10,324	10,009	11,099	12,014	12,931	13,849	38
Burning	0	0	0	0	0	0	0	-
Chemical & Nutrient Applications	891	891	891	891	891	891	891	0
Fugitive Dust	0	0	0	0	0	0	0	-
Non-road Engines	1	1	1	1	1	2	2	50
LFV Total	**8,337**	**11,216**	**10,901**	**11,991**	**12,907**	**13,824**	**14,741**	**35**

Sources	CO_2 emissions (tonnes/year)							
	1990	1995	2000	2005	2010	2015	2020	Growth 2000-2020 (%)
Livestock Animals	0	0	0	0	0	0	0	-
Manure Management	0	0	0	0	0	0	0	-
Burning	0	0	0	0	0	0	0	-
Chemical & Nutrient Applications	4,394	4,394	4,394	4,394	4,394	4,394	4,394	0
Fugitive Dust	0	0	0	0	0	0	0	-
Non-road Engines	95,814	115,167	135,044	152,545	169,777	187,138	204,409	51
LFV Total	**100,208**	**119,561**	**139,438**	**156,939**	**174,171**	**191,532**	**208,803**	**50**

Sources	CH_4 emissions (tonnes/year)							
	1990	1995	2000	2005	2010	2015	2020	Growth 2000-2020 (%)
Livestock Animals	10,416	10,168	9,613	10,538	10,570	10,604	10,639	11
Manure Management	4,966	6,145	5,894	6,520	6,907	7,293	7,680	30
Burning	86	85	84	84	84	84	84	0
Chemical & Nutrient Applications	0	0	0	0	0	0	0	-
Fugitive Dust	0	0	0	0	0	0	0	-
Non-road Engines	18	17	14	6	4	3	3	-82
LFV Total	**15,486**	**16,415**	**15,605**	**17,148**	**17,565**	**17,985**	**18,405**	**18**

Sources	N_2O emissions (tonnes/year)							
	1990	1995	2000	2005	2010	2015	2020	Growth 2000-2020 (%)
Livestock Animals	0	0	0	0	0	0	0	-
Manure Management	82	131	127	143	158	173	188	48
Burning	0	0	0	0	0	0	0	-
Chemical & Nutrient Applications	262	262	262	262	262	262	262	0
Fugitive Dust	0	0	0	0	0	0	0	-
Non-road Engines	39	46	54	61	68	75	82	51
LFV Total	**383**	**439**	**443**	**466**	**488**	**510**	**532**	**20**

Sources	CO_2E emissions (tonnes/year)							
	1990	1995	2000	2005	2010	2015	2020	Growth 2000-2020 (%)
Livestock Animals	218,728	213,530	201,879	221,290	221,980	222,684	223,410	11
Manure Management	129,739	169,562	163,196	181,233	194,030	206,829	219,630	35
Burning	1,815	1,789	1,763	1,763	1,763	1,763	1,763	0
Chemical & Nutrient Applications	85,547	85,547	85,547	85,547	85,547	85,547	85,547	0
Fugitive Dust	0	0	0	0	0	0	0	-
Non-road Engines	108,414	129,942	152,220	171,731	191,059	210,559	229,968	51
LFV Total	**544,243**	**600,370**	**604,605**	**661,564**	**694,378**	**727,381**	**760,318**	**26**

Figure 4-5: Emission Trends for the LFV (1990-2020)

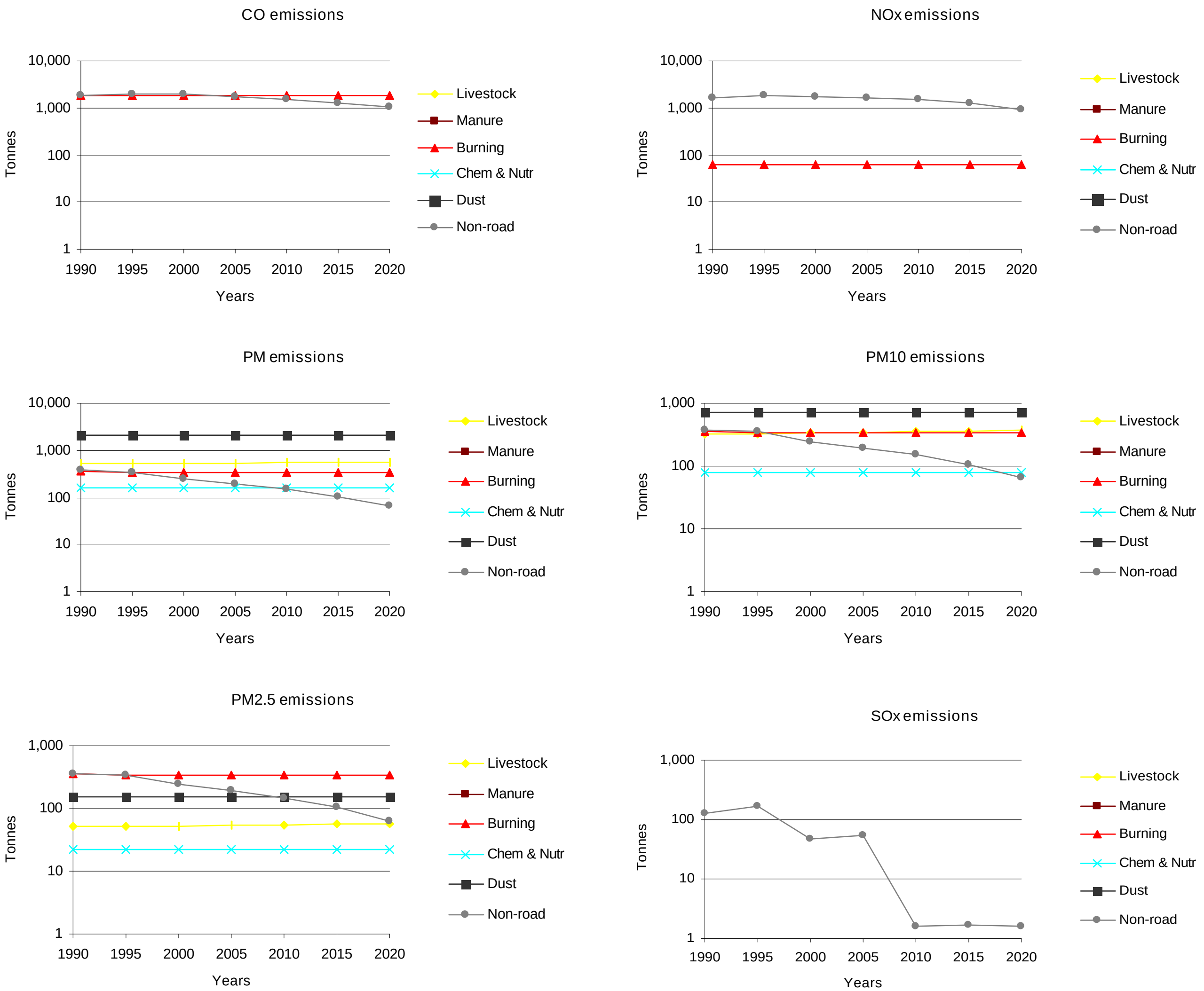
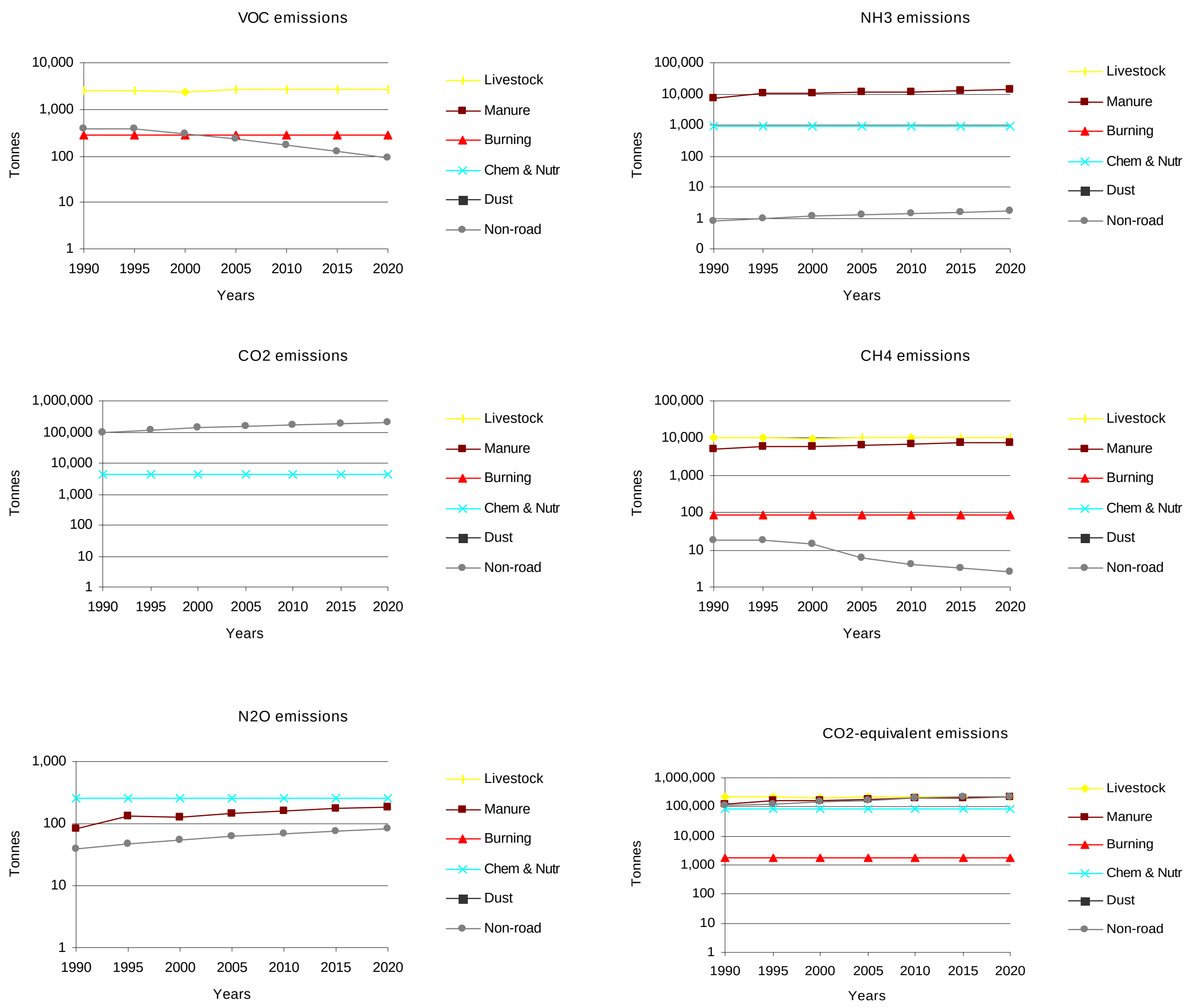


Figure 4-5 (con't): Emission Trends for the LFV (1990-2020)



5. EXISTING BEST MANAGEMENT PRACTICES

Agriculture and Agri-Food Canada (AAFC) define Best Management Practices, or BMPs, as pollution prevention farming methods which provide “practical ways to ensure that risks to the environment are minimized without sacrificing economic productivity” (AAFC, 2004).

BMPs for agricultural sources tend to focus on water resources, and to a lesser extent, soil. Many of the BMPs listed in the literature deal with the prevention or reduction of contamination of surface or groundwater from surface runoff of sediments, nutrients or pesticides. However, a number of these BMPs will also have additional benefits with respect to prevention or reduction of air emissions from agricultural operations.

AAFC categories BMPs into three general types:

- **Reducing inputs** – by reducing the amounts of potentially harmful substances (such as pesticides, fertilizers, manures or other nutrients) used in agriculture, their impact on the environment can be minimized. This type of BMP is an important element of pollution prevention and can be achieved through specific management strategies such as nutrient management and integrated pest management, which are described in more detail below.
- **Controlling erosion and runoff** – through practices which prevent erosion and reduce the movement of pesticides and nutrients from agricultural land. Examples include strip-cropping, shelterbelts, use of cover crops, conservation tillage and continuous cropping.
- **Barriers and buffers** – can physically be constructed or planted to intercept and contain sediment and nutrients from being carried away from agricultural lands. Grassed waterways, vegetative strips and field borders are examples of buffers that can be used. The vegetation also stabilizes the banks and shores from the erosive action of the waterway itself.

A list of existing best management practices (BMPs) which are applicable to agricultural sources in the LFV have been compiled through literature review and consultation with government officials and the agriculture community.

This section includes:

- a discussion of air quality issues which can be addressed by BMPs
- compilation of a list of potential BMPs for major agricultural emission sources classified according to nine general categories

Where data is available, the listing includes estimation of the reductions in emissions (% reduction, or tonnes reduced) which would result from implementation of BMPs, and a discussion on barriers to the adoption of BMPs.

Section 6 discusses government tools that may be used to increase adoption of BMPs, and Section 7 reviews available information on the cost and cost-effectiveness of BMPs.

5.1 OVERVIEW OF AIR QUALITY ISSUES ADDRESSED BY BMPS

5.1.1 Carbon Dioxide

The carbon cycle in agricultural cropped land involves the absorption of carbon dioxide (CO_2) from the atmosphere by plant leaves, and the subsequent transformation via photosynthesis into carbon-containing compounds such as sugars, carbohydrates, cellulose and lignin. Some of these compounds are used by plants for their own energy, and converted back to CO_2, while the remaining carbon is either removed during harvest or returned to the soil. The residue which is returned to the soil becomes part of the soil organic matter, which decomposes, releasing CO_2 back to the atmosphere. The rate of the carbon cycle varies depending on the climate, soil and crop type.

If livestock are present on the farm, a portion of the harvested material is fed to the animals or used as bedding material. Some of the carbon is released to the atmosphere by animals as CO_2, some is removed as animal products, and much is returned to the soil as manure. Livestock-based systems often retain higher portions of carbon on the farms.

A change in the way farmland is managed can disrupt the carbon cycle and affect the amount of carbon stored. There is less input of new carbon to farmland as a result of the removal of carbon due to the harvesting of fields, and a speeding up of the conversion of soil carbon to CO_2 because of cultivation.

The carbon content of soil can be increased by:

- Adding organic matter
- Reducing decay rate
- Storing carbon in plant material

5.1.2 Methane Emissions

Methane is one of the principal greenhouse gases, having a global warming potential of 21. The main sources of methane emissions from agricultural operations are microbial decomposition of organic matter, including plant material, animal wastes, and animal digestive systems, and to a lesser extent, fuel combustion and burning of residues.

Significant CH_4 emissions occur from ruminant animals, such as cattle, sheep and goats. These animals have a fore-stomach where feed material is partially digested, under mostly anaerobic (no oxygen) conditions, increasing the production of methane.

Methane is also formed from carbon in animal wastes. Animal manure can decompose under aerobic or anaerobic conditions, depending on how it is stored and handled. Stockpiling of solid manure, or the use of liquid storage systems, tends to minimize the availability of oxygen and therefore increase the formation of methane.

Soils can either release methane or absorb it, depending primarily on the moisture content. It is believed that the amounts of CH_4 absorbed by soils are small compared to total agricultural emissions; "even large increases in the amount of CH_4 absorption by soils would offset only a small proportion of current emissions from livestock and manure" (AAFC, 1999).

5.1.3 Nitrous Oxide Emissions

According to AAFC, agricultural activities account for up to 70% of nitrous oxide (N_2O) emissions from human activity. Most N_2O from agriculture is produced in the soil. The nitrogen cycle involves the nitrogen from plant litter being returned to the soil, where it is gradually decomposed by microorganisms to form ammonium (NH_4^+) and further converted to nitrate (NO_3^-). These forms are taken up by live plants, which obtain most of their nitrogen they by absorbing nitrate and ammonium from soil water through their roots.

In farmlands, the nitrogen cycle is more complex, as grain and other products remove large amounts of nitrogen from the field. To continue the nitrogen cycle and maintain crop growth, the lost nitrogen must be replaced with inputs from the outside, via:

- Application of nitrogen-containing fertilizers
- The use of legumes such as alfalfa, clover, beans and peas to “fix” nitrogen; legumes have nodules on their roots which contain bacteria that convert N_2 into a form available for plants.

Although these methods of injection of nitrogen sustain food production, they can result in losses of nitrogen into the environment, through leaching into groundwater or emissions to air in various forms. Losses are highest when the amounts injected exceed what plants can use, or occur at a time when plants are not growing.

Nitrous oxide can form during either nitrification or de-nitrification in the N cycle.

5.1.4 Criteria Air Contaminants

The criteria air contaminants, or CACs, include CO, VOC, NOx, SOx, and particulate matter. These CACs can be emitted directly into the atmosphere from agricultural sources but also contribute to reactions in the atmosphere to form secondary pollutants, including ground-level ozone and secondary particulate, both of which contribute to smog in the region. The contributors to formation of ground-level ozone are primarily nitrogen oxides and volatile organic compounds, and to a much lesser degree, carbon monoxide. Secondary particulate arises both from direct emissions (i.e., primary particulate) and by reaction of NOx, SOx, VOCs, ammonia and other gases in the atmosphere.

In rural areas, vegetation is a significant source of VOC emissions. Crops that emit VOCs include tomatoes, potatoes, soybeans, wheat, lettuce and rice. Nitrogen oxide emissions originate mostly from the combustion of fossil fuel, used to heat buildings and greenhouses, and in farm equipment. Primary particulate matter from agriculture comes from soil erosion, smoke from agricultural burning, fuel combustion, and tillage.

5.1.5 Ammonia

As described in Section 5.1.2 above, farming practices rely heavily on additional inputs of nitrogen, which can result in releases of not only N_2O, but also NH_3. Globally, agriculture is a major source of atmospheric emissions of ammonia from human activity. The three main sources on farms are:

- Animal wastes – of the nitrogen consumed by farm animals in feed, only about one-fifth is retained by the animal, with the remainder excreted in feces and urine. Some of this occurs as urea, which readily converts to NH_3 and CO_2. Losses of nitrogen can also occur during manure storage, and some is lost as ammonia. Some NH_3 is also released when manure is applied to land.
- Fertilizers – two forms are especially important, anhydrous ammonia and urea.
- Crop residues – appreciable amounts of NH_4^+ can be produced during the decay of nitrogen-rich residues like legume green manures. If these residues decay on the soil surface, they can convert to NH_3 and be lost to the atmosphere.

5.2 REVIEW OF BMPS

Tables 5-1 through 5-9 list agricultural BMPs according to the following nine general categories:

- Soil and Irrigation Management
- Crop Management
- Waste and Residue Management
- Management of Equipment and Fuels
- Livestock Production
- Manure Storage, Handling and Disposal
- Nutrient Management and Application
- Pesticide Storage, Handling and Application
- Fugitive Emissions of VOCs and Dust

Table 5-1: BMPs for Soil and Irrigation Management

BMP	Potential Emission Reductions	Barriers to Adoption
Reduced Tillage Historically, tilling has been used to control weeds and prepare land for seeding. Intensive tillage is no longer necessary with new herbicides and seeding equipment, and some farms have eliminated the practice altogether. With no till the field is left virtually undisturbed from harvest to planting, except for nutrient injection. Fields are no longer plowed, and plant residues remain on the soil to offer protection from erosion. Weed control is accomplished primarily with herbicides. No till or reduced till farming can lead to substantial increases in soil carbon because it retains plant residue and increases organic matter. The results have been inconsistent, and vary with climate, soil properties, length of time without tilling, crop rotation and other factors. Reducing tillage reduces the amount of soil disturbance, which minimizes particulate emissions, and also reduces the use of machinery, and therefore fossil fuel use for equipment..	• GHGs: 110,000 – 2,468,000 tonnes CO_2-equivalent per year (Canada wide basis) • N_2O: Some studies in Canada suggest that N_2O emissions may be lower in no-till than in conventional tillage. • Dust and particulate matter • Contaminants associated with fuel combustion, including GHGs, particulate matter, CO, NOx, VOC, SOx	• Ability to measure soil carbon gains is difficult • Limited data on N_2O emissions from various tillage systems • Can result in a shift to increased herbicide use • Attitudinal change needed from historical practices
Remove Land Permanently From Cultivation Reverting farmland back to its original vegetative state eliminates removal of carbon in products, such that all the carbon trapped by photosynthesis is returned to the soil. However, farm productivity is lost.	• CO_2	• Loss of farm land
Improve water management Water is often the limiting factor for crop growth. In dry areas, yields can be increased by irrigating or by trapping and storing water more effectively. In areas of excess water, improved drainage is needed.	• CO_2	• capital costs associated with trapping, storage, or drainage systems
Restore wetlands Some wetlands areas have been drained to allow crop growth, and re-submerging of soils would limit oxygen supply and prevent decay.	• CO_2	• Reduction in available farm land
Improve soil aeration Emissions of N_2O can be reduced by managing soil water – draining, avoiding over-application, and using tillage practices that improve soil structure	• N_2O	• Cost associated with drainage • May require education or change from historic practices
Lime acid soils N_2O emission is favoured by acidic conditions, which can be neutralized through the addition of lime to acidic soils.	• N_2O	• Cost associated with lime addition

Table 5-2: BMPs for Crop Management

BMP	Potential Emission Reductions	Barriers to Adoption
Grow more perennial forage crops Perennial crops grow for more months of the year and can trap more CO_2; they also dry out the soil more, require no tillage, and decay rates may be slower.	• CO_2	• May not be practical, depending on crops produced at farm
Reduce or Eliminate summer fallow Summer fallow means leaving land unplanted for a growing season, which was once practiced to help control weeds, replenish soil moisture, and increase available soil nutrients. Soils that are frequently under summer fallow have lower carbon content than those that are cropped annually; fallow hastens decomposition of soil carbon and reduces carbon input into the soil.	• GHGs 188,000 – 662,000 tonnes CO_2-equivalent per year (Canada wide basis) • Dust and particulate matter	• May lead to more additions of nutrients, or chemicals for weed, insect or disease control
Use cover crops For areas where the growing season is long enough, an off-season cover crop can be planted after the main crop has been harvested, to extract excess soil nitrate and prevent it from leaching or forming N_2O. Cover crops also provide a natural cover which reduces soil disturbance due to wind erosion and entrainment, minimizing emissions of particulate matter. Cover crop residues can also prevent wind erosion of soils.	• CO_2 • N_2O • Particulate matter	• Where residue cover is consistently high, cover crops may not be necessary. • Timing issues to eliminate cover crop during growing season. • Cover crops may overcomplicate the system because of the likely interaction with other system components (nutrients, residues, weed control, insect and disease management).
Use higher yielding crops or varieties Certain crops or crop varieties have more efficient photosynthesis and therefore produce more residues and return more carbon to the soil.	• CO_2	• This practice is limited by the marketable yield of the crop. • May not be practical, depending on crops or varieties produced at farm
Grow Legumes The use of legumes can provide a source of nitrogen and reduce the amount of fertilizer needed.	• CO_2	• May not be practical, depending on crops produced at farm

Table 5-3: BMPs for Waste and Residue Management

BMP	Potential Emission Reductions	Barriers to Adoption
Agricultural burning The burning of agricultural residues should be avoided where practicable. The burning of residues leads to direct emissions of CO_2 and reduces the amount of carbon added to the soil. Where agricultural burning is necessary, the following practices should be adhered to: • Avoid burning when venting index is poor • Avoid overloading fires • Increase fire intensity • Minimize smoldering stage • Control fuel properties (avoid compaction, allow fuel to dry before burning) • Control the length of time of burns • Ensure there are no contaminants in the fire	• GHGs: CO_2, CH_4, N_2O • Particulate matter, CO, NOx, VOC, SOx	• Burning may be the most practical and least time-consuming method for disposal of residues • Education may be needed with respect to burning practices

Table 5-4: BMPs for Management of Agricultural Non-Road Equipment and Fuels

BMP	Potential Emission Reductions	Barriers to Adoption
Increase energy use efficiency of equipment Most cropping systems use external energy sources which depend on the burning of fossil fuels. The main use of fuel is to power the machinery for tillage, planting, harvesting and other field operations, as well as transportation, irrigation, drying of crops, heating of buildings and equipment used in livestock operations.	• CO_2 • CACs: Particulate matter, CO, NOx, VOC, SOx	• Capital cost if existing equipment is replaced with more energy efficient machinery
Equipment operation and maintenance • Avoid unnecessary equipment use • Maintain the equipment properly • Operate the equipment within the specified load range	• CO_2 • CACs: Particulate matter, CO, NOx, VOC, SOx	• May lead to additional maintenance costs, but these should be partially offset by fuel savings • Education /training may be needed
Use of cleaner burning or alternate fuels Switching to cleaner burning fuels (e.g. reducing the use of diesel fuels) or to electrical equipment can reduce emissions	• Particulate matter (including diesel particulate) • NOx	• Main issue is cost, particularly if existing equipment is replaced
Fuel storage Minimize petroleum gas venting from fuel storage	• VOC	• Capital costs if storage tanks are replaced or retrofitted
Minimize Emissions from greenhouse boilers • If solid fuels are used, they should be dried prior to firing, to minimize energy requirements. • Implement rigorous maintenance program for boilers	• Particulate matter, • CO, • NOx, • VOC, • SOx	• Fuel cost fluctuations • Negative public perception of air quality impacts of burning fuels other than natural gas • May lead to additional maintenance costs, but these should be partially offset by fuel savings

Table 5-5: BMPs for Livestock Production

BMP	Potential Emission Reductions	Barriers to Adoption
Integrate livestock into cropping systems Feeding crops to livestock can be an effective form of carbon recycling if the manure produced is managed properly.	• CO_2	• May be cost issues associated with manure management • May require a change from historical practices
Improve grazing management Management of grazing can be complex, influenced by the amount of crop consumed by animals, the amount of carbon returned as manure, the condition of the soil due to hoof action, and other factors.	• CO_2	• Likely requires additional training
Production, Nutrition and Ration Management For dairy cows, measures such as increasing milking frequency, reductions in crude protein intake, feed management via amino acids, and combined feed management strategies can reduce NH_3 emissions.	• NH_3 emissions can be reduced by 5% to 16% (Tetra Tech, 2003)	• May be cost issues associated with modifying feed strategy
Change rations to reduce digestion time The longer the feed remains in the rumen, the more carbon is converted to methane. The digestion time can be reduced by using more easily digestible feeds, chopping the feed to aid digestion, minimizing the use of high fibre grasses and hays, feeding concentrated supplements, and harvesting feeds at a stage where they are more succulent.	• CH_4 • one study with steers showed that a 63% increase in the passage rate of matter through the rumen, reduced CH_4 emissions by 29% (Agriculture Canada, 1999)	• May be cost issues associated with modifying feed rations
Add edible oils The addition of certain oils, such as canola or coconut, may reduce methane production by inhibiting the activity of CH_4-producing bacteria.	• CH_4	• Though quite effective, this practice may not always be economical
Use ionophores Already widely used in beef production, ionophores are feed additives that inhibit the formation of CH_4 by bacteria in the rumen.	• CH_4	• There is some evidence to suggest that rumen microbes can adapt to specific ionophores, such that a rotation of additives may be needed

BMP	Potential Emission Reductions	Barriers to Adoption
Alter the type of bacteria in the rumen This practice is still at the research stage, but involves the introduction into the rumen of genetically modified bacteria that produce less CH_4.	• GHG 7,506,000 tonnes CO_2-equivalent per year (Canada wide basis) • CH_4	• No specific methane inhibitors currently registered for use • Effects of inhibitors on animal performance and product quality not known • May lead to public resistance due to widespread use of chemicals
Improve production efficiency Any practices which increase the productivity per animal can reduce overall CH_4 emissions	CH_4	• Emission reductions would be offset if production increases (i.e. more animals)
Minimize nitrogen excretion from livestock Farmers can reduce the nitrogen content of manure by using rations with a better nitrogen balance, by avoiding excess nitrogen in the animals' diet, or possibly by adding bacteria that help convert uric acid to nitrate.	NH_3	• May be cost issues associated with modifying diet

Table 5-6: BMPs for Manure Storage and Handling

BMP	Potential Emission Reductions	Barriers to Adoption
Use solid rather than liquid manure storage systems Most of the CH_4 from manure is produced during storage. Oxygen supply is typically better in solid manure storage than in liquid, which would promote more CO_2 formation and decreased CH_4.	• CH_4 • Odour	• Capital cost associated with switching from liquid to solid manure storage and handling system
Solid manure storage practices Solid manure storage systems should have a cover (roof), an impermeable base, and run-off control.	• GHG 440,000 – 1,310,000 tonnes CO_2-equivalent per year (Canada wide basis) • CH_4 • Odour	• Capital cost of storage cover • Awareness of environmental issues associated with handling and storage of livestock wastes is essential.
Liquid manure storage practices If liquid manure storage systems are used, the following practices should be observed: • Tanks and lagoons should be covered • Bottom-loading tanks should be used to minimize aeration	• GHG 560,000 – 5,510,000 tonnes CO_2-equivalent per year (Canada wide basis) • CH_4 • Odour	• Capital cost of storage cover
Apply manure to land as soon as possible Extended manure storage times will lead to increased CH_4 formation. By applying manure to land as soon as possible, CH_4 emissions will be minimized.	• CH_4	• Longer storage times are sometimes necessary when the land is frozen, too wet, or planted to crops.
Use manure more efficiently Because manure can be costly to transport it is sometimes applied in excess in localized areas. More efficient use of manure could prevent waste (loss of nutrients) and also displace fertilizer use.	• GHGs • CACs	• Excess manure may be applied as means of disposal
Minimize amount of bedding in manure Manure with less bedding material, such as straw, contains less carbon that can be converted to CH_4.	• CH_4	• Requires change in historical practice

BMP	Potential Emission Reductions	Barriers to Adoption
Keep storage tanks cool Lower manure storage temperatures slow the rate of decomposition. This can be achieved by insulating storage tanks or placing them below ground. Maintaining cooler temperatures can also reduce NH3 emissions.	• CH_4 • Odour • NH_3	• Capital cost associated with burying or insulating tanks. • May be increased costs for manure handling if stored below grade
Burn methane as fuel Methane produced from manure can be collected and burned as fuel.	• CH_4	• Gas collection systems require capital investment • May be technical issues with gas quality
Avoid landfilling manure Small amounts of agricultural manure are disposed of in landfills, which wastes the nutrient materials in the manure and leads to increased emissions of CH_4, since the waste decomposition process in most landfills occurs under anaerobic conditions.	• CH_4	• Landfilling of wastes may be the most convenient option
Aerate manure during composting To make it easier to transport, manure is sometimes composted before applying to land. CH4 from compost production can be minimized by ensuring the compost piles are aerated (to provide oxygen), either by turning the compost frequently or providing a ventilation system.	• CH_4 • Odour	• More controlled composting systems have higher capital and operating costs.
Improve manure handling in the barn Changes in manure handling procedures can be implemented to minimize the exposure of manure to air – manure can be removed more frequently, barns can be washed with water, liquid wastes can be collected in deep narrow troughs to reduce surface area.	• NH_3 – daily feed apron cleaning and manure removal can reduce ammonia emissions by 30% to 50% (Tetra Tech, 2003) • Odour	• Increased costs for daily removal, cleaning • Changing collection troughs may have cost impact
Improve manure storage Ammonia losses during storage can be minimized by reducing exposure to air and lowering storage temperatures. Covers placed on tanks, or cover material such as mineral oil, straw or peat on lagoons or tanks can reduce losses. The addition of acid to manure or the covering of composting manure piles with acidic peat can also minimize NH_3 loss.	• NH_3 • Odour	• Cost of cover or cover material • Handling costs for cover material or material added to compost

Table 5-7: BMPs for Nutrient Management and Application

BMP	Potential Emission Reductions	Barriers to Adoption
Apply more nutrients A study has shown that regular manure application can increase the amount of soil carbon, both from the direct application of carbon in the manure, and increased crop growth and return of residues. Application of fertilizer can increase soil carbon content. However, studies have shown that the increase comes from increased crop yields, and the subsequent increase in residue returned to the soil.	• CO_2	• Additional fertilizer costs
Match fertilizer additions to plant needs This practice involves applying just enough nitrogen for use by crops, without leaving any excess available N_2. Synchronization can be improved through soil tests and estimates of nitrogen releases from residues and organic matter. A technique known as "precision farming" involves the application of nitrogen at different rates for fields where fertility needs vary.	• N_2O	• Training may be needed to develop nutrient management plans, or to implement precision farming
Use fertilizer more efficiently The production and transportation of fertilizer is energy-intensive. Methods of applying fertilizer that minimize excess and increase yields from less fertilizer can decrease CO_2 emissions.	• CO_2	• Training may be needed to better understand crop nutrient requirements and to calculate optimum fertilizer amounts
Optimize timing of fertilizer and manure application The timing of application of nitrogen is important, and ideally should occur just before the time of maximum uptake by the crop. Fertilizer and manure should not be applied in the fall, and the plough-down of nitrogen-rich crops like legumes should coincide with crop demands.	• GHG 500,000 tonnes CO_2-equivalent per year (Canada wide basis) • N_2O	• Narrow window between spring thaw and seeding • Increased problems with soil compaction • Increased manure storage costs
Use improved fertilizer formulations Research suggests that certain forms of fertilizer emit more N_2O than others – for example, the highest emissions have been linked to anhydrous ammonia and the lowest to forms containing nitrate (NO_3-). Another option is the use of slow release fertilizer such as sulphur-coated urea.	• N_2O	• Additional fertilizer costs or application costs • May require additional training on alternative formulations
Use nitrification inhibitors Certain chemicals can be applied with fertilizers or manures to inhibit the formation of nitrate from ammonium, which can suppress N_2O formation.	• N_2O	• Additional costs associated with inhibitors • May require additional training on use of inhibitors

BMP	Potential Emission Reductions	Barriers to Adoption
Use improved methods of fertilizer application Reductions in ammonia losses from fertilizer application can be achieved by ensuring good contact between the fertilizer and moist soil. Urea should be placed either below the soil surface, or tilled in immediately after application. Anhydrous ammonia should be injected into moist soil at a depth sufficient to prevent diffusion to the surface. Quick and effective mixing with soil can minimize losses of ammonia during application. Examples include tillage or irrigation immediately after application, or planning to apply just before rain. Fertilizer should be placed in close proximity to the roots of crops to improve the efficiency of nutrient use and minimize application rates.	• NH_3 • N_2O	• May require different application methods, equipment, or be more time-consuming
Avoid excessive manure application Applying manure at rates that just supply plant demands can reduce N_2O emissions. However, manure is often applied to land as a means of disposal, in rates that can be excessive.	• GHG 1,271,000 – 26,350,000 tonnes CO2-equivalent per year (Canada wide basis) • N_2O	• Don't know current fall application patterns • Need to develop better quantitative estimates of N_2O reductions with change in practice • Too much manure can lead to poor crop performance, water pollution and create excessive odours
Use manure more efficiently Because manure can be costly to transport it is sometimes applied in excess in localized areas. More efficient use of manure could prevent waste (loss of nutrients) and also displace fertilizer use. Producers should start by testing cropland soil and manure regularly for nutrient content. Factors to consider when determining application rates include: soil type, acreage, the crop to be grown and the type of manure.	• CO_2	• Solid manure should be spread when the soil is dry and completely thawed. In ideal situations, tilling should follow within 24 hours. This timing may not always be practical
Grow legumes The use of legumes can provide a source of nitrogen and reduce the amount of fertilizer needed	• CO_2	• May not be practical, depending on crops produced at farm
Maintain records of all fertilizers applied Keeping accurate records of all agricultural chemicals can help save money and aid in making informed management decisions	• NH_3 • N_2O	• May require attitudinal change, and education on why practice is beneficial

Table 5-8: BMPs for Pesticide Storage, Handling and Application

BMP	Potential Emission Reductions	Barriers to Adoption
Integrated Pest Management IPM involves a mix of cultural, biological and chemical control methods, allowing growers to save money on inputs and use fewer pesticide applications. An IPM program includes pest monitoring, pest identification and pest thresholds.	• VOC • Hazardous air pollutants	• Training may be needed for new application equipment
Pesticide equipment calibration and loading Pesticide application equipment should be properly calibrated and in good repair, to minimize losses.	• VOC • Hazardous air pollutants	• May require attitudinal change; incentive is cost savings
Pesticide storage Pesticide storage structures should be designed and built to keep pesticides secure and isolated from the surrounding environment.	• VOC • Hazardous air pollutants	• May require attitudinal change, and education on why practice is beneficial
Locating mixing and loading activities Caution should be used when handling, mixing and loading pesticides; some options include portable mixing centres, and permanent mixing and loading facilities.	• VOC • Hazardous air pollutants	• Capital cost associated with portable or permanent mixing centres • Training may be needed in proper mixing and loading techniques
Maintain records of all pesticides applied Keeping accurate records of all agricultural chemicals can help save money and aid in making informed management decisions.	• VOC • Hazardous air pollutants	• May require attitudinal change, and education on why practice is beneficial
Pesticide waste management • Washwater for application equipment should be properly managed • Pesticide containers should be rinsed when empty • Spills should be cleaned up as soon as possible	• VOC • Hazardous air pollutants	• May require attitudinal change, and education on why practice is beneficial

Table 5-9: BMPs to Reduce Fugitive Emissions of VOCs and Dust

BMP	Potential Emission Reductions	Barriers to Adoption
Solvents and degreasers • Keep basins or cans of solvent covered to minimize evaporation • Keep an inventory of solvents • Collect used solvents and degreasers for proper disposal	• VOC • Hazardous air pollutants	• May require attitudinal change, and education on why practice is beneficial
Paint Use • Use improved transfer efficiency spray application equipment • Use lower VOC content paints	• VOC • particulate matter • Hazardous air pollutants	• Capital cost of new spray application equipment • Training may be needed for new application equipment • Lower VOC content paints may produce a different result
Modify Activities That May Create Dust Applies to tillage, harvesting, grain handling, livestock handling, feed processing • Work soils when moisture conditions are such that dust generation is minimized • Practice minimum tillage • Bale rather than chop straw • Limit activities during high winds	• VOC • PM_{10} control efficiency for reduced tillage estimated between 25 – 60%, (URS/ERG, 2001) • PM_{10} control efficiency by limiting activities during high winds estimated between 3% to 25%, (URS/ERG, 2001) • Hazardous air pollutants	• Timing may be an issue, i.e., it may not be possible to limit activities to times when conditions to minimize dust are optimum • Could be facilitated by purchasing a device to measure wind speed; training or education may be required
General Sanitation and Housekeeping • Practice dust suppression techniques • Clean up dust accumulations in the barn • Use clean low dust litter for bedding • Wash down interiors and exteriors of barns to remove dust accumulations • Clean fans, hoods and screens regularly to avoid dust build up	• Dust and particulate matter	• May require attitudinal change, and education on why practice is beneficial

BMP	Potential Emission Reductions	Barriers to Adoption
Properly locate ventilation exhaust fans • Direct discharge away from other buildings and neighbours • Take advantage of prevailing winds to carry particulates away from sensitive areas	• Dust and particulate matter	• May be cost issues if discharge points need to be modified • Timing may be an issue
Equip fans with hoods that deflect exhausted air towards the ground	• Dust and particulate matter	• May be cost issues associated with hoods
Establish and maintain adequate buffers around farm buildings	• Dust and particulate matter	• May not be practical or may impact on availability of land
Maintain ground level foliage to trap dust, clean up dust to ensure foliage remains effective	• Dust and particulate matter	• Added costs to establish and maintain foliage

6. GOVERNMENT TOOLS AND INITIATIVES THAT MAY BE USED TO INCREASE ADOPTION OF BMPS

Air quality programs for agricultural operations were reviewed for several Canadian and U.S. jurisdictions. The requirements range from regulatory to voluntary, with many providing guidelines and educational materials for use by the agricultural community.

6.1 REGULATORY

In many jurisdictions, including B.C., there are regulatory requirements for open burning which are applicable to burning of agricultural residues. There are also laws and regulations at federal and state/provincial levels which govern safe handling of chemicals used in agriculture such as pesticides, fungicides and insecticides. However, specific rules or legislation with mandatory air pollution control requirements for agricultural operations are not common.

6.1.1 State of California

The State of California is in the process of revising its programs to address air pollution from agricultural sources. Prior to 2003, California state law contained provisions which exempted agriculture from air regulations. Facilities engaged in growing crops or raising of fowl or animals were exempt from permitting requirements. However, open burning of agricultural wastes have been regulated for many years, with a requirement for growers to obtain a burn permit and to respect designated burn days.

California Senate Bill 700 was signed into law in September 2003. It requires air pollution control districts in serious PM_{10} non-attainment areas to develop regulations requiring best available control measures and best available retrofit control technology on sources of primary PM_{10} and precursors, including tilling, discing, cultivating, the raising of animals and fugitive dust sources. Sources of ozone precursor emissions are also addressed in the bill. In addition, air pollution control districts will require agricultural operating permits under Title V of the federal Clean Air Act.

Senate Bill 700 assigns the California Air Pollution Control Officers Association with the responsibility to develop a clearinghouse for available agricultural emission control measures, by 2005.

6.1.2 San Joaquin Valley Unified Air Pollution Control District

The San Joaquin Valley is one of the California districts in the spotlight, because agriculture is its most important industry. The San Joaquin Valley Air Basin in California is classified as a serious non-attainment area for PM_{10}. The U.S. Federal Clean Air Act requires such areas to implement Best Available Control Measures and Best Available Control Technology on all significant sources of emissions. Staff of the San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD) have identified agricultural sources as significant sources of PM_{10} emissions and a source for emission reductions. The most recent inventory for the area indicates that agriculture related sources produce more than half of all directly emitted PM_{10} emissions.

The SJVUAPCD is in the process of implementing a Conservation Management Practices (CMP) program, which includes practices that reduce the emissions of both direct PM_{10} and PM_{10} precursor emissions from agricultural sources. Two new rules have recently been adopted:

- Rule 4550 – Conservation Management Practices

- Rule 3190 – Conservation Management Practices Plan Fee

Rule 4550 is not prescriptive, in that it requires growers and producers to select at least one CMP most appropriate for their operation from each of a series of identified CMP categories. Working with a technical committee and stakeholders, a list of CMPs have been developed in the following broad categories:

- Practices that reduce or eliminate the need to disturb the soil or manure;
- Practices that protect the soil from wind erosion;
- Equipment modifications to physically produce less PM_{10};
- Applying water or dust suppressants to reduce emissions entrained by moving vehicles and equipment;
- Reducing speed or access on unpaved roads and parking areas;
- Alternative practices to waste burning; and
- Practices that reduce pesticide use or emissions from agricultural internal combustion engines.

A CMP handbook is being developed for affected sources, and it is expected that the District will conduct a major review of the list of CMPs every three years.

Rule 4550 applies to :

- Agricultural operations of 100 contiguous acres or more of cropland,
- Animal feeding operations (AFO) with 500 or more, mature dairy cows; 190 or more beef cattle or heifers; 82,000 or more laying hens;125,000 or more chickens (except layers); and 55,000 or more turkeys.

Rule 4550 would not apply to other types of AFOs such as swine, horse or sheep.

To recover costs related to the CMP program, Rule 3190 imposes a schedule of fees based on the cost of evaluating plans and monitoring and enforcing activities.

6.1.3 South Coast Air Quality Management District

The South Coast Air Quality Management District (SCAQMD) has developed Proposed Rule 1127, which is aimed at reducing ammonia, VOCs and PM_{10} from dairy operations.

The SCAQMD exceeds state and federal ambient air quality standards for PM_{10} and ozone. The District's Air Quality Management Plan includes a control measure for emissions from livestock waste. The control measure calls for a 50% reduction in ammonia and a 30% reduction in VOC emissions from 1997 AQMP base year (1993) levels by 2006. Measures for this sector must also address PM_{10}, with the passing of California Senate Bill 700 in September 2003. SB700 removes the exemption for agricultural sources from regulatory requirements and requires that districts designated as serious PM_{10} non-attainment areas must adopt best available control measures for agricultural stationary sources of air pollution by July 1, 2005, with implementation no later than July 1, 2006.

The proposed rule applies to agricultural operations or facilities that are directly related to raising cows and/or producing milk from cows. It is proposed that farms that have fewer than 50 cows would be exempt from the rule. PR1127 will also affect manure processing operations, such as composting facilities and anaerobic digesters. The rule would:

- Require Best Management Practices on dairies, including:
  - procedures when removing manure from a corral
  - paving of feedlanes
  - minimizing excess water in corrals

- more frequent manure removal

- Impose new manure disposal requirements
- Impose new manure processing approval requirements
- Establish requirements for alternative manure composting operations that allow manure composting in in-vessel systems

6.1.4 Maricopa County, Arizona

In 1996, the U.S. EPA designated Maricopa County in Arizona as a serious PM_{10} non-attainment area, resulting in the need for emission reduction programs for several previously unregulated sources, including agriculture. In 1998, the Governor's Agricultural Best Management Practices Committee was formed, and its task was to develop an agricultural PM_{10} general permit that would address the need for controls for agricultural sources. The committee sought to identify feasible, effective, common sense BMPs that minimized negative impacts on local agriculture.

The general permit applies to any agricultural operation greater than 10 contiguous acres within the Maricopa County area, with the exception of tribal lands. The general permit requires that at least one BMP be implemented to control PM_{10} for each of three categories – tillage and harvest, non-cropland, and cropland. A Guide to Agricultural PM_{10} Best Management Practices was published in 2001, to accompany the general permit. The guide provides background information on PM_{10}, documents 34 BMPs within the three categories, and sets out requirements for keeping records in respect of implementation of BMPs. There are no fees associated with the general permit.

6.2 NON-REGULATORY

6.2.1 Agriculture and Agri-Food Canada

Sustainable agriculture is at the centre of Agriculture and Agri-Food Canada's (AAFC) mandate. The Agricultural Policy Framework integrates environmental, economic and social considerations. To ensure that progress is being made in achieving the objectives of the framework, AAFC has developed a series of logic models which set targets and provide indicators to measure performance. Within the environmental logic model, some air quality related targets include:

- A reduction in the average level of residual nitrogen from agriculture
- A reduction in agricultural greenhouse gas emissions
- The completion of a basic environmental scan covering all farms so as to identify farms and/or agricultural regions posing significant risk to the environment
- The completion of an environmental farm plan or an equivalent agri-environmental plan for all farms where agricultural activity is found to pose significant risk to the environment as identified through the aforementioned process.
- Implementation of environmental farm plans on a minimum of 75% of aforementioned farms

6.2.2 National Climate Change Process

In response to the Kyoto Protocol, Canada's First Ministers created the National Climate Change

Secretariat who established 16 Issue Tables to examine options for reducing Canada's GHG emissions. In their Options Reports, the Issue Tables identified, analyzed and evaluated policy options for GHG reduction in their respective sectors.

Foundation papers for both the agriculture and agri-food sectors were finalized in April 1999, and an Options Report for the Agriculture and Agri-Food Table was completed in January 2000. The paper examines climate change issues and agriculture, reviews and evaluates existing GHG mitigation practices, and describes the reductions that can be accomplished under each option identified as well as the social, economic and other relevant implications.

The Table's suggested measures focus on improving scientific understanding of N_2O and CH_4 and communicating BMPs to the agricultural sector.

Through Canada's National Climate Change Process (NCCP), a National Implementation Strategy on Climate Change has been developed, and agreement has been reached on the First National Climate Change Business Plan, which contains over 300 federal/provincial and territorial government actions and measures to address climate change.

One of the actions undertaken by the Government of Canada to meet commitments under the Kyoto Protocol is the initiation of the Action Plan 2000 on climate change. Under this plan, Agriculture and Agri-Food Canada will address agricultural emissions of GHGs. Resources are allocated for the Greenhouse Gas Mitigation Program for Canadian Agriculture to address agricultural GHG reductions in the areas of soil, nutrient and livestock management. The GHG Mitigation Program will identify BMPs that address GHGs, which will be packaged into suites of BMPs to address on-farm GHG reduction and enhance carbon sequestration through improvements to soil, nutrient and livestock management practices.

6.2.3 B.C.

Environmental farm planning is underway in B.C., and agreements have been put in place with five farm organizations to deliver programs for agricultural producers under the Agricultural Policy Framework. The organizations are the B.C. Cattlemen's Association, the B.C. Fruit Growers' Association, the Certified Organic Association of B.C., the Comox Valley Farmers' Institute and the B.C. Greenhouse Growers' Association.

The B.C Ministry of Agriculture, Food and Fisheries has developed Environmental Guidelines for Producers, including:

- Beef Producers
- Berry Producers
- Dairy Producers
- Tree Fruit and Grape Producers
- Greenhouse Growers
- Horse Owners
- Mushroom Producers
- Nursery and Turf Industry

These are currently being revised and will be replaced by the B.C. Environmental Farm Plan Reference Guide. The guide will list and describe farm practices in B.C. and provide references to existing government legislation, industry guidelines and other sources of information. The reference material may provide suggestions for beneficial management practices to mitigate the impact of specific farm practices. However, it is not intended that these practices be implemented on an industry wide basis, nor are they intended to serve as formal standards.

6.2.4 Guidelines and Educational Materials

As the list of BMPs in Section 5 of this report was compiled, it was noted that there are numerous agencies or jurisdictions in Canada and the United States which publish guidelines or educational materials for agricultural sources. These materials sometimes support regulatory initiatives, but more often are used to provide technical assistance for agricultural facilities to select and voluntarily implement best management practices. These agencies and jurisdictions include:

- Agriculture and Agri-Food Canada
  - Agricultural Best Management Practices
  - The Health of Our Air: Toward Sustainable Agriculture in Canada
- Alberta Ministry of Agriculture, Food and Rural Development
- Ontario Ministry of Agriculture and Food – Best Management Practices Series
- Canada-Saskatchewan Agri-Food Innovation Fund – Agricultural Best Management Practices for the Canadian Prairies
- Prince Edward Island, Department of Agriculture, Fisheries, Aquaculture and Forestry: Best Management Practices
- Colorado State University Cooperative Extension – Best Management Practices for Colorado Agriculture
- Florida Department of Agriculture and Consumer Services – Best Management Practices
- Oregon Department of Agriculture – Best Management Practices
- University of Maryland, College of Agricultural & Natural Resources – Fact Sheets

A more detailed list of these resources, along with website links, is provided in Appendix C.

7. ECONOMIC ANALYSIS

The work initially proposed for this project did not entail a detailed cost-benefit analysis, due to the limited budget available. The workplan instead called for the use of a cost-benefit model previously developed by Levelton, which has been applied in other projects such as the B.C. Clean Transportation Analysis Project and a study for the GVRD on emission reduction options for the heavy-duty diesel vehicle fleet in the Lower Fraser Valley. It was originally proposed that this model be customized for the current study, to analyse the effects of emission reductions from candidate BMPs for the agriculture sector and the associated health benefits that may result from the implementation of these practices in the LFV. Key inputs to the model include baseline emissions, control cost, implementation schedule and control efficiency. Final outputs include cost effectiveness and net cost-benefit that are determined based on annualized costs and benefits of the control option over its life span.

Due to budget considerations, it was proposed that the cost benefit model would be run only for those BMPs where cost and efficiency data could be found or reasonably estimated. However, if cost and efficiency data proved to be lacking to allow for a reasonable cost benefit analysis, the proposal called for a qualitative ranking of the BMPs. BMP costs and emission reduction efficiencies have been estimated to the extent possible by the study team, with input from government agency personnel and published literature.

In general, there is a lack of adequate data for use in the cost-benefit model. The available data on cost-effectiveness of measures is described in the sections below. Each initiative described below also cites its economic analysis as preliminary, or comments on the lack of available data and the need for further research.

Due to the lack of detailed cost data, a more qualitative approach has been used to identify the most promising agricultural BMPs for the LFV area, as described in Section 8.

7.1 AGRICULTURE AND AGRI-FOOD CLIMATE CHANGE TABLE

The work to develop the Options Report for the Agriculture and Agri-Food Climate Change Table included an extensive and systematic search for emission reduction technologies, focusing on greenhouse gases. The Table found that “In most cases, little was known about the effect of alternative technologies or about the economic costs of the technologies. It became abundantly clear that more research was required to evaluate these technologies”.

The Options report includes an analysis of the GHG reduction potential of various strategies, using the Canadian Economic and Emissions Model for Agriculture (CEEMA). Economic impact analysis was developed, which focused on the costs to producers of adopting the various strategies, the impacts on regional economic activities and employment, and competitiveness implications for agricultural producers.

Data on expected changes to GHG emissions, changes in revenues for the agricultural sector and information on additional costs and adoption rates of the actions were used to develop estimates of the cost per tonne of GHG for each action. These cost-effectiveness values and estimated GHG reductions were then plotted on cost curves, at both the national and provincial level. These curves can be used to identify the lower cost opportunities for reducing GHG emissions from agriculture.

Additional information on the economic analysis conducted for the Climate Change Table, including the cost curves themselves, were requested from Agriculture and Agri-Food Canada. However, there was no response to the consulting team’s requests.

The Agriculture and Agri-Food Climate Change Table views the economic modeling effort as a work in progress, and has suggested a number of areas for improvement. Nevertheless, this analysis represents one of the few sources of measure-specific cost data available. Data on cost-effectiveness of individual measures, where available, is provided in Section 7 on preferred BMPs. Additional information on the cost analysis is provided in Appendix E.

7.2 GVRD

In 2001, the report "Harmonized Measures for Reducing Greenhouse Gases and Air Pollution in the LFV" (Sheltair et al, 2001) for the GVRD, FVRD, BC Ministry of Water Land and Air Protection and Environment Canada. This report identified emission reduction measures for priority sectors in the LFV, which would be amenable to a harmonized approach for the co-management of CACs and GHGs. Only two measures were identified for agricultural emissions:

- Expand Best Management Practice Guidelines to include GHG and CAC reduction practices
- Develop more sensitive emission estimation procedures to strengthen baseline and future emission estimates.

The first measure involves a review and adaptation of the series of Environmental Guidelines prepared by the BC Ministry of Agriculture, Food and Fisheries to provide guidance on minimizing emissions of GHGs, CACs and odour. This measure was estimated to result in reductions of 85 tonnes per year of particulate matter and 60 tonnes per year of VOC by 2010. Total GHG reductions would be reduced by 5 – 10%. The cost effectiveness of this measure (in $ per tonne of GHG removed) was estimated under three scenarios: low $2/tonne, best guess $6/tonne and high $85/tonne.

A cost-effectiveness ratio was not determined for the second measure, as it is intended to strengthen the information base but not directly reduce emissions.

7.3 National Research Council

Both the U.S. Environmental Protection Agency and U.S. Department of Agriculture have funded studies which led to the report "Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs", prepared by a committee appointed by the National Research Council.

The report was commissioned to:

- Review and evaluate the scientific basis for estimating the emissions to the atmosphere of various specified substances from confined livestock and poultry operations;
- Review the characteristics of the agricultural animal industries, methods for measuring and estimating air emissions, and potential best management practices for mitigating emissions;

The committee concluded that "available estimates of emission factors, rates, and concentrations are sufficiently uncertain and provide a poor basis for regulating or managing air emissions from animal feeding operations (AFOs). Nevertheless, some best management practices to mitigate the adverse effects of air emissions appear at face value to warrant their use, even as new information on mitigation and best management practices is being developed. While the committee favors a strong focus on research to develop needed new information, the use of clearly effective measures should be continued while new information is being developed."

One of the committee's findings is that "there is a general paucity of credible scientific information on the effects of mitigation technology on concentrations, rates, and fates of air emissions from AFOs. However, the implementation of technically and economically feasible management practices (e.g., manure incorporation into soil) designed to decrease emissions should not be delayed."

The report recommends that BMPs "aimed at mitigating AFO air emissions should continue to be improved and applied as new information is developed on their character, amount, and dispersion of these air emissions, and on their health and environmental effects. A systems analysis should include impacts of a BMP on other parts of the entire system."

7.4 San Joaquin Valley Unified Air Pollution Control District

As described in Section 6.1.2, the San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD) is in the process of implementing a Conservation Management Practices (CMP) program to reduce the emissions of both direct PM_{10} and PM_{10} precursor emissions from agricultural sources. The California Health and Safety Code requires analysis of emissions reductions and cost-effectiveness for new rulemaking activities.

The emissions reduction and the cost effectiveness for Rule 4550 are based on limited information available. A preliminary analysis was conducted for cropland, dairy, poultry, and feedlot source categories. For each CMP category, the calculations are based on the control efficiency of the measure, the percentage of sources that would be subject to the rule, a factor to estimate the extent of compliance with rules, and the probability of use of each of the CMPs. The estimated emissions reduction for Rule 4550 is 34.2 tons/day (31 tonnes per day) of PM_{10}.

Both a low and a high cost scenario were analyzed. The low cost scenario assumes that most operators would comply with the rule by implementing the lowest cost CMPs, while the high cost scenario assumes the use of CMPs that are more costly. Total sector costs (in U.S. dollars) were estimated to range from a savings of $104,000 per year (low scenario) to $30,856,000 per year (high scenario). Combining these annual costs with the estimated PM_{10} reductions results in an estimate of the overall cost-effectiveness of the package of CMPs from ($8)/ton (savings) to $2500/ton.

7.5 South Coast Air Quality Management District

As discussed in Section 6.1.3, the South Coast Air Quality Management District (SCAQMD) has developed Proposed Rule 1127, which is aimed at reducing ammonia, VOCs and PM_{10} from dairy operations.

Reductions from the impact of PR1127 are 1194 and 423 tons per year of ammonia and VOC respectively in 2010. The SCAQMD staff report estimates cost effectiveness for PR 1127 at $6,770 per ton of VOC reduced and $2,400 per ton of NH_3 reduced, and $1,770 per combined ton of NH_3 and VOC reduced.

7.6 California Air Resources Board

As a result of the passing of Senate Bill 700 (see Section 6.1.1), the California Health and Safety Code, Division 26 (Air Resources), Section 40731 discusses the development of a clearinghouse of control measures and strategies for agricultural sources of emissions. The sources include but are not limited to: operations that create fugitive dust emissions; confined animal facilities; internal combustion engines used in the production of crops or the raising of animals or fowl; and other equipment, operation or activities associated with the growing of crops or raising of fowl.

This clearinghouse is scheduled to be developed by January 1, 2005 and should provide a source of information about the emission reduction potential and economics of the various control measures and management practices.

8. PREFERRED BEST MANAGEMENT PRACTICES

Due to the limited availability of detailed data to prepare a cost-benefit analysis on agricultural BMPs, a more qualitative approach was used. The list of preferred BMPs for application in the LFV in this section was based on:

- A qualitative judgement of BMPs as being in the low, medium, high or negative (cost savings) range in terms of cost-effectiveness,
- A review of barriers to implementation as described in Section 5,
- Discussions with industry and government representatives, and
- Consistency with the direction being provided to agriculture environmental issues by the BC Environmental Farm Plan Program and the Agriculture Environment Funds.

Data on the costs or cost-effectiveness of BMPs is discussed where available.

The BC Environmental Farm Plan Program and the Agriculture Environment Funds are existing programs which support environmental initiatives by the agricultural industry in BC. Although these programs focus more on water, soil and wildlife issues, the initiatives and beneficial management practices which they support would often reduce air emissions as well.

The British Columbia Environmental Farm Plan Program is a partnership between Agriculture and Agri-food Canada (AAFC), the BC Ministry of Agriculture, Food and Fisheries (BCMAFF) and the BC Agriculture Council (BCAC) to promote and assist in the development and implementation of Environmental Farm Plans (EFPs). The program is being delivered by the BC Agriculture Council (BCAC) as a third party delivery agent.

Environmental farm planning involves the review of individual farm operations and selection of beneficial management practices which will improve the environmental performance of that operation.

Under the Canada – British Columbia EFP Program, funding is available for several categories of beneficial management practices, including:

- Nutrient management;
- Riparian management;
- Grazing management;
- Irrigation planning;
- Integrated pest management; and
- Shelterbelts.

The Agriculture Environment Funds include the Agriculture Environment Partnership Initiative and the Agriculture Environment Sustainability Initiative.

The Agriculture Environment Partnership Initiative is an Agri-Food Futures Fund program created by Agriculture and Agri-Food Canada and the BC Ministry of Agriculture, Food and Fisheries. The program is administered by the BC Agriculture Council for the BC Investment Agriculture Foundation.

The Agriculture Environment Sustainability Initiative is an Agriculture and Agri-Food Canada created fund to encourage sustainable production practices. It is facilitated through trust agreement with the BC Investment Agriculture Foundation and managed by the British Columbia Agriculture Council.

8.1 Reduced Tillage and Cover Cropping

The climate in the Lower Fraser Valley dictates that some tillage is required to help maintain soil structure; however, there are certainly opportunities to reduce the amount of tillage even within existing crop management programs (for example, eliminate even one pass from a cultivation sequence). Reduced tillage can reduce costs while improving soil quality.

The amount of cover cropping is increasing in the LFV. The increase is driven more by nutrient management and soil erosion issues than by emission concerns. Nevertheless, there appears to be an opportunity to increase the amount of cover cropping in the LFV.

Reduced tillage and the increased use of cover cropping in areas planted to annual crops can increase soil organic matter. An increase of 1% in total soil organic matter content, for example from 10% to 11%, may be a realistic goal for the Lower Fraser Valley (pers. comm. Geoff Hughes-Games, BCMAFF).

The area over which such an increase may be achieved was estimated to be:

Total area of field crops less area of alfalfa and alfalfa mixes less
area of tame hay and fodder less area of forage seed for seed
+
Total area of vegetables
+
Total area of nursery products
+
Total area of sod
+
Area of strawberries
+
Area of raspberries

The increase in soil organic carbon which a 1% increase in soil organic matter would represent is based on the following assumptions:

- Soil organic matter is increased in the top 20 cm of soil
- Average bulk density of surface soils is 1250 kg/m^3
- Soil organic matter = 1.72 x soil organic carbon (Brady and Weil, 1996)

Using these assumptions, a 1% increase in soil organic matter would represent an increase in soil organic carbon of 14,535 kg/ha.

The potential for increasing soil organic carbon in the Lower Fraser Valley is summarized in the table below.

	FVRD	GVRD	LFV
Cropped area 2001, excl. Christmas trees	31,799	22,965	54,764
Area of potential soil organic matter increase	12,387	10,231	22,618
% of total cropped area	39%	45%	41%
Potential increase in soil organic carbon (tonnes)	180,044	148,713	328,757

Data on the economics of reduced tillage and cover cropping is limited. There appears to be an opportunity for cost savings in terms of both reduced tillage costs and reduced nutrient costs, partially offset by the cost of planting cover crops. An overall assessment of "conservation tillage[1]" conducted by AAFC – Prairie Farm Rehabilitation Program (2002) ranks this measure as **high benefit, moderate cost**. Data from the National Climate Change Process Measures Database (Appendix E) shows a cost effectiveness ranging from $-27 (cost savings) to $189 per tonne of CO_2-equivalent emissions.

8.2 Relay Cropping

Relay cropping involves interplanting one crop with another. After harvesting the primary crop, the relay crop, which was established during the growth of the primary crop, continues to grow.

In the Lower Fraser Valley, relay cropping is increasingly being used in silage corn production, with Italian ryegrass planted between the rows of corn.

After the corn is harvested, the ryegrass continues to grow during the fall and can be harvested prior to planting corn the next season. Relay cropping is practiced primarily as a soil conservation measure, but also provides an actively growing crop in the fall to which manure can be applied, increasing manure spreading opportunities. Under LFV conditions, the ryegrass relay crop can utilize up to 75 kg/ha of nitrogen.

The benefits of relay cropping include:

- An established cover crop after the corn is harvested which reduces the potential for soil erosion (both water and wind erosion);
- Increased manure spreading opportunities and improved utilization of manure nutrients which can displace the need for commercial fertilizers;
- Uptake of residual nitrate not utilized by the corn crop plus the nitrogen from fall applied manure thereby reducing the amount of nitrate in the soil and the potential for the formation of N_2O (through denitrification); and
- A source of forage when harvested in the spring.

The 2001 Census of Agriculture reported 7,385 ha in silage corn in the LFV. The area planted to relay crops in 2002 was about 565 ha with approximately 670 ha planted in 2003, an increase of almost 19% (pers. comm. Sandy Traichel, Abbotsford Soil Conservation Association). These statistics suggest that there are over 6,700 ha planted to silage corn without a relay crop being planted. Some of this area is planted to a cover crop once corn is harvested. The area planted to cover crops after corn harvesting in any one year is highly dependent on the date of harvest and weather. Relay cropping provides a more reliable means of having a cover crop in the fall.

Barriers to adoption of this practice have been weed control and the availability of appropriate equipment to plant the relay crops. A suitable pesticide is now available to LFV growers which provides adequate weed control for the corn crop without damaging the relay crop. The availability of appropriate equipment remains a constraint, however it is expected that as demand for planting relay crops increases, custom operators will obtain the necessary equipment.

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[1] Conservation tillage is described in the report as "a range of tillage practices aimed at reducing soil erosion and improving soil quality. It includes no-till or zero-till, minimum tillage and reduced tillage.

In summary, if relay cropping were practiced on the total corn silage area in the LFV, an additional area of about 6,700 ha could be planted to a relay crop.

Planting relay crops could provide the uptake of up to 75 kg-N/ha (assume an average uptake of 50 kg-N/ha) which might otherwise be leached from the soil as nitrates, or lost to the atmosphere as nitrous oxide (N_2O) through denitrification. Nitrates which are leached from the soil may be subject to later denitrification in surface waters (and groundwater).

It is expected that the benefits of relay cropping noted above exceed the costs associated with planting the relay crop and that relay cropping provides a net benefit to producers. The largest barrier to adoption may be producer awareness. The practice is actively being promoted by organizations such as the Abbotsford Soil Conservation Association, Agriculture and Agri-Food Canada and the BC Ministry of Agriculture, Food and Fisheries.

Data on the economics of relay cropping is limited. An overall assessment of "crop rotations", including inter-cropping and strip cropping, conducted by AAFC – Prairie Farm Rehabilitation Program (2002) ranks this measure as **moderate benefit, low cost**. The benefit was assessed as moderate due in part to the severity of winters in the prairies, which do not allow winter cropping. The benefit is therefore likely to be higher in the Lower Fraser Valley.

8.3 Riparian Areas and Field Margins

Cropping patterns are a business decision driven by economic considerations. Improved management in buffer and riparian areas could increase carbon sequestration while addressing other environmental issues. Vegetated buffer zones describe an area of native or planted vegetation that is located down-slope from an agricultural operation. Vegetated buffers may also act as windbreaks or barriers for transport of airborne pollutants. Riparian areas are zones found next to water bodies and act as buffers between surface water and upland areas.

Data on the cost and benefit of riparian areas and field margins is limited. An overall assessment conducted by AAFC – Prairie Farm Rehabilitation Program (2002) ranks vegetated buffers as **high benefit, moderate cost**, and riparian area management as **moderate benefit, moderate cost.**

8.4 Changing Feed Rations

The livestock industries are not yet at the position where the concern about emissions from livestock provides any motivation for changing feed rations. Rations are based on a least cost approach which considers only input costs relative to productivity. Phytase is being marketed as a feed additive which can reduce input costs rather than a means of reducing air emissions.

8.4.1 Dairy Rations

Improved feeding strategies for dairy cattle may decrease nitrogen excretion by up to 34% (CAST, 2002).

A strategy being currently being implemented in the Lower Fraser Valley, which more accurately balances different types of protein of dairy rations while decreasing the total crude protein being fed, has the potential to decrease the amount of N excreted by dairy animals by 20 to 25%. This strategy may result in some loss in milk production, but improves herd health, increases the life spans of the dairy cows and improves reproduction. Overall, the improved feeding strategy can substantially reduce the amount of nitrogen excreted with no net loss to farm profitability (pers. comm. Mary-Lou Swift). In summary, this strategy has the potential to decrease the amount of nitrogen excreted by dairy animals by 20 to 25% with no net cost to producers. This strategy has been investigated only for dairy cattle in the Lower Fraser Valley. Other feed ration measures for poultry operations are described in Section 8.4.2.

Extending the practice to utilize all of the available feeding strategies may decrease the amount of nitrogen excreted by up to 35%; however, the additional reductions may come at some net cost to producers.

8.4.2 Poultry Rations

The report "Evaluation of Options for Fraser Valley Poultry Manure Utilization" (Timmenga & Associates Inc. 2003) prepared for the Broiler Hatching Egg Producers' Association, the BC Chicken Growers Association, the BC Turkey Association and the Fraser Valley Egg Producers' Association, states the following:

> "Introduction of amino acid and phytase[2] amended, or micronized feed could reduce the nitrogen and phosphorus content of manure by 20 – 30%, depending on the type of feed ingredients in the ration. Phytase containing feed can be made available in the Lower Mainland and has been integrated in the layer sector. Due to different feed content, different economics, and required expensive feed processing, phytase has not been integrated in the broiler and turkey sectors to a significant extent. Amino acid enriched feed could also be made available, but sufficient testing capacity for analysis of amino acids in feed ingredients, does not presently exist in the Lower Mainland to facilitate large-scale adoption of such feed."

Several feeding strategies which have the potential to reduce the amount of nitrogen excreted by poultry have been investigated, including:

- Increase digestibility of feed ingredients,
- Phase feeding (change diets with changing age of the birds),
- Feed male and female broilers separately,
- Decrease the margin of safety in various ration concentrations, and
- Feed for maximum economic benefit rather than to manage manure characteristics or for performance.

Studies in the US have shown that decreasing the total protein in poultry rations while supplementing the diet with amino acids to achieve an optimal balance of amino acids can reduce the amount of nitrogen excreted by up to 30 to 40%.

Such a feeding strategy may not be economical in current poultry operations. To implement this type of feeding strategy equipment for routine and fast analysis of feed ingredients for the concentration of various amino acids would be required.

In summary, a realistic target for decreasing the amount of nitrogen excreted in poultry manure in the Lower Fraser Valley through improved feeding strategies is 25%. An upper limit in the decrease in the amount of nitrogen excreted through implementation of various feeding strategies may be as high as 40%.

[2] Phytase is a natural enzyme used as an animal feed supplement.

8.4.3 Summary of Feed Ration Measures

Data on the economics of changing feed rations is limited. There are new strategies currently being developed and implemented in the Lower Fraser Valley, which appear to have significant nitrogen (and therefore N_2O and NH_3) reduction benefits. Implementation of these strategies can reduce feed input costs, but may have some incremental costs associated with analysis and monitoring of feed ingredients.

Data from the National Climate Change Process Measures Database (Appendix E) shows a cost effectiveness for combined feeding strategies ranging from $34 to $115 per tonne of CO_2-equivalent emissions.

8.5 MANURE APPLICATIONS

The use of more efficient manure application methods is increasing, but the level of adoption is still low. The barrier to increased adoption is cost and operational problems.

8.5.1 Land application of dairy manure to grass land

Of the dairy manure which is not "injected":

- 25% is spread under hot, dry conditions where the ammonia retention factor (the amount of ammonia which is not volatilized) is 0%, and
- 75% is spread under cool, wet conditions where the ammonia retention factor is 44% (i.e., 56% of the applied ammonia is lost via volatilization).

The average ammonia retention factor for this non-injected manure is then 0.33 (0.25 x 0 + 0.75 x 0.44). The ammonia retention factor for manure applied with N-conserving methods is 0.90. If manure which is applied with more traditional application methods were to be applied with N-conserving methods the reduction in ammonia volatilization would be 0.57 ((1.0 – 0.33) – (1.0-0.90)).

Of the total nitrogen applied, approximately 55% is ammonia and the remainder organic nitrogen. Therefore, the reduction in ammonia volatilization would be equivalent to 0.314 of the total N applied (0.57 x 0.55) compared to traditional application methods.

If it is assumed that 25% of dairy manure is applied to corn land and is incorporated via cultivation and 75% is applied to grass land, in total, approximately 90% of dairy manure is handled as a liquid (or slurry) and 10% as a solid. It can be further assumed that the 10% solid is applied to corn land. Therefore 0.833 (0.75/0.9) of the total liquid dairy manure is applied to grass land.

The 2001 Census of Agriculture reports that for 2.4% of land to which liquid manure was applied the application method was injection. It is not known if this includes areas where manure was applied with other N-conserving methods such as the sleighfoot or AerWay applicators. Therefore assume that 5% of the liquid dairy manure was applied with N-conserving methods. The total amount of liquid dairy manure applied to grassland with traditional application methods would then be 79.1% (83.3% x 95%).

Using N-conserving liquid manure application methods, ammonia volatilization can be reduced by an amount equivalent to 31.4% of the total amount of nitrogen contained in 79.1% of the total amount of liquid dairy manure. This is equivalent to 24.8% of the total N in liquid dairy manure at the time of application, or 22.4% (24.8% x 90%) of the total N in all dairy manure, both liquid and solid, at the time of application.

8.5.2 Land application to corn land

An estimated (assumed) 25% of all dairy manure is applied to corn land. An estimated 10% of all dairy manure is solid, with all of this solid manure applied to corn land. Therefore, 15% of the total dairy manure would be applied to corn land as a liquid.

Liquid manure applied to corn land can be incorporated via cultivation to reduce ammonia volatilization. The rate of volatilization will depend on weather and on the length of time before incorporation. Guidelines provided by the BCMAFF (Nutrient Management Planning Handbook, draft, 2003) provides ammonia retention factors ranging from an average of 0.75 if the manure is incorporated within 1 day to an average of 0.55 if incorporated during the 5^{th} day after application.

There is no data available on average times of incorporation. Assuming that the timing of incorporation of liquid dairy manure applied to corn land were to change from the equivalent of 4 days after application to 3 days after application, the ammonia retention factor would increase from 0.60 to 0.67; 7% less ammonia would be volatilized. With 55% of the total N in liquid manure in the ammonia form, this would represent a reduction in ammonia losses of 3.9% of the total nitrogen in the liquid manure applied to corn land.

With such a change in the timing of incorporation, the 3.9% reduction in the amount of ammonia volatilized would apply to the 15% of the total dairy manure applied to corn land. Therefore improved timing of incorporation after applying liquid dairy manure to corn land could result in ammonia volatilization losses equivalent to 0.6% of the total nitrogen in all dairy manure at the time of application.

If the liquid dairy manure which is applied to corn land were applied with N-conserving methods, the ammonia retention factor would be 0.90. If current practices are equivalent to incorporation 4 days after application, the ammonia retention factor is estimated to average 0.60. This would represent a 30% reduction in ammonia volatilization. Applying this to the 55% ammonia content and to the 15% of the total manure applied to corn land as liquid, the reduced volatilization losses would be equivalent to 2.5% of the total N in all dairy manure at the time of application.

8.5.3 Summary of Manure Application Measures

In summary the use of N-conserving application methods in the application of liquid dairy manure to grassland may reduce ammonia volatilization losses by an amount equivalent to 22.4% of the total N in all dairy manure at the time of application.

Improving the timing of incorporation of liquid dairy manure applied to corn land and/or utilization of N-conserving methods in applying liquid dairy manure to corn land might reduce ammonia volatilization losses by an amount equivalent to 1.5% of the total N in all dairy manure at the time of application.

8.6 MANURE STORAGE

Covered manure storage systems are likely to have the lowest overall cost, and the amount of manure in covered storage is increasing. The barrier to increased adoption is perceived cost and a perceived need for additional water in the manure for ease of handling as a liquid. The capital costs of covered storages are certainly higher and the long term savings associated with handling less volume are spread over a number of years. Table 8-3 summarizes the advantages and disadvantages of different manure storage systems. It can be seen that cost impacts range from low (e.g. physical improvements in stockpiles and lining and covering with plastic) to high investment for bunkers and permanent covered storage systems. Reduced methane emission is a benefit, but is not part of the cost analysis typically done by producers.

Table 8-1: Summary of Manure Storage Type

Type	Advantages	Disadvantages	Remarks
1) Improved Stockpile	a) no investment cost b) water pollution potential reduced c) manure can be stored at or near the point of use d) new locations can be used each year or for many stockpiles	a) more time required for stockpile construction than for current practice b) moderate nutrient loss might occur c) potential exists for surface and ground water pollution	a) well-formed piles remain dry when a crust is formed
2) Covered Stockpiles	a) new locations can be used each year or for many stockpiles b) no special construction or equipment required c) manure can be stored at or near the point of use d) water pollution potential reduced	a) cover may last only one season b) possible nutrient movement c) potential to remove topsoil from storage site during unloading d) plastic subject to damage from wind and debris	a) low investment b) 6-mil plastic must be used c) cover must be well anchored to stay on the pile
3) Stockpiles With Temporary Ground Liners	a) nutrient loss minimized b) manure can be stored at or near the point of use c) new locations can be used each year or for many stockpiles d) water pollution potential reduced	a) ground plastic might cause some difficulty b) ground plastic will last only one season c) careful site preparation required to prevent ground liner puncture d) cover may last only one season e) plastic subject to damage from wind and debris	a) low investment b) 6-mil plastic must be used during piling, unloading and spreading operations c) cover must be well anchored to stay on the pile
4) Stockpiles With Permanent Ground Liners	a) can be located near fields b) potential water pollution significantly reduced c) fertilizer value conserved d) piling can occur during periods when soil moisture might prevent access to field storage sites	a) a permanent site is required that might not be convenient to all of the use sites b) runoff from the storage site will require control to prevent soil erosion c) cover subject to damage from wind and debris	a) moderate investment b) a compact pile or plastic cover is needed

5) Bunker-Type Storage Structures	a) potential water pollution significantly reduced b) fertilizer value conserved c) more manure can be stored in a smaller area d) covers can be easily secured-possible damage can be minimized allowing longer life e) can be used for grain or fertilizer storage when not storing manure	a) requires a plastic or fabric cover b) requires a permanent site that might not be convenient to use sites c) requires runoff control around the site to prevent soil erosion	a) high investment
6) Storage Structures With Permanent Roofs	a) potential water pollution significantly reduced b) fertilizer value conserved c) can be used for storage of machinery, grain or fertilizer when not storing manure	a) requires runoff protection around the site to prevent soil erosion b) haven for birds providing possible disease from farm to farm c) requires a permanent site that might not be convenient to use sites d) reduced drive through capability for manure compaction which reduces structural capacity e) dry material may become airborne in winds unless sides are closed f) structural maintenance required	a) high investment b) if wood construction, fire potential from spontaneous combustion c) metal construction transmission from subject to rapid corrosion

Source: College of Agriculture and Natural Resources, University of Maryland, 1990

8.7 NUTRIENT MANAGEMENT

Improved nutrient management which maximizes the benefit of manure nutrients and reduces the need for fertilizer nutrients can represent a savings for the producer. The interest in the Lower Fraser Valley in improved nutrient management is increasing due in part to environmental concerns, but further improvements can certainly be made. This is a promising BMP in that implementation would generate large benefits while reducing production costs for producers. However, there is a need to educate producers to adopt more sophisticated nutrient management.

Nutrient management is centred on applying only the amount of plant nutrient that is required to make up the difference between what is available from soils and what is needed to produce a target yield. Determining the amount of nutrients to apply requires a good estimate of yield potential, and a selection of the type and amount of nutrient inputs, including manure. Nutrient placement and timing of application are also important factors.

Data on the economics of reduced tillage and cover cropping is limited. Farmers are likely to be receptive to nutrient management systems and plans because of the potential to save money. An overall assessment of nutrient management conducted by AAFC – Prairie Farm Rehabilitation Program (2002) ranks this measure as **high benefit, moderate cost,** and **low benefit moderate cost,** when used for high input and low input crops, respectively. Data from the National Climate Change Process Measures Database (Appendix E) shows a cost effectiveness ratios in the negative range ($-7 to $-26 per tonne of CO_2-equivalent emissions) representing an overall cost saving.

8.8 IMPROVED FUEL STORAGE

Improved fuel storage practices are a relatively low cost BMP which should be adopted by all producers. Fuel dispensing areas should be designed and managed to prevent or contain spills, and to minimize soil or water contamination. Fuel pumps should be situated on impermeable surfaces and pumps should be equipped with automatic shutoff mechanisms to prevent overfilling and spillage. Storage tanks themselves should be equipped with improved seals and emission control devices to minimize breathing and working losses.

8.9 DUST CONTROL

Poultry operations are a significant source of dust which has been investigated in the Lower Fraser Valley. Outdoor storage of used poultry litter should be designed to prevent contact with precipitation and to prevent windblown dispersion. Examples include full, covered enclosures, partially enclosed structures with walls situated in the prevailing wind direction, and covering of outdoor storage piles with secured tarps. Fugitive dust can be partially reduced with the use of windblocks, in the form of either physical barriers or vegetation barriers to wind.

A simple BMP which can be implemented with no cost is to limit activity during high wind events. The Arizona Department of Environmental Quality, for example, has a BMP which does not allow tillage or soil preparation activity when the measured wind speed (at a height of six feet above ground) exceeds 25 miles per hour (40 km/h). As suggestions for implementation, the BMP guide states that farmers should have access to a device to measure wind speed, and an individual farm policy which includes training with respect to the practice. Arizona's BMP guide also includes a measure to reduce farm vehicle or farm equipment speeds below 20 mph (32 km/h) on unpaved private farm roads, to minimize fugitive road dust emissions. This measure could be augmented with posted speed limit signs, speed limit signs within the vehicles themselves, or the use of speed bumps.

The potential for decreasing dust emissions from poultry operations, using a vegetated filter, is being investigated by the B.C. Sustainable Poultry Farming Group (SPFG). Dust emissions from a poultry operation have been monitored over a period of four growing cycles to characterize and estimate the quantity of dust emissions. Future work will include the strategic planting of trees to act as a vegetated filter and monitoring the effectiveness of this vegetated filter in reducing dust emissions.

Work in Delaware on the use of trees as vegetated filters indicates that reductions in dust emissions of 50% may be achievable (pers. comm. Kevin Chipperfield, SPFG).

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 UPDATE OF EMISSION INVENTORY FOR AGRICULTURAL SOURCES IN THE LOWER FRASER VALLEY

Recent emission inventories and forecasts prepared by the Greater Vancouver Regional District show that agricultural operations are important sources of emissions of air pollutants which contribute to the formation of regional smog. In particular, the contribution of agriculture to emissions of ammonia, particulate matter and greenhouse gases is significant.

One of the key objectives of this project was to update the emissions inventory for agricultural sources in the Lower Fraser Valley airshed. Using the 2000 Lower Fraser Valley emission inventory and forecasts (GVRD, 2003) as the basis, the main revisions made were as follows:

- Updating of the base quantities used for animal emissions. The 2000 LFV inventory generally used data from the 1996 Census of Agriculture, or extrapolated to 2000. For the current study, it was decided to use data from the 2001 Census of Agriculture as being more representative of the year 2000.
- Emissions from manure production and management have been reported in their own category, separate from the "livestock animals" category used in the 2000 LFV inventory. However, emissions are still calculated separately for each animal category. Recent methodologies developed by Environment Canada and U.S. EPA were reviewed. The Environment Canada methodology was applied for this study, with refinement of the data on manure management and landspreading techniques.
- Subsequent to the publishing of the 2000 LFV inventory report, a new version of the U.S. EPA NONROAD model was released in 2004. Revised emission results from this new model, supplied by the GVRD, were used to update the 2000 inventory and forecasts for agricultural non-road equipment.

Some recommendations about future agricultural emission inventory refinements, or developments which should be monitored are listed below.

- Emissions from fuel combustion in boilers used to heat greenhouses are not presently included in agricultural emission inventory totals, nor are they quantified. Based on a review of data pertaining to boilers registered under the B.C. Boiler and Pressure Vessel Safety program (Levelton, 2004), greenhouse boilers account for nearly 11% of the aggregate heating capacity of boilers in the Lower Mainland. This percentage could be used to approximate the percentage of emissions from the overall space heating category, if all boilers were utilized at the same fraction of capacity. Moreover, fuel use and operatng practices are not the same for all sectors. More detailed assessment of emissions from greenhouse boilers may be warranted, particularly in light of fuel switching issues, such as the conversion from natural gas to distillate oil or solid fuels such as wood waste, which have different emission impacts.
- The GVRD could be approached to consider separating out agricultural sources in future emission inventory compilations. While there is an agricultural sources category, the burning, space heating, non-road engine, miscellaneous area source and solvent evaporation categories also include certain agricultural source emissions.
- Emissions of greenhouse gases and ammonia from agricultural operations are increasingly being studied. For example, the National Agri-Environmental Health Analysis and Reporting Program (NAHARP), under Agriculture and Agri-Food Canada, includes the development of a set of agri-environmental indicators to determine how

environmental conditions within agriculture are changing over time, and how such changes can be explained. Work on developing more detailed emission inventories of NH_3 from agricultural sources, and associated indicators, is expected to start in the near future.

9.2 Best Management Practices for Agricultural Sources in the Lower Fraser Valley

A second objective of this project was to review existing best management practices in the Lower Fraser Valley and other jurisdictions, and develop a list of preferred BMPs for application in this airshed.

Research conducted for this study showed that many jurisdictions use BMP compilations and programs for the agricultural sector. Although many of these BMPs focus on water quality and soil, most also have associated benefits with respect to air emission reductions.

Initially, the intent of this study was to develop a list of preferred BMPs based on an assessment of costs and benefits associated with the measures. However, it was found that reliable data on the costs of implementing agricultural BMPs is lacking. Two primary reasons for the lack of economic information are:

- Agricultural best management practices have not been required as part of regulatory programs, and information on costs and benefits has not been needed to justify their implementation. However, in some jurisdictions such as California and Arizona, where agricultural sources have been identified as priority sources with respect to attainment of PM_{10} standards, new regulatory programs are being put in place. As a result, more information on economics of agricultural emission reductions and controls will become available.
- Many of the BMPs have low cost implications, or even represent a cost savings to the agricultural sector.

Because of the lack of detailed cost data, a more qualitative approach was used to select a list of the most promising BMPs for application in the Lower Fraser Valley. The parameters used in this assessment included: a qualitative ranking of BMPs as being of high, medium, low or negative cost; a review of barriers to implementation; discussion with industry and government representatives; and consistency with direction being provided to agriculture sources under federal and provincial environmental programs.

From the long list of BMPs reviewed, a short list of preferred BMPs was prepared, consisting of:

- Reduced tillage and cover cropping;
- Relay cropping;
- Management of riparian areas and field margins;
- Changing feed rations for both dairy and poultry operations;
- Improved application of manure to grass land and corn land;
- Improved manure storage systems and practices;
- Nutrient management programs and plans;
- Improved fuel storage; and
- Dust control.

Based on a review of government tools being used in other jurisdictions, a regulatory approach is not recommended for the adoption of agricultural BMPs in the Lower Fraser Valley. Command and control approaches have not historically been used for the agricultural sector, and there is even some question as to the regulatory authority of the BC MWLAP and GVRD to regulate air emissions from agricultural sources. The FVRD does not have delegated regulatory powers with respect to air pollution control.

For many of the BMPs listed above, cost is not the most significant barrier to implementation, but rather attitude and a need to overcome resistance to changing historical practices. The BMPs have low or negative cost implications, yet provide significant opportunity for emission reductions. This combination should allow the use of voluntary, education-based approaches.

Some of the elements which should be considered in implementing the BMPs are:

- Develop communication materials which explain the low costs and emission reduction benefits of implementing BMPs, and emphasize the potential cost savings through adoption of better management practices. Another benefit is improved public perception of agricultural operations.

- Because of the variability in the agricultural sector, guidance documents and training materials should be developed. These could build on BCMAFF Environmental Guidelines and Environmental Farm Plan reference guides. As described in Section 6, many jurisdictions as well as academic organizations, have technical assistance materials developed for agricultural BMPs, which could provide a useful resource for the development of similar materials in the Lower Fraser Valley.

- Utilize the interest in environmental stewardship and sustainable agriculture from the agricultural community. Engage the agricultural sector in the development of BMP programs and develop partnerships. Agricultural advisory committees are used in many U.S. jurisdictions, and are already in place in GVRD and FVRD.

- Capitalize on the extensive body of research underway and anticipated for this sector, both by agricultural organizations and government agencies.

Although regulatory programs are not recommended, there are lessons to be learned from some which have been put in place recently. The programs in California districts and Arizona are not overly prescriptive. Agricultural proponents are given some flexibility in choosing BMPs from an overall list, which is supplemented by technical guidance materials. The Arizona program appears to be less onerous from an administrative perspective, using a group permit for qualifying agricultural sources.

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APPENDIX A

Original GVRD Agricultural Emission Estimates for LFV for 2000

Table A-1: Original GVRD Agricultural Emission Estimates for LFV for 2000

GVRD	emissions (tonnes/year)										
	CO	NO_x	particulate matter			SO_x	VOC	NH_3	greenhouse gases		
			PM	PM_{10}	$PM_{2.5}$				CO_2	CH_4	N_2O
Agricultural											
Wind Erosion			128	64	14						
Fugitive Dust from Tilling			533	112	22						
Fertilizer Application			18	9	3			305	1,963		88
Pesticides Applied			34	17	5						
Cattle			63	40	6		585	421		2,550	5
Wildlife							3			18	
Pigs			7	5	1		1	36		24	0
Sheep			10	6	1		10	14		41	
Poultry			2	1	0		8	2,193		1,193	16
Horses			111	71	11		31	65		56	
Miscellaneous Animals								81		93	
Subtotal			**907**	**325**	**63**		**637**	**3,115**	**1,963**	**3,975**	**109**
Burning											
Agricultural	1,249	43	237	237	237		194			58	
Subtotal	**1,249**	**43**	**237**	**237**	**237**		**194**			**58**	
Non Road Engines											
Agricultural Equipment	772	1,565	74	74	68	53	179	5	109,129	5	16
Subtotal	**772**	**1,565**	**74**	**74**	**68**	**53**	**179**	**5**	**109,129**	**5**	**16**

FVRD	emissions (tonnes/year)										
	CO	NO_x	particulate matter			SO_x	VOC	NH_3	greenhouse gases		
			PM	PM_{10}	$PM_{2.5}$				CO_2	CH_4	N_2O
Agricultural											
Wind Erosion			836	418	93						
Fugitive Dust from Tilling			605	127	25						
Fertilizer Application			35	17	5			586	2,431		178
Pesticides Applied			30	15	4						
Cattle			69	44	7		1,513	1,318		8,848	10
Wildlife							2			12	
Pigs			162	104	16		25	1,004		669	3
Sheep			9	6	1		9	17		52	
Poultry			2	1	0		9	4,642		2,114	20
Horses			37	24	4		10	24		56	
Miscellaneous Animals								155		74	
Subtotal			**1,788**	**757**	**155**		**1,568**	**7,747**	**2,431**	**11,825**	**211**
Burning											
Agricultural	554	19	105	105	105		86			26	
Subtotal	**554**	**19**	**105**	**105**	**105**		**86**			**26**	
Non Road Engines											
Agricultural Equipment	603	1,723	80	80	74	59	186	5	119,622	4	18
Subtotal	**603**	**1,723**	**80**	**80**	**74**	**59**	**186**	**5**	**119,622**	**4**	**18**

LFV	emissions (tonnes/year)										
	CO	NO_x	particulate matter			SO_x	VOC	NH_3	greenhouse gases		
			PM	PM_{10}	$PM_{2.5}$				CO_2	CH_4	N_2O
Agricultural											
Wind Erosion			964	482	107						
Fugitive Dust from Tilling			1,138	239	48						
Fertilizer Application			54	26	8			891	4,394		266
Pesticides Applied			64	32	9						
Cattle			131	84	13		2,098	1,738		11,398	14
Wildlife							4			31	
Pigs			170	109	17		26	1,040		693	3
Sheep			19	12	2		18	31		93	
Poultry			4	3	0		17	6,835		3,307	37
Horses			149	95	15		41	89		112	
Miscellaneous Animals								237		166	
Subtotal			**2,694**	**1,082**	**219**		**2,205**	**10,862**	**4,394**	**15,800**	**320**
Burning											
Agricultural	1,803	62	342	342	342		280			84	
Subtotal	**1,803**	**62**	**342**	**342**	**342**		**280**			**84**	
Non Road Engines											
Agricultural Equipment	1,375	3,288	154	154	142	112	365	10	228,751	10	34
Subtotal	**1,375**	**3,288**	**154**	**154**	**142**	**112**	**365**	**10**	**228,751**	**10**	**34**

APPENDIX B

Detailed Listings of the Backcast and Forecast of Updated LFV Agricultural Emissions

Backcast and Forecast of Updated CO Emissions for the LFV

LFV Sources	CO emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	0	0	0	0	0	0	0
Pigs	0	0	0	0	0	0	0
Sheep	0	0	0	0	0	0	0
Poultry	0	0	0	0	0	0	0
Horses	0	0	0	0	0	0	0
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	1,857	1,830	1,803.4	1,803	1,803	1,803	1,803
Subtotal	**1,857**	**1,830**	**1,803**	**1,803**	**1,803**	**1,803**	**1,803**
Chemical & Nutrient Applications							
Fertilizers	0	0	0	0	0	0	0
Manure	0	0	0	0	0	0	0
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	1,822	1,936	1,922	1,731	1,526	1,280	1,080
Subtotal	**1,822**	**1,936**	**1,922**	**1,731**	**1,526**	**1,280**	**1,080**
LFV Total	**3,679**	**3,766**	**3,726**	**3,535**	**3,329**	**3,083**	**2,883**

Backcast and Forecast of Updated CO Emissions for the GVRD

GVRD Sources	CO emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	0	0	0	0	0	0	0
Pigs	0	0	0	0	0	0	0
Sheep	0	0	0	0	0	0	0
Poultry	0	0	0	0	0	0	0
Horses	0	0	0	0	0	0	0
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	1,287	1,268	1,249	1,249	1,249	1,249	1,249
Subtotal	**1,287**	**1,268**	**1,249**	**1,249**	**1,249**	**1,249**	**1,249**
Chemical & Nutrient Applications							
Synthetic Fertilizers	0	0	0	0	0	0	0
Organic Fertilizers	0	0	0	0	0	0	0
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	814	866	870	784	692	581	491
Subtotal	**814**	**866**	**870**	**784**	**692**	**581**	**491**
GVRD Total	**2,100**	**2,133**	**2,120**	**2,034**	**1,942**	**1,831**	**1,741**

Backcast and Forecast of Updated CO Emissions for the FVRD

FVRD Sources	CO emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	0	0	0	0	0	0	0
Pigs	0	0	0	0	0	0	0
Sheep	0	0	0	0	0	0	0
Poultry	0	0	0	0	0	0	0
Horses	0	0	0	0	0	0	0
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	570	562	554	554	554	554	554
Subtotal	**570**	**562**	**554**	**554**	**554**	**554**	**554**
Chemical & Nutrient Applications							
Fertilizers	0	0	0	0	0	0	0
Manure	0	0	0	0	0	0	0
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	1,008	1,071	1,052	947	834	699	588
Subtotal	**1,008**	**1,071**	**0**	**947**	**834**	**699**	**588**
FVRD Total	**1,579**	**1,633**	**1,606**	**1,501**	**1,388**	**1,253**	**1,142**

Backcast and Forecast of Updated NOx Emissions for the LFV

LFV Sources	NO_X emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	0	0	0	0	0	0	0
Pigs	0	0	0	0	0	0	0
Sheep	0	0	0	0	0	0	0
Poultry	0	0	0	0	0	0	0
Horses	0	0	0	0	0	0	0
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	64	63	62	62	62	62	62
Subtotal	**64**	**63**	**62**	**62**	**62**	**62**	**62**
Chemical & Nutrient Applications							
Fertilizers	0	0	0	0	0	0	0
Manure	0	0	0	0	0	0	0
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	1,637	1,799	1,737	1,628	1,490	1,237	943
Subtotal	**1,637**	**1,799**	**1,737**	**1,628**	**1,490**	**1,237**	**943**
LFV Total	**1,701**	**1,863**	**1,799**	**1,690**	**1,552**	**1,299**	**1,005**

Backcast and Forecast of Updated NOx Emissions for the GVRD

GVRD Sources	NO_X emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	0	0	0	0	0	0	0
Pigs	0	0	0	0	0	0	0
Sheep	0	0	0	0	0	0	0
Poultry	0	0	0	0	0	0	0
Horses	0	0	0	0	0	0	0
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	44	44	43	43	43	43	43
Subtotal	**44**	**44**	**43**	**43**	**43**	**43**	**43**
Chemical & Nutrient Applications							
Synthetic Fertilizers	0	0	0	0	0	0	0
Organic Fertilizers	0	0	0	0	0	0	0
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	741	814	787	738	675	561	428
Subtotal	**741**	**814**	**787**	**738**	**675**	**561**	**428**
GVRD Total	**785**	**858**	**830**	**781**	**718**	**604**	**471**

Backcast and Forecast of Updated NOx Emissions for the FVRD

FVRD Sources	NO_X emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	0	0	0	0	0	0	0
Pigs	0	0	0	0	0	0	0
Sheep	0	0	0	0	0	0	0
Poultry	0	0	0	0	0	0	0
Horses	0	0	0	0	0	0	0
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	20	19	19	19	19	19	19
Subtotal	**20**	**19**	**19**	**19**	**19**	**19**	**19**
Chemical & Nutrient Applications							
Fertilizers	0	0	0	0	0	0	0
Manure	0	0	0	0	0	0	0
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	897	985	950	890	814	676	515
Subtotal	**897**	**985**	**950**	**890**	**814**	**676**	**515**
FVRD Total	**916**	**1,005**	**969**	**909**	**834**	**695**	**534**

Backcast and Forecast of Updated PM Emissions for the LFV

LFV Sources	PM emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	131	128	120	132	132	132	132
Pigs	221	213	216	216	216	216	216
Sheep	21	22	23	24	26	27	28
Poultry	4	4	6	7	8	9	10
Horses	140	149	153	161	170	178	187
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**517**	**516**	**519**	**540**	**551**	**561**	**573**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	352	347	342	342	342	342	342
Subtotal	**352**	**347**	**342**	**342**	**342**	**342**	**342**
Chemical & Nutrient Applications							
Fertilizers	54	54	54	54	54	54	54
Manure	0	0	0	0	0	0	0
Pesticides	107	107	107	107	107	107	107
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**160**	**160**	**160**	**160**	**160**	**160**	**160**
Fugitive Dust							
Wind Erosion	911	911	911	911	911	911	911
Tilling	1,220	1,220	1,220	1,220	1,220	1,220	1,220
Subtotal	**2,131**	**2,131**	**2,131**	**2,131**	**2,131**	**2,131**	**2,131**
Non-road Engines							
Agricultural Equipment	375	349	247	194	153	106	65
Subtotal	**375**	**349**	**247**	**194**	**153**	**106**	**65**
LFV Total	**3,536**	**3,503**	**3,399**	**3,368**	**3,337**	**3,300**	**3,271**

Backcast and Forecast of Updated PM Emissions for the GVRD

GVRD Sources	PM emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	69	67	63	69	69	69	69
Pigs	8	7	7	7	7	7	7
Sheep	9	10	10	11	11	12	12
Poultry	1	1	2	2	3	3	3
Horses	101	108	111	117	123	129	136
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**188**	**193**	**194**	**206**	**213**	**220**	**228**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	244	240	237	237	237	237	237
Subtotal	**244**	**240**	**237**	**237**	**237**	**237**	**237**
Chemical & Nutrient Applications							
Synthetic Fertilizers	18	18	18	18	18	18	18
Organic Fertilizers	0	0	0	0	0	0	0
Pesticides	35	35	35	35	35	35	35
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**54**	**54**	**54**	**54**	**54**	**54**	**54**
Fugitive Dust							
Wind Erosion	256	256	256	256	256	256	256
Tilling	443	443	443	443	443	443	443
Subtotal	**700**	**700**	**700**	**700**	**700**	**700**	**700**
Non-road Engines							
Agricultural Equipment	170	158	112	88	69	48	29
Subtotal	**170**	**158**	**112**	**88**	**69**	**48**	**29**
GVRD Total	**1,355**	**1,345**	**1,296**	**1,285**	**1,273**	**1,258**	**1,247**

Backcast and Forecast of Updated PM Emissions for the FVRD

FVRD Sources	PM emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	63	61	57	63	63	63	63
Pigs	214	205	209	209	209	209	209
Sheep	12	13	13	14	14	15	16
Poultry	3	3	4	5	5	6	7
Horses	38	41	42	44	46	49	51
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**329**	**322**	**325**	**334**	**338**	**341**	**345**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	108	107	105	105	105	105	105
Subtotal	**108**	**107**	**105**	**105**	**105**	**105**	**105**
Chemical & Nutrient Applications							
Fertilizers	35	35	35	35	35	35	35
Manure	0	0	0	0	0	0	0
Pesticides	72	72	72	72	72	72	72
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**107**	**107**	**107**	**107**	**107**	**107**	**107**
Fugitive Dust							
Wind Erosion	654	654	654	654	654	654	654
Tilling	777	777	777	777	777	777	777
Subtotal	**1,431**	**1,431**	**1,431**	**1,431**	**1,431**	**1,431**	**1,431**
Non-road Engines							
Agricultural Equipment	206	191	135	106	84	58	35
Subtotal	**206**	**191**	**135**	**106**	**84**	**58**	**35**
FVRD Total	**2,181**	**2,159**	**2,103**	**2,084**	**2,064**	**2,042**	**2,024**

Backcast and Forecast of Updated PM_{10} Emissions for the LFV

LFV Sources	PM_{10} emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	84	82	77	84	84	84	84
Pigs	142	136	138	138	138	138	138
Sheep	14	14	15	16	16	17	18
Poultry	2	3	4	5	5	6	6
Horses	89	95	98	103	109	114	120
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**331**	**330**	**332**	**346**	**352**	**359**	**367**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	352	347	342	342	342	342	342
Subtotal	**352**	**347**	**342**	**342**	**342**	**342**	**342**
Chemical & Nutrient Applications							
Fertilizers	26	26	26	26	26	26	26
Manure	0	0	0	0	0	0	0
Pesticides	52	52	52	52	52	52	52
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**79**	**79**	**79**	**79**	**79**	**79**	**79**
Fugitive Dust							
Wind Erosion	455	455	455	455	455	455	455
Tilling	256	256	256	256	256	256	256
Subtotal	**712**	**712**	**712**	**712**	**712**	**712**	**712**
Non-road Engines							
Agricultural Equipment	375	349	247	194	153	106	65
Subtotal	**375**	**349**	**247**	**194**	**153**	**106**	**65**
LFV Total	**1,849**	**1,816**	**1,711**	**1,673**	**1,638**	**1,597**	**1,563**

Backcast and Forecast of Updated PM_{10} Emissions for the GVRD

GVRD Sources	PM_{10} emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	44	43	40	44	44	44	44
Pigs	5	5	5	5	5	5	5
Sheep	6	6	6	7	7	8	8
Poultry	1	1	1	1	2	2	2
Horses	65	69	71	75	79	83	87
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**120**	**124**	**124**	**132**	**136**	**141**	**146**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	244	240	237	237	237	237	237
Subtotal	**244**	**240**	**237**	**237**	**237**	**237**	**237**
Chemical & Nutrient Applications							
Synthetic Fertilizers	9	9	9	9	9	9	9
Organic Fertilizers	0	0	0	0	0	0	0
Pesticides	17	17	17	17	17	17	17
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**26**	**26**	**26**	**26**	**26**	**26**	**26**
Fugitive Dust							
Wind Erosion	128	128	128	128	128	128	128
Tilling	93	93	93	93	93	93	93
Subtotal	**221**	**221**	**221**	**221**	**221**	**221**	**221**
Non-road Engines							
Agricultural Equipment	170	158	112	88	69	48	29
Subtotal	**170**	**158**	**112**	**88**	**69**	**48**	**29**
GVRD Total	**782**	**769**	**720**	**705**	**690**	**673**	**660**

Backcast and Forecast of Updated PM_{10} Emissions for the FVRD

FVRD Sources	PM_{10} emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	40	39	37	40	40	40	40
Pigs	137	131	133	133	133	133	133
Sheep	8	8	8	9	9	10	10
Poultry	2	2	3	3	3	4	4
Horses	24	26	27	28	30	31	33
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**211**	**206**	**208**	**214**	**216**	**218**	**221**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	108	107	105	105	105	105	105
Subtotal	**108**	**107**	**105**	**105**	**105**	**105**	**105**
Chemical & Nutrient Applications							
Fertilizers	17	17	17	17	17	17	17
Manure	0	0	0	0	0	0	0
Pesticides	35	35	35	35	35	35	35
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**52**	**52**	**52**	**52**	**52**	**52**	**52**
Fugitive Dust							
Wind Erosion	327	327	327	327	327	327	327
Tilling	163	163	163	163	163	163	163
Subtotal	**490**	**490**	**490**	**490**	**490**	**490**	**490**
Non-road Engines							
Agricultural Equipment	206	191	135	106	84	58	35
Subtotal	**206**	**191**	**135**	**106**	**84**	**58**	**35**
FVRD Total	**1,067**	**1,047**	**991**	**968**	**948**	**924**	**904**

Backcast and Forecast of Updated $PM_{2.5}$ Emissions for the LFV

LFV Sources	$PM_{2.5}$ emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	13	13	12	13	13	13	13
Pigs	22	21	22	22	22	22	22
Sheep	2	2	2	2	3	3	3
Poultry	0	0	1	1	1	1	1
Horses	14	15	15	16	17	18	19
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**52**	**52**	**52**	**54**	**55**	**56**	**57**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	352	347	342	342	342	342	342
Subtotal	**352**	**347**	**342**	**342**	**342**	**342**	**342**
Chemical & Nutrient Applications							
Fertilizers	8	8	8	8	8	8	8
Manure	0	0	0	0	0	0	0
Pesticides	15	15	15	15	15	15	15
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**22**	**22**	**22**	**22**	**22**	**22**	**22**
Fugitive Dust							
Wind Erosion	101	101	101	101	101	101	101
Tilling	51	51	51	51	51	51	51
Subtotal	**152**	**152**	**152**	**152**	**152**	**152**	**152**
Non-road Engines							
Agricultural Equipment	364	338	239	189	148	102	63
Subtotal	**364**	**338**	**239**	**189**	**148**	**102**	**63**
LFV Total	**942**	**911**	**808**	**759**	**720**	**675**	**636**

Backcast and Forecast of Updated $PM_{2.5}$ Emissions for the GVRD

GVRD Sources	$PM_{2.5}$ emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	7	7	6	7	7	7	7
Pigs	1	1	1	1	1	1	1
Sheep	1	1	1	1	1	1	1
Poultry	0	0	0	0	0	0	0
Horses	10	11	11	12	12	13	14
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**19**	**19**	**19**	**21**	**21**	**22**	**23**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	244	240	237	237	237	237	237
Subtotal	**244**	**240**	**237**	**237**	**237**	**237**	**237**
Chemical & Nutrient Applications							
Synthetic Fertilizers	3	3	3	3	3	3	3
Organic Fertilizers	0	0	0	0	0	0	0
Pesticides	5	5	5	5	5	5	5
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**7**	**7**	**7**	**7**	**7**	**7**	**7**
Fugitive Dust							
Wind Erosion	28	28	28	28	28	28	28
Tilling	19	19	19	19	19	19	19
Subtotal	**47**	**47**	**47**	**47**	**47**	**47**	**47**
Non-road Engines							
Agricultural Equipment	164	153	109	89	77	74	77
Subtotal	**164**	**153**	**109**	**89**	**77**	**74**	**77**
GVRD Total	**482**	**467**	**419**	**401**	**390**	**388**	**391**

Backcast and Forecast of Updated $PM_{2.5}$ Emissions for the FVRD

FVRD Sources	$PM_{2.5}$ emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	6	6	6	6	6	6	6
Pigs	21	21	21	21	21	21	21
Sheep	1	1	1	1	1	2	2
Poultry	0	0	0	0	1	1	1
Horses	4	4	4	4	5	5	5
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**33**	**32**	**33**	**33**	**34**	**34**	**35**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	108	107	105	105	105	105	105
Subtotal	**108**	**107**	**105**	**105**	**105**	**105**	**105**
Chemical & Nutrient Applications							
Fertilizers	5	5	5	5	5	5	5
Manure	0	0	0	0	0	0	0
Pesticides	10	10	10	10	10	10	10
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**15**	**15**	**15**	**15**	**15**	**15**	**15**
Fugitive Dust							
Wind Erosion	73	73	73	73	73	73	73
Tilling	33	33	33	33	33	33	33
Subtotal	**105**	**105**	**105**	**105**	**105**	**105**	**105**
Non-road Engines							
Agricultural Equipment	199	186	131	103	81	56	34
Subtotal	**199**	**186**	**131**	**103**	**81**	**56**	**34**
FVRD Total	**460**	**444**	**388**	**362**	**340**	**315**	**294**

Backcast and Forecast of Updated SOx Emissions for the LFV

LFV Sources	SO_X emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	0	0	0	0	0	0	0
Pigs	0	0	0	0	0	0	0
Sheep	0	0	0	0	0	0	0
Poultry	0	0	0	0	0	0	0
Horses	0	0	0	0	0	0	0
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Chemical & Nutrient Applications							
Fertilizers	0	0	0	0	0	0	0
Manure	0	0	0	0	0	0	0
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	126	169	47	54	2	2	2
Subtotal	**126**	**169**	**47**	**54**	**2**	**2**	**2**
LFV Total	**126**	**169**	**47**	**54**	**2**	**2**	**2**

Backcast and Forecast of Updated SOx Emissions for the GVRD

GVRD Sources	SO_X emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	0	0	0	0	0	0	0
Pigs	0	0	0	0	0	0	0
Sheep	0	0	0	0	0	0	0
Poultry	0	0	0	0	0	0	0
Horses	0	0	0	0	0	0	0
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Chemical & Nutrient Applications							
Synthetic Fertilizers	0	0	0	0	0	0	0
Organic Fertilizers	0	0	0	0	0	0	0
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	57	77	22	24	1	1	1
Subtotal	**57**	**77**	**22**	**24**	**1**	**1**	**1**
GVRD Total	**57**	**77**	**22**	**24**	**1**	**1**	**1**

Backcast and Forecast of Updated SOx Emissions for the FVRD

FVRD Sources	SO_X emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	0	0	0	0	0	0	0
Pigs	0	0	0	0	0	0	0
Sheep	0	0	0	0	0	0	0
Poultry	0	0	0	0	0	0	0
Horses	0	0	0	0	0	0	0
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Chemical & Nutrient Applications							
Fertilizers	0	0	0	0	0	0	0
Manure	0	0	0	0	0	0	0
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	69	93	26	29	1	1	1
Subtotal	**69**	**93**	**26**	**29**	**1**	**1**	**1**
FVRD Total	**69**	**93**	**26**	**29**	**1**	**1**	**1**

Backcast and Forecast of Updated VOC Emissions for the LFV

LFV Sources	VOC emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	2,474	2,407	2,256	2,479	2,479	2,479	2,479
Pigs	34	33	33	33	33	33	33
Sheep	20	21	22	23	24	25	27
Poultry	15	16	25	28	31	35	38
Horses	38	41	42	44	47	49	51
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**2,582**	**2,518**	**2,378**	**2,608**	**2,615**	**2,622**	**2,629**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	288	284	280	280	280	280	280
Subtotal	**288**	**284**	**280**	**280**	**280**	**280**	**280**
Chemical & Nutrient Applications							
Fertilizers	0	0	0	0	0	0	0
Manure	0	0	0	0	0	0	0
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	386	376	306	229	168	123	93
Subtotal	**386**	**376**	**306**	**229**	**168**	**123**	**93**
LFV Total	**3,256**	**3,178**	**2,964**	**3,117**	**3,063**	**3,024**	**3,002**

Backcast and Forecast of Updated VOC Emissions for the GVRD

GVRD Sources	VOC emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	642	624	585	643	643	643	643
Pigs	1	1	1	1	1	1	1
Sheep	9	9	10	10	11	11	12
Poultry	5	5	8	9	10	11	12
Horses	28	30	31	32	34	36	37
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**684**	**670**	**634**	**695**	**699**	**702**	**705**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	200	197	194	194	194	194	194
Subtotal	**200**	**197**	**194**	**194**	**194**	**194**	**194**
Chemical & Nutrient Applications							
Synthetic Fertilizers	0	0	0	0	0	0	0
Organic Fertilizers	0	0	0	0	0	0	0
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	174	170	139	104	76	56	42
Subtotal	**174**	**170**	**139**	**104**	**76**	**56**	**42**
GVRD Total	**1,058**	**1,036**	**967**	**993**	**969**	**951**	**941**

Backcast and Forecast of Updated VOC Emissions for the FVRD

FVRD Sources	VOC emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	1,832	1,783	1,671	1,836	1,836	1,836	1,836
Pigs	33	32	32	32	32	32	32
Sheep	11	12	12	13	14	14	15
Poultry	10	11	17	19	21	24	26
Horses	10	11	12	12	13	13	14
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**1,897**	**1,849**	**1,744**	**1,913**	**1,916**	**1,920**	**1,923**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	89	87	86	86	86	86	86
Subtotal	**89**	**87**	**86**	**86**	**86**	**86**	**86**
Chemical & Nutrient Applications							
Fertilizers	0	0	0	0	0	0	0
Manure	0	0	0	0	0	0	0
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	212	206	168	125	92	67	51
Subtotal	**212**	**206**	**168**	**125**	**92**	**67**	**51**
FVRD Total	**2,198**	**2,142**	**1,997**	**2,124**	**2,094**	**2,073**	**2,060**

Backcast and Forecast of Updated NH_3 Emissions for the LFV

LFV Sources	NH_3 emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	0	0	0	0	0	0	0
Pigs	0	0	0	0	0	0	0
Sheep	0	0	0	0	0	0	0
Poultry	0	0	0	0	0	0	0
Horses	0	0	0	0	0	0	0
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Manure Management							
Livestock wastes	7,445	10,324	10,009	11,099	12,014	12,931	13,849
Subtotal	**7,445**	**10,324**	**10,009**	**11,099**	**12,014**	**12,931**	**13,849**
Burning							
Agricultural	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Chemical & Nutrient Applications							
Fertilizers	891	891	891	891	891	891	891
Manure	0	0	0	0	0	0	0
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**891**	**891**	**891**	**891**	**891**	**891**	**891**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	1	1	1	1	1	2	2
Subtotal	**1**	**1**	**1**	**1**	**1**	**2**	**2**
LFV Total	**8,337**	**11,216**	**10,901**	**11,991**	**12,907**	**13,824**	**14,741**

Backcast and Forecast of Updated NH_3 Emissions for the GVRD

GVRD Sources	NH_3 emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	0	0	0	0	0	0	0
Pigs	0	0	0	0	0	0	0
Sheep	0	0	0	0	0	0	0
Poultry	0	0	0	0	0	0	0
Horses	0	0	0	0	0	0	0
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Manure Management							
Livestock wastes	1,947	2,871	2,787	3,121	3,415	3,708	4,002
Subtotal	**1,947**	**2,871**	**2,787**	**3,121**	**3,415**	**3,708**	**4,002**
Burning							
Agricultural	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Chemical & Nutrient Applications							
Synthetic Fertilizers	305	305	305	305	305	305	305
Organic Fertilizers	0	0	0	0	0	0	0
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**305**	**305**	**305**	**305**	**305**	**305**	**305**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	0	0	1	1	1	1	1
Subtotal	**0**	**0**	**1**	**1**	**1**	**1**	**1**
GVRD Total	**2,253**	**3,176**	**3,092**	**3,427**	**3,720**	**4,014**	**4,308**

Backcast and Forecast of Updated NH_3 Emissions for the FVRD

FVRD Sources	NH_3 emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	0	0	0	0	0	0	0
Pigs	0	0	0	0	0	0	0
Sheep	0	0	0	0	0	0	0
Poultry	0	0	0	0	0	0	0
Horses	0	0	0	0	0	0	0
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Manure Management							
Livestock wastes	5,497	7,453	7,222	7,977	8,600	9,223	9,846
Subtotal	**5,497**	**7,453**	**7,222**	**7,977**	**8,600**	**9,223**	**9,846**
Burning							
Agricultural	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Chemical & Nutrient Applications							
Fertilizers	586	586	586	586	586	586	586
Manure	0	0	0	0	0	0	0
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**586**	**586**	**586**	**586**	**586**	**586**	**586**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	1	1	1	1	1	1	1
Subtotal	**1**	**1**	**1**	**1**	**1**	**1**	**1**
FVRD Total	**6,084**	**8,040**	**7,808**	**8,564**	**9,187**	**9,810**	**10,433**

Backcast and Forecast of Updated CO_2 Emissions for the LFV

LFV Sources	CO_2 emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	0	0	0	0	0	0	0
Pigs	0	0	0	0	0	0	0
Sheep	0	0	0	0	0	0	0
Poultry	0	0	0	0	0	0	0
Horses	0	0	0	0	0	0	0
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Chemical & Nutrient Applications							
Fertilizers	0	0	0	0	0	0	0
Manure	0	0	0	0	0	0	0
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	4,394	4,394	4,394	4,394	4,394	4,394	4,394
Subtotal	**4,394**	**4,394**	**4,394**	**4,394**	**4,394**	**4,394**	**4,394**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	95,814	115,167	135,044	152,545	169,777	187,138	204,409
Subtotal	**95,814**	**115,167**	**135,044**	**152,545**	**169,777**	**187,138**	**204,409**
LFV Total	**100,208**	**119,561**	**139,438**	**156,939**	**174,171**	**191,532**	**208,803**

Backcast and Forecast of Updated CO_2 Emissions for the GVRD

GVRD Sources	CO_2 emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	0	0	0	0	0	0	0
Pigs	0	0	0	0	0	0	0
Sheep	0	0	0	0	0	0	0
Poultry	0	0	0	0	0	0	0
Horses	0	0	0	0	0	0	0
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Chemical & Nutrient Applications							
Synthetic Fertilizers	0	0	0	0	0	0	0
Organic Fertilizers	0	0	0	0	0	0	0
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	1,963	1,963	1,963	1,963	1,963	1,963	1,963
Subtotal	**1,963**	**1,963**	**1,963**	**1,963**	**1,963**	**1,963**	**1,963**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	43,422	52,160	61,159	69,092	76,899	84,762	92,585
Subtotal	**43,422**	**52,160**	**61,159**	**69,092**	**76,899**	**84,762**	**92,585**
GVRD Total	**45,385**	**54,123**	**63,123**	**71,055**	**78,862**	**86,726**	**94,549**

Backcast and Forecast of Updated CO_2 Emissions for the FVRD

FVRD Sources	CO_2 emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	0	0	0	0	0	0	0
Pigs	0	0	0	0	0	0	0
Sheep	0	0	0	0	0	0	0
Poultry	0	0	0	0	0	0	0
Horses	0	0	0	0	0	0	0
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Manure Management							
Livestock wastes	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Burning							
Agricultural	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Chemical & Nutrient Applications							
Fertilizers	0	0	0	0	0	0	0
Manure	0	0	0	0	0	0	0
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	2,431	2,431	2,431	2,431	2,431	2,431	2,431
Subtotal	**2,431**	**2,431**	**2,431**	**2,431**	**2,431**	**2,431**	**2,431**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	52,392	63,007	73,884	83,453	92,878	102,375	111,823
Subtotal	**52,392**	**63,007**	**73,884**	**83,453**	**92,878**	**102,375**	**111,823**
FVRD Total	**54,823**	**65,438**	**76,315**	**85,884**	**95,309**	**104,806**	**114,254**

Backcast and Forecast of Updated CH_4 Emissions for the LFV

LFV Sources	CH_4 emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	9,897	9,628	9,024	9,917	9,917	9,917	9,917
Pigs	137	132	134	134	134	134	134
Sheep	80	85	88	92	97	102	107
Poultry	64	71	107	121	135	149	163
Horses	153	163	169	177	186	196	206
Miscellaneous Animals	84	89	92	97	102	107	113
Subtotal	**10,416**	**10,168**	**9,613**	**10,538**	**10,570**	**10,604**	**10,639**
Manure Management							
Livestock wastes	4,966	6,145	5,894	6,520	6,907	7,293	7,680
Subtotal	**4,966**	**6,145**	**5,894**	**6,520**	**6,907**	**7,293**	**7,680**
Burning							
Agricultural	86	85	84	84	84	84	84
Subtotal	**86**	**85**	**84**	**84**	**84**	**84**	**84**
Chemical & Nutrient Applications							
Fertilizers	0	0	0	0	0	0	0
Manure	0	0	0	0	0	0	0
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	18	17	14	6	4	3	3
Subtotal	**18**	**17**	**14**	**6**	**4**	**3**	**3**
LFV Total	**15,486**	**16,415**	**15,605**	**17,148**	**17,565**	**17,985**	**18,405**

Backcast and Forecast of Updated CH_4 Emissions for the GVRD

GVRD Sources	CH_4 emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	2,256	2,195	2,057	2,260	2,260	2,260	2,260
Pigs	5	4	5	5	5	5	5
Sheep	35	38	39	41	43	45	47
Poultry	17	18	28	31	35	39	42
Horses	111	119	122	129	135	142	149
Miscellaneous Animals	18	19	20	21	22	23	24
Subtotal	**2,442**	**2,393**	**2,270**	**2,487**	**2,500**	**2,514**	**2,528**
Manure Management							
Livestock wastes	1,269	1,733	1,670	1,868	2,016	2,165	2,313
Subtotal	**1,269**	**1,733**	**1,670**	**1,868**	**2,016**	**2,165**	**2,313**
Burning							
Agricultural	60	59	58	58	58	58	58
Subtotal	**60**	**59**	**58**	**58**	**58**	**58**	**58**
Chemical & Nutrient Applications							
Synthetic Fertilizers	0	0	0	0	0	0	0
Organic Fertilizers	0	0	0	0	0	0	0
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	7	7	6	3	2	1	1
Subtotal	**7**	**7**	**6**	**3**	**2**	**1**	**1**
GVRD Total	**3,779**	**4,192**	**4,004**	**4,416**	**4,576**	**4,738**	**4,901**

Backcast and Forecast of Updated CH_4 Emissions for the FVRD

FVRD Sources	CH_4 emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	7,641	7,434	6,967	7,656	7,656	7,656	7,656
Pigs	133	127	129	129	129	129	129
Sheep	45	47	49	51	54	57	60
Poultry	48	52	79	89	100	110	121
Horses	42	45	46	48	51	54	56
Miscellaneous Animals	66	70	73	76	80	84	89
Subtotal	**7,974**	**7,775**	**7,343**	**8,051**	**8,070**	**8,090**	**8,110**
Manure Management							
Livestock wastes	3,697	4,411	4,224	4,652	4,890	5,129	5,367
Subtotal	**3,697**	**4,411**	**4,224**	**4,652**	**4,890**	**5,129**	**5,367**
Burning							
Agricultural	27	26	26	26	26	26	26
Subtotal	**27**	**26**	**26**	**26**	**26**	**26**	**26**
Chemical & Nutrient Applications							
Fertilizers	0	0	0	0	0	0	0
Manure	0	0	0	0	0	0	0
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	10	10	8	3	2	2	1
Subtotal	**10**	**10**	**8**	**3**	**2**	**2**	**1**
FVRD Total	**11,708**	**12,223**	**11,601**	**12,732**	**12,989**	**13,246**	**13,505**

Backcast and Forecast of Updated N_2O Emissions for the LFV

LFV Sources	N_2O emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	0	0	0	0	0	0	0
Pigs	0	0	0	0	0	0	0
Sheep	0	0	0	0	0	0	0
Poultry	0	0	0	0	0	0	0
Horses	0	0	0	0	0	0	0
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Manure Management							
Livestock wastes	82	131	127	143	158	173	188
Subtotal	**82**	**131**	**127**	**143**	**158**	**173**	**188**
Burning							
Agricultural	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Chemical & Nutrient Applications							
Fertilizers	115	115	115	115	115	115	115
Manure	146	146	146	146	146	146	146
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**262**	**262**	**262**	**262**	**262**	**262**	**262**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	39	46	54	61	68	75	82
Subtotal	**39**	**46**	**54**	**61**	**68**	**75**	**82**
LFV Total	**383**	**439**	**443**	**466**	**488**	**510**	**532**

Backcast and Forecast of Updated N_2O Emissions for the GVRD

GVRD Sources	N_2O emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	0	0	0	0	0	0	0
Pigs	0	0	0	0	0	0	0
Sheep	0	0	0	0	0	0	0
Poultry	0	0	0	0	0	0	0
Horses	0	0	0	0	0	0	0
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Manure Management							
Livestock wastes	28	45	43	49	54	59	65
Subtotal	**28**	**45**	**43**	**49**	**54**	**59**	**65**
Burning							
Agricultural	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Chemical & Nutrient Applications							
Synthetic Fertilizers	40	40	40	40	40	40	40
Organic Fertilizers	47	47	47	47	47	47	47
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**87**	**87**	**87**	**87**	**87**	**87**	**87**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	14	21	25	28	31	34	37
Subtotal	**14**	**21**	**25**	**28**	**31**	**34**	**37**
GVRD Total	**129**	**153**	**155**	**164**	**172**	**180**	**189**

Backcast and Forecast of Updated N_2O Emissions for the FVRD

FVRD Sources	N_2O emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	0	0	0	0	0	0	0
Pigs	0	0	0	0	0	0	0
Sheep	0	0	0	0	0	0	0
Poultry	0	0	0	0	0	0	0
Horses	0	0	0	0	0	0	0
Miscellaneous Animals	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Manure Management							
Livestock wastes	54	86	84	94	104	114	124
Subtotal	**54**	**86**	**84**	**94**	**104**	**114**	**124**
Burning							
Agricultural	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Chemical & Nutrient Applications							
Fertilizers	76	76	76	76	76	76	76
Manure	99	99	99	99	99	99	99
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	0	0	0	0	0	0	0
Subtotal	**175**	**175**	**175**	**175**	**175**	**175**	**175**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	25	25	30	34	37	41	45
Subtotal	**25**	**25**	**30**	**34**	**37**	**41**	**45**
FVRD Total	**255**	**286**	**288**	**302**	**316**	**330**	**343**

Backcast and Forecast of Updated CO_2e Emissions for the LFV

LFV Sources	CO_2E emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	207,834	202,196	189,504	208,247	208,247	208,247	208,247
Pigs	2,882	2,767	2,810	2,810	2,810	2,810	2,810
Sheep	1,678	1,785	1,844	1,938	2,037	2,140	2,249
Poultry	1,350	1,481	2,245	2,539	2,833	3,128	3,422
Horses	3,221	3,427	3,540	3,721	3,912	4,110	4,319
Miscellaneous Animals	1,763	1,875	1,937	2,036	2,140	2,249	2,363
Subtotal	**218,728**	**213,530**	**201,879**	**221,290**	**221,980**	**222,684**	**223,410**
Manure Management							
Livestock wastes	129,739	169,562	163,196	181,233	194,030	206,829	219,630
Subtotal	**129,739**	**169,562**	**163,196**	**181,233**	**194,030**	**206,829**	**219,630**
Burning							
Agricultural	1,815	1,789	1,763	1,763	1,763	1,763	1,763
Subtotal	**1,815**	**1,789**	**1,763**	**1,763**	**1,763**	**1,763**	**1,763**
Chemical & Nutrient Applications							
Fertilizers	35,791	35,791	35,791	35,791	35,791	35,791	35,791
Manure	45,362	45,362	45,362	45,362	45,362	45,362	45,362
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	4,394	4,394	4,394	4,394	4,394	4,394	4,394
Subtotal	**85,547**	**85,547**	**85,547**	**85,547**	**85,547**	**85,547**	**85,547**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	108,414	129,942	152,220	171,731	191,059	210,559	229,968
Subtotal	**108,414**	**129,942**	**152,220**	**171,731**	**191,059**	**210,559**	**229,968**
LFV Total	**544,243**	**600,370**	**604,605**	**661,564**	**694,378**	**727,381**	**760,318**

Backcast and Forecast of Updated CO_2e Emissions for the GVRD

GVRD Sources	CO_2E emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	47,374	46,089	43,196	47,468	47,468	47,468	47,468
Pigs	97	94	95	95	95	95	95
Sheep	742	789	815	857	901	947	995
Poultry	352	386	585	661	738	814	891
Horses	2,341	2,490	2,572	2,703	2,842	2,986	3,138
Miscellaneous Animals	375	399	412	433	455	479	503
Subtotal	**51,281**	**50,246**	**47,675**	**52,218**	**52,500**	**52,789**	**53,090**
Manure Management							
Livestock wastes	35,251	50,221	48,503	54,383	59,121	63,861	68,603
Subtotal	**35,251**	**50,221**	**48,503**	**54,383**	**59,121**	**63,861**	**68,603**
Burning							
Agricultural	1,258	1,239	1,221	1,221	1,221	1,221	1,221
Subtotal	**1,258**	**1,239**	**1,221**	**1,221**	**1,221**	**1,221**	**1,221**
Chemical & Nutrient Applications							
Synthetic Fertilizers	12,249	12,249	12,249	12,249	12,249	12,249	12,249
Organic Fertilizers	14,722	14,722	14,722	14,722	14,722	14,722	14,722
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	1,963	1,963	1,963	1,963	1,963	1,963	1,963
Subtotal	**28,935**	**28,935**	**28,935**	**28,935**	**28,935**	**28,935**	**28,935**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	47,921	58,840	68,928	77,781	86,539	95,372	104,163
Subtotal	**47,921**	**58,840**	**68,928**	**77,781**	**86,539**	**95,372**	**104,163**
GVRD Total	**164,646**	**189,481**	**195,262**	**214,538**	**228,316**	**242,178**	**256,012**

Backcast and Forecast of Updated CO_2e Emissions for the FVRD

FVRD Sources	CO_2E emissions (tonnes/year)						
	1990	1995	2000	2005	2010	2015	2020
Livestock Animals							
Cattle	160,460	156,107	146,308	160,779	160,779	160,779	160,779
Pigs	2,784	2,674	2,715	2,715	2,715	2,715	2,715
Sheep	936	995	1,028	1,081	1,136	1,194	1,254
Poultry	998	1,095	1,660	1,878	2,096	2,313	2,531
Horses	881	937	968	1,017	1,070	1,124	1,181
Miscellaneous Animals	1,387	1,476	1,525	1,602	1,685	1,770	1,860
Subtotal	**167,447**	**163,284**	**154,204**	**169,072**	**169,480**	**169,895**	**170,320**
Manure Management							
Livestock wastes	94,489	119,341	114,693	126,851	134,909	142,968	151,027
Subtotal	**94,489**	**119,341**	**114,693**	**126,851**	**134,909**	**142,968**	**151,027**
Burning							
Agricultural	558	550	542	542	542	542	542
Subtotal	**558**	**550**	**542**	**542**	**542**	**542**	**542**
Chemical & Nutrient Applications							
Fertilizers	23,541	23,541	23,541	23,541	23,541	23,541	23,541
Manure	30,640	30,640	30,640	30,640	30,640	30,640	30,640
Pesticides	0	0	0	0	0	0	0
Limestone/Dolomite	2,431	2,431	2,431	2,431	2,431	2,431	2,431
Subtotal	**56,612**	**56,612**	**56,612**	**56,612**	**56,612**	**56,612**	**56,612**
Fugitive Dust							
Wind Erosion	0	0	0	0	0	0	0
Tilling	0	0	0	0	0	0	0
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-road Engines							
Agricultural Equipment	60,492	71,102	83,292	93,950	104,520	115,187	125,805
Subtotal	**60,492**	**71,102**	**83,292**	**93,950**	**104,520**	**115,187**	**125,805**
FVRD Total	**379,597**	**410,889**	**409,343**	**447,026**	**466,062**	**485,203**	**504,305**

APPENDIX C

Additional information on Agricultural Emission Factors and Emissions

Table C-1: Breakdown Of Updated Manure Management And Nonroad Engine Emissions For The LFV

	emissions (tonnes/year)											
	CO	NO_x	particulate matter			SO_x	VOC	NH_3	greenhouse gases			
			PM	PM_{10}	$PM_{2.5}$				CO_2	CH_4	N_2O	CO_2E
Manure Management												
Dairy Cattle	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,371.8	0.0	2,384.6	2.8	50,935.0
Non Dairy Cattle	0.0	0.0	0.0	0.0	0.0	0.0	0.0	399.1	0.0	36.3	4.2	2,070.5
Pigs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,037.2	0.0	495.0	5.1	11,970.2
Sheep	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.9	0.0	5.0	0.0	104.4
Poultry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6,844.3	0.0	2,934.4	115.1	97,309.0
Horses	0.0	0.0	0.0	0.0	0.0	0.0	0.0	88.6	0.0	37.0	0.0	776.0
Miscellaneous Animals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	236.7	0.0	1.5	0.0	31.2
Subtotal	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**10,008.6**	**0.0**	**5,893.8**	**127.2**	**163,196.3**
Non-road Engines												
2-Wheel Tractors	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agricultural Mowers	5.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	13.9	0.0	0.0	14.7
Agricultural Tractors	1,466.4	1,691.9	240.1	240.1	232.9	45.3	285.2	1.1	131,673.8	4.8	53.5	148,357.9
Balers	7.5	0.7	0.1	0.1	0.1	0.0	0.5	0.0	54.1	0.0	0.0	57.5
Combines	9.3	26.5	4.6	4.6	4.5	0.5	2.5	0.0	1,442.7	0.0	0.6	1,625.6
Hydro Power Units	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irrigation Sets	27.7	8.2	0.6	0.6	0.6	0.2	1.6	0.0	573.9	7.6	0.2	785.4
Sprayers	41.7	3.3	0.7	0.7	0.6	0.1	3.3	0.0	297.5	0.2	0.1	328.1
Swathers	11.6	4.5	0.7	0.7	0.7	0.1	0.9	0.0	279.2	0.1	0.1	309.8
Tillers > 6 HP	353.1	1.8	0.1	0.1	0.1	0.1	12.1	0.0	708.7	1.3	0.0	740.7
Other Agricultural Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**434.2**	**17.8**	**2.0**	**2.0**	**1.9**	**46.3**	**306.1**	**1.1**	**135,043.7**	**14.0**	**54.5**	**152,219.8**
LFV Total	**434.2**	**17.8**	**2.0**	**2.0**	**1.9**	**46.3**	**306.1**	**10,009.7**	**135,043.7**	**5,907.8**	**181.6**	**315,416.1**

Table C-2: Breakdown of updated manure management and nonroad engine emissions for the GVRD

	emissions (tonnes/year)								greenhouse gases			
	CO	NO_x	particulate matter			SO_x	VOC	NH_3	greenhouse gases			
			PM	PM_{10}	$PM_{2.5}$				CO_2	CH_4	N_2O	CO_2E
Manure Management												
Dairy Cattle	0.0	0.0	0.0	0.0	0.0	0.0	0.0	271.1	0.0	483.7	0.7	10,379.0
Non Dairy Cattle	0.0	0.0	0.0	0.0	0.0	0.0	0.0	148.6	0.0	19.0	2.5	1,174.9
Pigs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	34.8	0.0	17.1	0.2	413.5
Sheep	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.5	0.0	2.2	0.0	46.6
Poultry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2,173.3	0.0	1,120.7	39.9	35,918.5
Horses	0.0	0.0	0.0	0.0	0.0	0.0	0.0	64.4	0.0	26.8	0.0	563.8
Miscellaneous Animals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	81.2	0.0	0.3	0.0	6.6
Subtotal	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**2,786.9**	**0.0**	**1,670.0**	**43.3**	**48,502.8**
Non-road Engines												
2-Wheel Tractors	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agricultural Mowers	2.5	0.0	0.0	0.0	0.0	0.0	0.1	0.0	6.9	0.0	0.0	7.4
Agricultural Tractors	664.7	766.5	108.8	108.8	105.5	20.5	129.2	0.5	59,650.9	2.2	24.2	67,208.9
Balers	2.5	0.2	0.0	0.0	0.0	0.0	0.2	0.0	18.0	0.0	0.0	19.1
Combines	4.6	13.2	2.3	2.3	2.2	0.2	1.2	0.0	721.3	0.0	0.3	812.8
Hydro Power Units	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irrigation Sets	10.5	2.9	0.2	0.2	0.2	0.1	0.6	0.0	197.1	2.8	0.1	274.2
Sprayers	19.0	1.5	0.3	0.3	0.3	0.0	1.5	0.0	135.7	0.1	0.0	149.7
Swathers	4.4	1.7	0.3	0.3	0.3	0.0	0.3	0.0	104.7	0.0	0.0	116.2
Tillers > 6 HP	161.9	0.8	0.0	0.0	0.0	0.0	5.5	0.0	324.8	0.6	0.0	339.4
Other Agricultural Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**870.1**	**786.9**	**111.9**	**111.9**	**108.5**	**21.0**	**138.6**	**0.5**	**61,159.5**	**5.8**	**24.7**	**68,927.7**
GVRD Total	**870.1**	**786.9**	**111.9**	**111.9**	**108.5**	**21.0**	**138.6**	**2,787.4**	**61,159.5**	**1,675.8**	**68.0**	**117,430.5**

Table C-3: Breakdown Of Updated Manure Management And Nonroad Engine Emissions For The FVRD

	emissions (tonnes/year)											
	CO	NO_x	particulate matter			SO_x	VOC	NH_3	greenhouse gases			
			PM	PM_{10}	$PM_{2.5}$				CO_2	CH_4	N_2O	CO_2E
Manure Management												
Dairy Cattle	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,100.7	0.0	1,900.9	2.1	40,555.9
Non Dairy Cattle	0.0	0.0	0.0	0.0	0.0	0.0	0.0	250.5	0.0	17.3	1.7	895.7
Pigs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,002.4	0.0	477.9	4.9	11,556.8
Sheep	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.4	0.0	2.8	0.0	57.8
Poultry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4,671.0	0.0	1,813.7	75.2	61,390.5
Horses	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.2	0.0	10.1	0.0	212.2
Miscellaneous Animals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	155.4	0.0	1.2	0.0	24.5
Subtotal	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**7,221.6**	**0.0**	**4,223.8**	**83.9**	**114,693.4**
Non-road Engines												
2-Wheel Tractors	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agricultural Mowers	2.5	0.0	0.0	0.0	0.0	0.0	0.1	0.0	6.9	0.0	0.0	7.4
Agricultural Tractors	801.6	925.5	131.4	131.4	127.4	24.8	156.0	0.6	72,022.9	2.6	29.3	81,149.0
Balers	5.0	0.5	0.0	0.0	0.0	0.0	0.3	0.0	36.1	0.0	0.0	38.4
Combines	4.6	13.2	2.3	2.3	2.2	0.2	1.2	0.0	721.3	0.0	0.3	812.8
Hydro Power Units	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irrigation Sets	17.2	5.4	0.4	0.4	0.4	0.1	1.0	0.0	376.8	4.7	0.1	511.3
Sprayers	22.7	1.8	0.4	0.4	0.3	0.0	1.8	0.0	161.8	0.1	0.0	178.5
Swathers	7.2	2.8	0.4	0.4	0.4	0.1	0.6	0.0	174.5	0.0	0.1	193.6
Tillers > 6 HP	191.2	1.0	0.0	0.0	0.0	0.1	6.5	0.0	383.9	0.7	0.0	401.2
Other Agricultural Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	**1,052.2**	**950.2**	**134.9**	**134.9**	**130.9**	**25.3**	**167.5**	**0.6**	**73,884.2**	**8.3**	**29.8**	**83,292.1**
FVRD Total	**1,052.2**	**950.2**	**134.9**	**134.9**	**130.9**	**25.3**	**167.5**	**7,222.2**	**73,884.2**	**4,232.0**	**113.6**	**197,985.5**

Table C-4: Detailed List Of Updated Livestock Yearly Emission Factors By Animal Class For The LFV Agricultural Emissions Inventory

		Emission Factors						
Sources	**Units**	**VOC**	**PM**	**PM_{10}**	**$PM_{2.5}$**	**CH_4**	**N_2O**	**NH_3**
Cattle	Kg/head	18.34	15.07[b]	9.64[b]	1.51[b]	73.35/19.68[a]	0.06	14.40
Dairy Cattle	Kg/head	-	-	-	-	82.80/27.01[a]	0.03	17.38
Non Dairy Cattle	Kg/head	-	15.07	9.64	1.51	43.57/0.99[a]	0.14	9.06
Swine	Kg/head	0.23	1.51	0.96	0.15	0.93/3.46[a]	0.04	7.24
Sows	Kg/head	-	-	-	-	1.66/7.98[a]	0.06	-
Boars	Kg/head	-	-	-	-	1.30/10.79[a]	0.06	-
Other Swine	Kg/head	-	-	-	-	0.85/2.88[a]	0.03	-
Sheep	Kg/head	1.42	1.51	0.96	0.15	5.70/0.32 [a]	-	2.01
Ewes and Rams	Kg/head	-	-	-	-	7.82/0.54 [a]	-	2.01
Replacements	Kg/head	-	-	-	-	-	-	2.01
Other lambs	Kg/head	-	-	-	-	3.70/0.11 [a]	-	-
Poultry	Kg/1000head	1.57	0.40	0.26	0.04	6.30 /0.17[c a]	6.35	0.35 [c]
Laying hens and pullets	Kg/1000head	-	-	-	-	12.49 /0.01[c a]	4.34	0.36 [c]
Other Poultry	Kg/1000head	-	-	-	-	4.19 / 0.23[c a]	7.04	0.35 [c]
Turkeys	Kg/1000head	-	-	-	-	10.06 /0.27[c a]	19.86	1.10 [c]
Horses	Kg/head	4.14	15.07	9.64	1.51	16.55/3.63 [a]	-	8.70
Miscellaneous Animals	Kg/head	-	-	-	-	11.41/0.18 [a]	-	0.83

[a] values from enteric digestion/ values from manure;
[b] EF apply to beef cattle only;
[c] Value is in kg/head.

Table C-5: Summary Table Of All Updates Made To The 2000 GVRD LFV Agricultural Emissions Inventory

Sources	Base Quantities	Emission Factors							Comments
		VOC	PM	PM_{10}	$PM_{2.5}$	CH_4	N_2O	NH_3	
Livestock	Yes	No	No	No	No	No	Yes	Yes	• Updated BQ to 2001 • Revised manure management practices for each type of animal • Revised version of EC methodology for NH_3
Agricultural Burning	No	No	No	No	No	No	No	No	
Fertilizers	No	No	No	No	No	No	No	No	
Pesticides	Yes	No	No	No	No	No	No	No	• Updated BQ to 2001
Limestone/Dolomite	No	No	No	No	No	No	No	No	
Tilling	Yes	No	No	No	No	No	No	No	• Updated BQ to 2001
Wind Erosion	Yes	No	No	No	No	No	No	No	• Updated BQ to 2001
Nonroad Equipment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	• Revised results from GVRD using EPA NONROAD 2004 model

Table C-6: Summary Table Of The Growth Surrogates Applied To The Backcast And Forecast Of The Updated 2000 LFV Agricultural Emissions Inventory

Sources	Description	1990	1995	2000	2005	2010	2015	2020
Livestock	Cattle	1.0967	1.0670	1.0000	1.0989	1.0989	1.0989	1.0989
	Pigs	1.0256	0.9848	1.0000	1.0000	1.0000	1.0000	1.0000
	Sheep	0.9100	0.9680	1.0000	1.0510	1.1050	1.1610	1.2200
	Poultry	0.6012	0.6595	1.0000	1.1310	1.2620	1.3930	1.5240
	Horses	0.9100	0.9680	1.0000	1.0510	1.1050	1.1610	1.2200
	Misc. Animals	0.9100	0.9680	1.0000	1.0510	1.1050	1.1610	1.2200
Manure Management	Dairy Cattle	1.0967	1.0670	1.0000	1.0989	1.0989	1.0989	1.0989
	Non Dairy Cattle	1.0967	1.0670	1.0000	1.0989	1.0989	1.0989	1.0989
	Pigs	1.0256	1.0256	1.0000	1.0000	1.0000	1.0000	1.0000
	Sheep	0.9100	1.0256	1.0000	1.0510	1.1050	1.1610	1.2200
	Poultry	0.6012	1.0256	1.0000	1.1310	1.2620	1.3930	1.5240
	Horses	0.9100	1.0256	1.0000	1.0510	1.1050	1.1610	1.2200
	Misc. Animals	0.9100	0.9680	1.0000	1.0510	1.1050	1.1610	1.2200
Burning	Agricultural	1.0297	1.0147	1.0000	1.0000	1.0000	1.0000	1.0000
Chemical & Nutrient Applications	Fertilizer	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	Manure	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	Pesticide	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	Limestone/Dolomite	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Fugitive Dust	Wind Erosion	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	Tilling	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Table C-7: Number of animals in the LFV (Statistics Canada, 2001)

Sources	Sources	Units
Cattle	Dairy Cattle	78,946
	Non Dairy Cattle	44,072
Swine	Sows	15,381
	Boars	554
	Other Swine	127,344
Sheep	Ewes and Rams	7,471
	Other lambs	7,933
Poultry	Laying hens and pullets	4,233,313
	Other Poultry	13,127,029
Turkeys		772,899
Horses		10,184
Miscellaneous Animals		8,087

APPENDIX D

Sources of information on BMPs

Agriculture and Agri-Food Canada – Agricultural Best Management Practices

http://www.agr.gc.ca/pfra/water/agribtm_e.htm

B.C Ministry of Agriculture, Food and Fisheries

- Farm Practices in B.C. Reference Guide
- Environmental Guidelines for Producers
  - Beef Producers
  - Berry Producers
  - Dairy Producers
  - Tree Fruit and Grape Producers
  - Greenhouse Growers
  - Horse Owners
  - Mushroom Producers
  - Nursery and Turf Industry

http://www.agf.gov.bc.ca/resmgmt/fppa/environ/envguide.htm

Alberta Ministry of Agriculture, Food and Rural Development

- Environmental Stewardship
- Integrated Cropping
- Irrigation
- Soil Conservation
- Soil Fertility
- Soil Management
- Soil Maps & Data
- Water Quality
- Water Supply
- Agriculture's Legal Responsibilities Regarding Air Emissions
- Manure Composting Manual
- Meeting Odour Head On
- On-Farm Composting: A Review of the Literature
- Pesticide Drift Management
- Reducing the Risk of Bystander Pesticide Exposure
- Researching CFO Air Emissions and Human Health
- A Workbook on Greenhouse Gas Mitigation for Agricultural Managers
- Greenhouse Gas Emissions from Composting of Agricultural Wastes
- National Greenhouse Gas Mitigation Program For Canadian Agriculture Launched

http://www.agric.gov.ab.ca/app21/rtw/selcat.jsp

Ontario Ministry of Agriculture and Food – Best Management Practices Series • An Introduction to Best Management Practices • A First Look • Field Crops • Horticultural Crops • Irrigation Management • No-till: Making It Work • Pesticide Storage, Handling, and Application • Water Management • Water Wells • Integrated Pest Management • Nutrient Management • Soil Conservation • Environmental Farm Plans http://www.gov.on.ca/OMAFRA/english/environment/index.html
Arizona Department of Environmental Quality • Guide to Agricultural PM10 Best Management Practices, Maricopa County, Arizona PM10 Nonattainment Area http://www.azdeq.gov/environ/air/prevent/pcp.html#bmp
Colorado State University Cooperative Extension – Best Management Practices for Colorado Agriculture • Best Management Practices for Colorado Agriculture: An Overview • Best Management Practices for Nitrogen Fertilization • Best Management Practices for Irrigation Management • Best Management Practices for Phosphorous Fertilization • Best Management Practices for Crop Pests • Best Management Practices for Agricultural Pesticide Use • Best Management Practices for Pesticide and Fertilizer Storage and Handling http://www.ext.colostate.edu/pubs/crops/pubcrop.html
Florida Department of Agriculture and Consumer Services – BMP Manuals • Silviculture • Cow/Calf • Blended Fertilizer Plants • Aquaculture • Agrichemical Equipment • Vegetable & Agronomic Crops Draft http://www.floridaagwaterpolicy.com/publications.html

Oregon Department of Agriculture – Best Management Practices
• Irrigation Water Management
• Erosion Prevention and Sediment Control
  ➢ Buffers/Filter Strips
  ➢ Cover Crops
  ➢ Other
• Crop Nutrient Management
  ➢ Manure Management
  ➢ Fertilizer Management
• Pesticide Management
• Chemigation/Fertigation
• Grazing/Pasture Management
• Fertilizer and Farm Chemical Storage
• Dairy Wastewater Management
http://www.oda.state.or.us/nrd/water_quality/bmp.html

University of Maryland, College of Agricultural & Natural Resources – Fact Sheets – Crops, Livestock and Nursery Series http://www.agnr.umd.edu/MCE/Publications/Category.cfm?ID=C

APPENDIX E

ADDITIONAL INFORMATION ON BMP COSTS

Options Report for the Agriculture and Agri-Food Climate Change Table

Data on emission reductions is expressed relative to a Business As Usual (BAU) scenario. The tables show GHG emission reductions over the life of the project, and in the year 2010 (to illustrate the first commitment period under the Kyoto Protocol). The costs of abatement include capital and operating costs, which in some cases are negative, reflecting a cost savings. Both private and public sector costs are estimated. The costs are accumulated over the life of the project, and expressed in terms of present value, discounted at 0%, 5% and 10% (shown in the tables as PV0, PV5 and PV10). Finally, the cost effectiveness of the measure is shown in $ per tonne of GHG reduced. Dollar values are expressed in 1995 dollars.

Table E-1: Summary of Economic Data for [Management Practice] – Sample Format

Project Start: 2xxx Project End: 2xxx

	Private Sector			Public Sector				Unit Cost		
	($ thousands)			($ thousands)				($ per tonne)		
	Project Life NPV ($1,000) 20 years									
	Priv. 1	Priv. 2	Priv. 3	Fed.	Prov.	Mun.	TBA	Private	Govt.	Total
PV0	--	--	--	--	--	--	--	--	--	--
PV5	--	--	--	--	--	--	--	--	--	--
PV10	--	--	--	--	--	--	--	--	--	--

Change in GHG Emissions (TonnesCO_2eq)

Project Total xxxx

Change in Total GHG Emissions 2010 yyyy

Source: Canada's National Climate Change Process
National Measures Database
http://www.nccp.ca/NCCP/national_process/issues/index_e.html

Table E-2: Summary of Economic Data for Increased No-Till for B.C.

Project Start: 2000 Project End: 2020

	Private Sector ($ thousands)			Public Sector ($ thousands)				Unit Cost ($ per tonne)		
	Project Life NPV ($1,000) 20 years									
	Priv. 1	Priv. 2	Priv. 3	Fed.	Prov.	Mun.	TBA	Private	Govt.	Total
PV0	140	1,754	0	-987	0	0	0	394	-205	189
PV5	76	959	0	-854	0	0	0	215	-178	38
PV10	46	573	0	-748	0	0	0	129	-156	-27

Change in GHG Emissions (TonnesCO_2eq)

Project Total 4,809

Change in Total GHG Emissions 2010 295

Source: Canada's National Climate Change Process
National Measures Database
http://www.nccp.ca/NCCP/national_process/issues/index_e.html

Table E-3: Summary of Economic Data for Combined Feeding Strategies – B.C.

Project Start: 2000 Project End: 2020

	Private Sector ($ thousands)			Public Sector ($ thousands)				Unit Cost ($ per tonne)		
	Project Life NPV ($1,000) 20 years									
	Priv. 1	Priv. 2	Priv. 3	Fed.	Prov.	Mun.	TBA	Private	Govt.	Total
PV0	-400	-60,859	0	-205	0	0	0	115	0	115
PV5	-205	-31,217	0	-178	0	0	0	59	0	59
PV10	-116	-17,588	0	-156	0	0	0	33	0	34

Change in GHG Emissions (TonnesCO_2eq)

Project Total -532,609

Change in Total GHG Emissions 2010 -25,362

Source: Canada's National Climate Change Process
National Measures Database
http://www.nccp.ca/NCCP/national_process/issues/index_e.html

Table E-4: Summary of Economic Data for Improved Nutrient Management – B.C.

Project Start: 2000 Project End: 2020

	Private Sector ($ thousands)			Public Sector ($ thousands)				Unit Cost ($ per tonne)		
	Project Life NPV ($1,000) 20 years									
	Priv. 1	Priv. 2	Priv. 3	Fed.	Prov.	Mun.	TBA	Private	Govt.	Total
PV0	29,640	-18,743	0	-1,077	0	0	0	-29	3	-26
PV5	16,203	-10,247	0	-933	0	0	0	-16	2	-13
PV10	9,686	-6,125	0	-816	0	0	0	-10	2	-7

Change in GHG Emissions(TonnesCO_2eq)

Project Total -374,072

Change in Total GHG Emissions 2010 -22,949

Source: Canada's National Climate Change Process
National Measures Database
http://www.nccp.ca/NCCP/national_process/issues/index_e.html