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Particulate Matter Emissions Inventory for the Comox Valley 2015 Base Year

Final Report

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SUBMITTED TO

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EXECUTIVE SUMMARY

RWDI AIR Inc. (RWDI) was retained by the BC Ministry of Environment (BC MOE) to compile a Particulate Matter (PM) emissions inventory for the Comox Valley Regional District (CVRD). In this report, RWDI presents an inventory of particulate matter emissions including total particulate matter (TPM), particulate matter 10 microns and smaller in aerodynamic diameter (PM_{10}) and particulate matter 2.5 microns and smaller in aerodynamic diameter ($PM_{2.5}$) for a 2015 Base year. Emissions were quantified from point (industrial), area, and mobile sources as well as road dust. Specific focus was placed on wood combustion in various forms, including: residential woodstoves for space heating; residential yard waste; shrubs and trees from land-clearing; and, forest harvesting slash burning.

Total PM, PM_{10}, and $PM_{2.5}$ in the CVRD are estimated to be 875, 707, and 592 tonnes, respectively, excluding road dust. Emissions of TPM, PM_{10}, and $PM_{2.5}$ by source and source sector are shown in Table 1.

Fugitive road dust is estimated to contribute 92% of the total PM, 78% of the PM_{10}, and 46% of the $PM_{2.5}$ in the region. However, most fugitive road dust is in the coarse (>44 µm) size fraction (Pace, 2005) and thus settles out of the air in close proximity (e.g., meters to tens of meters) to the emission source (Desert Research Institute, 2000).

When excluding road dust sources from the emission summary, the key sources of TPM in the region are open burning (48%), and space heating (25%), followed by agricultural (10%) and mobile (9%) sources. Industrial sources make up less than 1% of the TPM in the region. Emissions of PM_{10} follow similar patterns to TPM in the CVRD. There are more significant differences in the contribution from different source types to $PM_{2.5}$ emissions. Dominant sources of $PM_{2.5}$ in the region are open burning (45%), space heating (35%), and mobile sources (12%).

Table 1: Particulate Matter Emissions for the CVRD

Emission Source			2015 Emissions (tonnes per year)		
			TPM	PM_{10}	$PM_{2.5}$
Point	Industrial Sources		1.6	0.6	0.2
	Point Subtotal		***1.6***	***0.6***	***0.2***
Area	Space Heating	Natural Gas - Residential	1.2	1.2	1.2
		Natural Gas - Commercial/Industrial	1.0	1.0	1.0
		Propane	0.2	0.2	0.2
		Wood	225.6	213.0	212.8
		Heating Oil	0.5	0.5	0.5
		Space Heating Subtotal	***228.5***	***215.9***	***215.7***
	Agricultural	Synthetic Fertilizer Application	0.2	0.1	0.03
		Tilling	35.5	35.5	7.5
		Harvesting	0.3	0.3	0.05
		Wind Erosion	51.1	25.6	3.8
		Livestock movements	4.1	1.2	0.2
		Crop Residue Burning	0.9	0.8	0.8
		Agricultural Subtotal	***92.1***	***63.6***	***12.4***
	Open Burning	Provincially Regulated – Pile	348.9	247.8	215.9
		Provincially Regulated – Area	57.5	42.4	36.7
		Municipally Regulated – Pile	6.2	4.8	4.1
		Recreational Fires	0.01	0.01	0.009
		Regional/Municipal - Backyard Burns	17.2	17.2	17.2
		Wildfire	3.5	2.6	2.4
		Open Burning Subtotal	***433.4***	***314.8***	***276.2***
	Miscellaneous	Meat Cooking	15.5	15.5	15.5
		Cigarettes	0.5	0.5	0.5
		Dry Cleaning	0.01	0.01	0.01
		Crematorium	0.01	0.01	0.01
		Structural Fires	0.3	0.3	0.3
		Miscellaneous Subtotal	***16.4***	***16.4***	***16.4***
	Area subtotal		***770.3***	***610.7***	***520.7***
Mobile	On-road	Light-duty	11.6	11.6	10.8
		Heavy-duty vehicles	10.4	10.4	10.0
	Non-road vehicles		34.1	33.7	32.6
	Marine Vessels		19.4	19.4	17.8
	Aircraft		3.3	3.3	3.0
	Mobile Subtotal		***78.7***	***78.3***	***74.1***
Fugitive Dust	Industrial Sources		3.7	1.1	0.1
	Construction Operations		23.3	23.3	4.7
	Landfills		22.8	12.6	8.4
	Fugitive Dust Subtotal		***49.8***	***36.9***	***13.1***
Total (no road dust)			***900.5***	***726.5***	***608.1***
Paved and unpaved roads			11,087.3	2,615.9	522.6
Total (with Road dust)			***11,987.8***	***3,342.4***	***1,130.7***

Notes: Totals may not equal the sum of components due to rounding.

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1 INTRODUCTION

The BC Ministry of Environment (BC MOE) retained RWDI AIR Inc. (RWDI) to provide an air emissions inventory of particulate matter (PM) in the Comox Valley Regional District (CVRD). This region encompasses the City of Courtenay, the Town of Comox, Village of Cumberland, CVRD Areas A, B and C, and all First Nations within these geographic areas. The PM inventory included all relevant emission sources in the region including point, area, and mobile sources as well as road dust for the Base Year 2015. Emissions were computed for total particulate matter (TPM), particulate matter 10 microns and smaller in aerodynamic diameter (PM_{10}) and particulate matter 2.5 microns and smaller in aerodynamic diameter ($PM_{2.5}$).

There is very little industry in the Comox Valley. The emissions inventory therefore focused on developing robust estimates from the area source category. Specific focus was placed on wood combustion in various forms, including: residential woodstoves for space heating; residential yard waste, shrubs and trees from land-clearing; and, forest harvesting slash burning.

2 PARTICULATE MATTER EMISSIONS ESTIMATION METHODS

Particulate matter emissions in the CVRD arise from industrial, mobile and area sources as well as road dust.

Industrial facilities in the CVRD include the following:

- Cement facilities;
- Concrete facilities; and
- Asphalt facilities.

Area sources include the following:

- Space heating;
- Open burning;
- Agricultural activities; and
- Miscellaneous sources.

Agricultural area sources include:

- Wind erosion and tilling of soils;
- Harvesting of crops;
- Agricultural open burning;
- Dust from livestock; and
- Synthetic fertilizer application.

Open burning sources include:

- Burning activities regulated and tracked (through permit or other means) by provincial and local authorities; and
- Wildfires that are not deliberately set.

Mobile sources of PM include:

- On-road vehicles;
- Off-road vehicles;
- Aircraft;
- Marine vessels; and,
- Rail sources.

Typically, emissions are expressed as a base quantity or 'activity' multiplied by an emission factor. The accuracy of the calculation thus hinges on both the accuracy of the base quantity data available and the latest scientific data to support the emission factors. A general emission equation is shown below.

$$Emissions = Base\ Quantity\ x\ Emission\ Factor$$

The specific emission equations, base quantities and emission factors used for each of the emission sources are listed in the sections below.

2.1 Industrial Sources

A search of BC MOE emission database revealed that three facilities had air discharge authorization for PM in the CVRD. Two of these facilities (Trueline Masonry and Landscape Products Ltd. and Hyland Precast Inc.) are cement and concrete manufacturing plants. one facility (Tayco Paving Co. Ltd) is an asphalt manufacturing plant.

Both Trueline Masonry and Landscape Products Ltd. and Hyland Precast Inc. only had allowable discharges for TPM. As no additional information was available for the $PM_{2.5}$ and PM_{10} fractions, only TPM is presented for these facilities. Tayco Paving reported air releases of PM to the 2014 National Pollutant Release Inventory (NPRI) from stack, storage and handling, fugitive, and road dust sources. For consistency with the rest of this report, the fugitive dust from roads from this facility are presented separately from the other industrial point source emissions. As the actual emissions for the other two facilities were not available, a conservative estimate was calculated using the maximum allowable discharges from their permits. The TPM emissions from industrial sources in the BC MOE authorization database and reported to the NPRI in 2014 are shown in Table 2.

Table 2: Particulate Matter Emissions from Industrial Sources in the Authorization Database and Reported to the NPRI in 2014 (tonnes per year)

Emission Source		2014 Emissions (tonnes per year)		
		TPM	PM_{10}	$PM_{2.5}$
Point	Tayco Paving Company	1.51	0.65	0.23
	Trueline Masonry and Landscape Products Ltd.	0.01	-	-
	Hyland Precast Inc.	0.07	-	-
	Point subtotal	***1.59***	***0.65***	***0.23***
Fugitive Dust	Industrial Sources Tayco Paving Company	3.74	1.06	0.11
	Fugitive Dust subtotal	***3.74***	***1.06***	***0.11***
Total		***5.33***	***1.71***	***0.34***

2.2 Area Sources

Area sources within the CVRD include space heating, agricultural sources, and open burning. Particular attention was given to developing estimates of emissions from residential woodstoves, residential and agricultural backyard burning, and land-clearing burning.

2.2.1 Space Heating

Particulate emissions from space heating result from the combustion of natural gas, propane, heating oil or wood for residential, commercial and industrial buildings. The Community Energy and Emissions Inventory of CEEI (Ministry of Environment, February 2014) estimates the energy use and greenhouse gas emissions from residential, commercial and industrial buildings by community. The CEEI directly obtains natural gas, propane (for some regions) and electricity data from the major utilities. Total consumption is estimated by region using the number of dwellings and average consumption by dwelling type. The consumption of heating oil, propane, and wood is estimated from the difference of the expected total energy consumption minus the actual reported by natural gas and electricity and piped propane utility providers. The latest CEEI report for 2010 was used for the space heating calculations. In addition, RWDI conducted a phone and email survey to collect sales volumes of propane, heating oil and wood used in residential and commercial/industrial space heating in the CVRD. Information on the data collection from fuel suppliers is discussed in the sections below.

2.2.1.1 Natural Gas Consumption

The CEEI obtains natural gas usage directly from utility providers. The values for residential and commercial consumption in the CVRD from the 2010 CEEI report were used. These values were then multiplied by the natural gas heating value (1,050 BTU/ft^3) from AP-42 Appendix A (US EPA, 1995) and the TPM emission factor from AP-42 Chapter 1, Section 4 on Natural Gas Combustion (US EPA, 1998). The amount of natural gas consumed and the relevant emission factors are listed in Table 3. All particulate matter from natural gas combustion is assumed to be less than 1.0 micron, consistent with the guidance from AP-42.

Table 3: Particulate Matter Emissions from Natural Gas Combustion (tonnes per year)

Building Type	Usage (GJ)	Emission Factor (kg/GJ)		
		TPM	PM_{10}	$PM_{2.5}$
Residential	379,654	0.0031		
Commercial	309,409			

2.2.1.2 Propane Consumption

RWDI attempted to contact five propane companies in the CVRD by phone and email. Two were distributors and three were suppliers. Of these, two did not respond and two declined to provide information. However, one provider who did not provide data (claiming confidentiality issues) confirmed that sales have remained constant over the last few years. They also confirmed that the 2010 CEEI consumption value for the CVRD was still a reasonable estimate for 2015.

The amount of propane from the 2010 CEEI report was multiplied by the propane heating value (94,000 BTU/gal) from AP-42 Appendix A (US EPA, 1995) and the TPM emission factor for commercial boilers from AP-42 Chapter 1, Section 5 on Liquefied Petroleum Gas Combustion (US EPA, 2008). Only a TPM emission factor was published; however, all the PM is assumed to be less than 1.0 µm. Emission factors from propane combustion are listed in Table 4.

Table 4: Particulate Matter Emissions from Propane Combustion (tonnes per year)

Boiler Type	Usage		Emission Factor ($kg/10^3$ L)		
	(GJ)	(L)	TPM	PM_{10}	$PM_{2.5}$
Commercial	71,153	2,717,742	0.084		

2.2.1.3 Heating Oil Consumption

RWDI attempted to contact two furnace oil providers in the CVRD. Emails were sent to both companies; however, neither responded. To calculate emissions from heating oil, the 2010 CEEI consumption value was multiplied by the distillate oil (No. 2 oil) heating value (140,000 BTU/gal) from AP-42 Appendix A (US EPA, 1995) and filterable PM emission factor for residential furnaces from AP-42 Chapter 1, Section 3 on Fuel Oil Combustion (US EPA, 1999). All PM was assumed to be less than 2.5 microns in diameter. Emission factors from heating oil combustion are listed in Table 5.

Table 5: Particulate Matter Emissions from Heating Oil Combustion (tonnes per year)

Firing Configuration	Usage		Emission Factor (kg/1000L)		
	(GJ)	(L)	TPM	PM_{10}	$PM_{2.5}$
Residential Furnace	412,618	10,581,884	0.048		

2.2.1.4 Residential Wood Burning

Prior research and monitoring efforts in the Comox Valley have suggested that residential wood burning is a considerable source of PM in the CVRD. As with all sources, the emission estimates are only as good as the quality of the base quantity data available. Unfortunately, unlike other fuel sources, consumption of wood is difficult to track accurately. Retail suppliers have no requirement to track or report volumes sold, and as there are a limited number of suppliers they are not inclined to share proprietary information publically. In addition, wood is freely available from many local and untraceable sources.

There are a few documents which can provide some information to help to quantify the amount of wood consumed in the CVRD as listed below.

- The 2010 Community Energy and Emissions Inventory (CEEI) (Ministry of Environment, February 2014)
- An Inventory of Wood-burning Appliance Use in British Columbia (Mustel Group Market Research, March 2012)
- Residential Wood-Burning Emissions in British Columbia (BC Ministry of Water, Land, and Air Protection (WLAP), May 2005)
- Wood Stove Inventory and Behaviour Analysis (Envirochem Services Inc., December 2012)

The first three reports all provide different methodologies and different values which can be used to calculate the wood consumed in the CVRD. A methodology to calculate the wood consumption using data from each of the first three reports is provided below along with a comparison of the results and presentation of the final approach used to calculate emissions. The fourth document is a summary of all residential burning surveys completed in BC to date (at the time of writing).

The 2010 CEEI (Ministry of Environment, February 2014) estimated the amount of heating oil, delivered propane and wood used for space heating in the CVRD by assuming average fuel consumption amounts by dwelling type and number of dwellings and subtracting the use of electricity, natural gas, and piped propane in the region. The CEEI estimated that 494,412 gigajoules of energy was obtained from wood in the CVRD.

The energy consumed in the CEEI was provided in gigajoules and was converted to tonnes of wood using Equation 1 and assuming a moisture content (MC) of 18% as per the Residential Wood Burning Report (WLAP, 2004)

Equation 1: Wood Consumption Conversion (from gigajoules to tonnes)

$$Wood\ Consumed\ (tonne) = Energy\ from\ Wood\ Consuption\ (GJ) \div \left(19.2 - \ (0.2164 \times MC)\right)$$

The quantity of wood consumed in 2010 using the CEEI as a raw data source is shown in Table 6 and Figure 1.

The BC MOE retained the Mustel Group to conduct a telephone survey of wood burning appliance use in BC in 2012 (Mustel Group Market Research, March 2012). The results from this survey included a detailed breakout of the number of survey respondents who use a wood burning appliance for a number of regions across BC. It was found that 20% of survey respondents in the Comox Valley use wood appliances, and 36% of the respondents in the entire "West Coast Region" (equivalent to Vancouver Island outside of other communities surveyed) use wood appliances. The report also collected information on the percentage splits of four major appliance types: wood stoves (63%); wood fireplaces (45%); wood burning central heat (3%); and, pellet stoves (5%). The Mustel Group also collected information on the amount of wood and pellets burned annually by household. BC statistics reports 29,231 households in the CVRD in 2015. The quantity of pellets and wood used in 2015 were estimated from the data in the Mustel Group report and are shown in Table 6 and Figure 1.

The British Columbia Ministry of Water, Land and Air Protection (WLAP) (BC Ministry of Water, Land, and Air Protection (WLAP), May 2005) completed a detailed emissions inventory for PM from wood burning equipment across the province in 2004. The WLAP report included a telephone survey of wood burning appliance use in British Columbia. The WLAP report used the survey results to quantify the amount of wood (and wood pellets) burned in each of 12 types of appliances for two regions on Vancouver Island: the Capital Regional District, and Other Vancouver Island. The total number of households in the Other Vancouver Island region at the time of the survey and the number of households in the CVRD in 2015 were used to estimate of the amount of wood and pellets burned in the CVRD (assuming 2004 behaviours). The quantity of pellets and wood used in 2015 estimated from the 2004 WLAP are shown in Table 6 and Figure 1.

In addition to the three methodologies for calculating wood consumption from the three documents described above, RWDI attempted to contact four firewood sales providers in the CVRD. Three providers could not be reached (unavailable due to full voicemail boxes, closed websites, etc.). One provider responded but declined to provide data due to confidentiality issues but confirmed that sales have increased approximately 20% since 2010 and confirmed the CEEI estimate of energy consumed from burning firewood (494,412 GJ) for residential heating in 2010.

Table 6: Comparison of Estimated Wood Consumed for Space Heating in the CVRD (tonnes)

Study Used to Estimate Wood Consumption	Wood Consumed in CVRD (tonnes)	
	Wood	Pellet
2010 CEEI	32,304	
Mustel 2012 - "West Coast" (36% wood appliance use)	25,788	3,604
Mustel 2012 - "Comox Valley" (20% wood appliance use)	14,413	2,014
WLAP 2004 (Provincial wood stove emissions inventory)	25,680	521

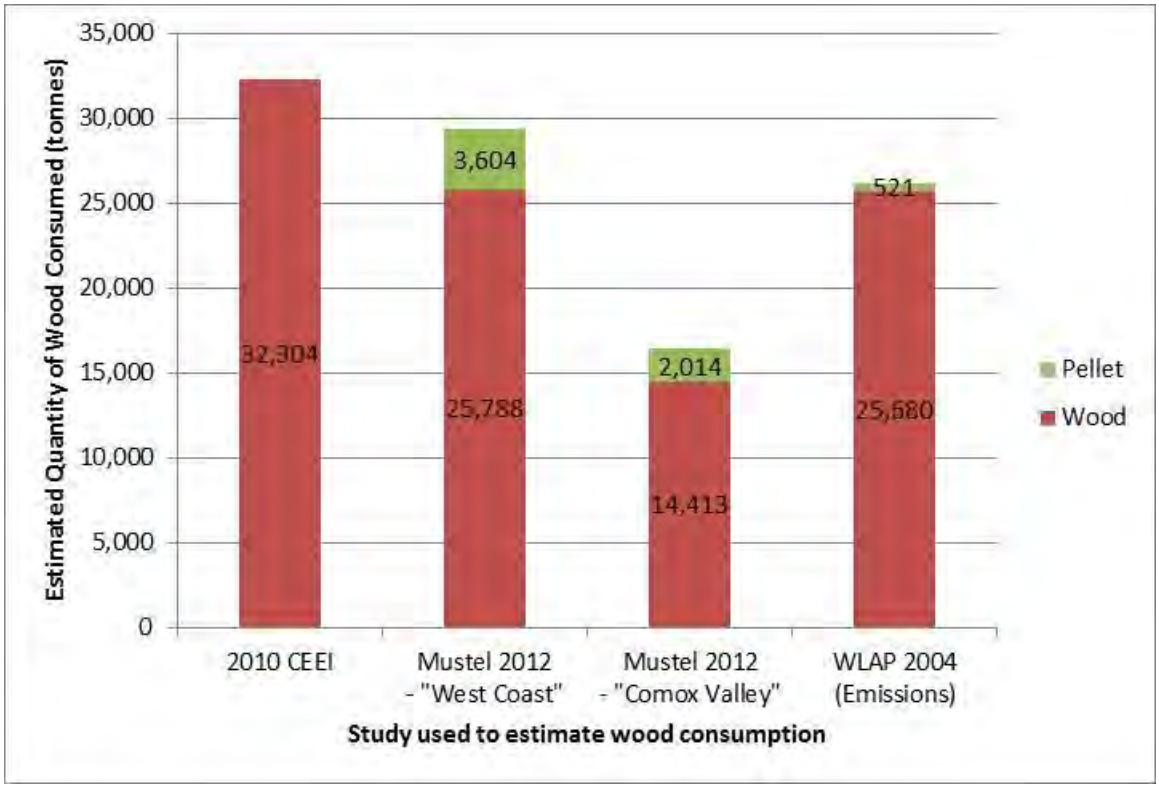

Figure 1: Estimated Quantity of Wood Consumed Using Different Studies

For this emissions inventory, it was assumed that 36% of households in the CVRD burned wood as per the Inventory of Wood-Burning Appliance use in the West Coast in 2012 (Mustel Group Market Research, March 2012). According to the Mustel Group report, 5% of wood-burning households burn pellets. Thus for simplicity, it was assumed that the remainder of households burning wood (95%) have cord wood burning appliances.

The methodology from the Residential Wood Burning Report (BC Ministry of Water, Land, and Air Protection (WLAP), May 2005) was used to estimate emissions from residential wood burning for space heating. The emission equation for PM from residential wood burning for space heating is shown in Equation 2.

Equation 2: Particulate Matter Emission Equation for Residential Wood Burning

$$PM = Wood\ Consumed\ (tonne) \times Percent\ of\ Applicance\ Type_{Other\ Vancouver\ Island}\ (\%) \times EF_{PM}(\frac{kgPM}{tonne\ wood})$$

Emissions from wood burning equipment are dependent on the type of appliance and technology used. As part of the detailed Residential Wood Burning Report (BC Ministry of Water, Land, and Air Protection (WLAP), May 2005), the amount of wood consumed by 11 types of technology was collected by survey across the Province.

The percentages of wood consumed by each appliance technology type for "Other Vancouver Island" (which excluded the Capital Regional District), excluding pellet stoves in 2004 is provided in Table 7. Results from the 2012 Mustel Survey (Mustel Group Market Research, March 2012) were used to allocate the total wood burned into each of the 11 technology types. The 2012 survey did not collect data for each of the 11 technology types, but rather provided the province-wide percentages of technology in larger groupings. The results of the 2004 and 2012 studies were used in combination to distribute the assumed cord wood consumption into 11 technology types, presented in Table 8.

The amount of wood burned per household was calculated from the average West Coast household use (2.2 cords/year/household), cord volume (2.27 m^3/cord) and wood species obtained from the Wood Stove Inventory and Behaviour Analysis Report (Envirochem Services Inc., December 2012). Densities for the BC wood species were obtained from the Residential Wood Burning Report (BC Ministry of Water, Land, and Air Protection (WLAP), May 2005) and used to calculate an average wood density. The amount of residential wood burned in the CVRD was determined by multiplying the amount of wood burned per household by the amount of wood burning households in the CVRD. Of those households assumed to burn wood, 95% were assumed to burn wood logs, and 5% were assumed to burn wood pellets. Finally, the amount of wood (25,788 tonnes wood logs) was multiplied by the percentage of each appliance type and appliance specific emission factors.

For pellet stoves, the same methodology was adopted. The amount of pellets burned per household was calculated from the average West Coast household use (78.3 bags/year/household) and bag weight (40 lbs/bag) obtained from the Wood Stove Inventory and Behaviour Analysis Report (Envirochem Services Inc., December 2012). To determine the amount of pellets burned in the CVRD, the average household amount was multiplied by the amount of wood burning households in the CVRD and assuming 5% of those households burned pellets. The amount of pellets (3604 tonnes) was then multiplied by the emission factors for pellet stoves.

Emission factors for each appliance type were obtained from the Residential Wood Burning (BC Ministry of Water, Land, and Air Protection (WLAP), May 2005) and shown in Table 9.

Table 7: Percentage of Wood Burning Appliance Types (%) from WLAP, 2004

Appliance Type	Fireplace; Advanced	Fireplace; Conventional Without glass doors	Central Furnace/Boiler (inside)	Central Furnace/Boiler	Central Furnace/Boiler (outside)	Fireplace Insert; Advanced Technology	Fireplace Insert; Catalytic	Fireplace Insert; Conventional	Woodstove; Advanced	Woodstove; Catalytic	Woodstove; Conventional	Pellet
% of Appliance Type	2%	14%	4%	0%	0%	2%	1%	9%	36%	5%	26%	-

Table 8: Percentage of Wood Burning Appliance Types (%) from Mustel, 2012 and WLAP, 2004

Appliance Type	Fireplace; Advanced	Fireplace; Conventional Without glass doors	Central Furnace/Boiler (inside)	Central Furnace/Boiler	Central Furnace/Boiler (outside)	Fireplace Insert; Advanced Technology	Fireplace Insert; Catalytic	Fireplace Insert; Conventional	Woodstove; Advanced	Woodstove; Catalytic	Woodstove; Conventional	Pellet
% of Appliance Type	7%	7%	2%	0%	1%	13%	1%	9%	51%	2%	7%	-

Table 9: Wood and Pellet Emission Factors (kg/tonne)

Appliance Type	Fireplace; Advanced	Fireplace; Conventional Without glass doors	Central Furnace/Boiler (inside)	Central Furnace/Boiler	Central Furnace/Boiler (outside)	Fireplace Insert; Advanced Technology	Fireplace Insert; Catalytic	Fireplace Insert; Conventional	Woodstove; Advanced	Woodstove; Catalytic	Woodstove; Conventional	Pellet
TPM Emission Factor	5.1	19.3	14.1	14.1	14.1	5.1	5.1	14.4	5.1	5.1	24.6	1.2
PM_{10} Emission Factor	4.8	18.5	13.3	13.3	13.3	4.8	4.8	13.6	4.8	4.8	23.2	1.1
$PM_{2.5}$ Emission Factor	4.8	18.4	13.3	13.3	13.3	4.8	4.8	13.6	4.8	4.8	23.2	1.1

2.2.2 Agricultural Sources

Particulate matter is produced from agricultural activities including the addition of synthetic fertilizers, tilling and harvesting of crops, wind erosion on fields, livestock husbandry, and the use of agricultural on- and non-road vehicles and equipment. Agricultural non-road vehicles and equipment is discussed further in section 2.3.2.

The Canadian Census of Agriculture provides the land in crops by crop type and the head of livestock (on a particular date) by Census Consolidated subdivision (CCS) every five years. The most current Census of Agriculture is from 2011, the 2016 Census data are not expected to be available until 2017 at the earliest. The base quantities used for the emissions from agricultural sources in this inventory were extracted from the 2011 Census of Agriculture for the CCSs for Comox Valley: Comox Valley A (5926021), Comox Valley B (Lazo North) (5926022), and Comox Valley C (Puntledge - Black Creek) (5926024). Census consolidated subdivisions (CCSs) within the CVRD are shown in Figure 2.

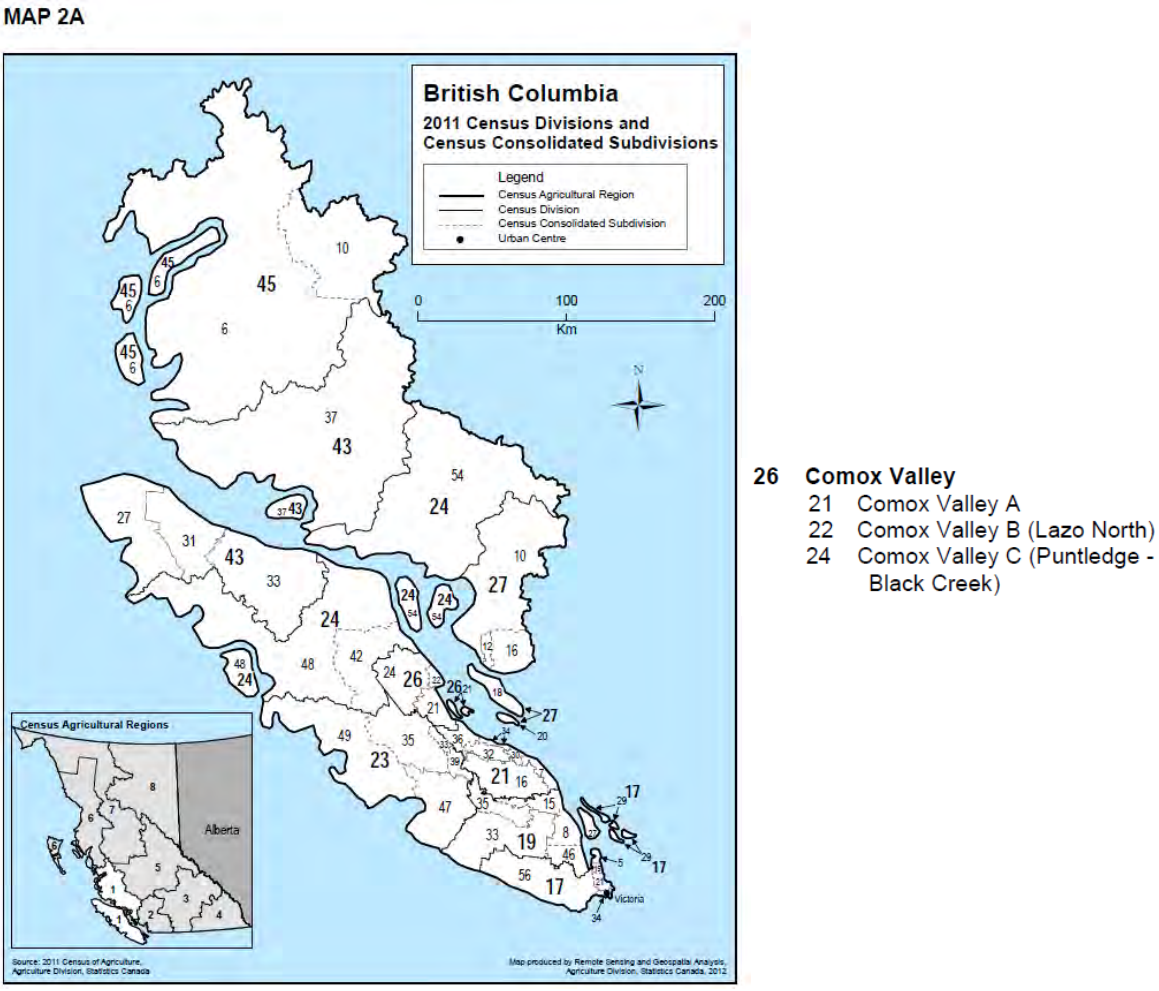

Figure 2: BC Census Division 1 (Vancouver Island-Coast) Showing Consolidated Subdivisions and the CVRD.

2.2.2.1 Synthetic Fertilizer Application

Particulate emissions were based on the method used by Environment Canada to calculate PM emissions from fertilizer application as part of the national emissions inventory. The emissions of PM are based on the quantity of fertilizer applied with global emission factors that account for the handling and storage as well as the spreading of fertilizers (Environment Canada, 2006). The general emission equation is shown in Equation 3. PM emission factors per tonne of fertilizer applied are shown in Table 10. The amount of fertilizer applied (summed per crop type) is equal to the area of land per crop multiplied by a fertilizer application density which varies by crop. The amount of fertilizer applied per crop uses the method developed by Sheppard *et al.* (Sheppard, Bittman, & Bruulsema, 2009) and is described further in Appendix 1. The area in each crop type by CCS is also shown in the Appendix.

Equation 3: Particulate Matter Emissions from Fertilizer Application

$$PM\ Emissions\ (kg) = Area\ of\ land\ per\ crop\ (hectare) \times Amount\ of\ Fertilizer\ applied\ per\ crop\ \left(\frac{kg}{ha}\right) \times PM\ Emission\ Factor\ \left(\frac{kg}{tonne}\right)$$

Table 10: Particulate Matter Emission Factors for Fertilizer Application

Pollutant	Emission Factor (kg/t Fertilizer)
TPM	2.23
PM_{10}	1.09
$PM_{2.5}$	0.31

2.2.2.2 Tilling

Particulate matter is released from the disturbance of soils during the tilling of fields and harvesting of crops. The EPA method for quantifying PM emissions from agricultural tilling activities was used with local improvements (Poon & Robbins, 2006). Tilling emissions are dependent on crop-specific and region-specific factors. Crop-specific factors including the area tilled and the number of tills per year (often expressed as the years between renovations). Region-specific factors include the moisture reduction factor (an expression of the local precipitation pattern) and the local silt content.

The general emission equation is shown in Equation 4. Emissions of TPM, PM_{10}, and $PM_{2.5}$ are calculated per crop type and per season. Emissions are based on the crop area (in hectares), the number of tillings (passes), and an emission factor calculated specifically for the region and season. The area per crop for each CCS is shown in Appendix 1.

Equation 4: Tilling Emission Equation

$$Emissions\ per\ crop\ per\ season\ _{(PM,PM_{10},PM_{2.5})} = Area\ per\ crop\ (ha) \times Number\ of\ tillings\ per\ crop\ and\ per\ season\ \times Emission\ Factor_{(PM,PM_{10},PM_{2.5})} \times Tillage\ Factor(unitless)$$

The number of tills per crop is based on the census agricultural region and the month. The number of tills (passes) for each region has been developed with expertise from Ministry of Agriculture staff as part of the BC Agricultural Air Emissions Inventory (RWDI, 2014). The detailed methodology for the number of tills per crop is shown in Appendix 1.

The tillage emission factor equation is shown in Equation 5. The base equation includes an empirically derived constant (5.38) multiplied by a moisture reduction factor, particle size multiplier, and the silt content. The particle size multiplier is used to estimate the fraction of TPM that is PM_{10} or $PM_{2.5}$. The particle size multiplier is typically assumed to be 0.21 for PM_{10} and 0.042 for $PM_{2.5}$.

Equation 5: Tilling Emission Factor Equation

$$Emission\ Factor_{(PM,PM_{10},PM_{2.5})} = 5.38\ \times Moisture\ reduction\ factor\ per\ season\ \times Particle\ size\ multiplier\ _{(PM,PM_{10},PM_{2.5})} \times Silt\ content\ per\ region\ (\%)^{0.6}$$

The moisture reduction factor reflects the precipitation accumulation which decreases the likelihood of particles becoming airborne. Moisture reduction factors were generated by month for each of the eight agricultural regions (based on the Census of Agriculture regions) for the detailed agricultural emissions inventory for the Ministry of Agriculture (MoA). The moisture reduction factors for Vancouver Island – Coast was used for the CVRD and are shown in Table 11.

Table 11: Moisture Reduction Factors for Tilling Emission Factor Equation

Month	Moisture Reduction Factor (unitless)
January	0.00
February	0.00
March	0.00
April	0.20
May	0.50
June	0.50
July	0.75
August	0.50
September	0.50
October	0.00
November	0.00
December	0.00

The silt content is a percentage based on typical soil type. The silt content values for each CCS were developed using data from the Soil Landscapes of Canada version 3.2, developed by Agriculture and Agri-Food Canada and shown in Table 12.

Table 12: Silt Content by CCS

CCS	Silt Content (%)
Comox Valley A	35.0
Comox Valley B Lazo North	43.6
Comox Valley C Puntledge - Black Creek	48.4

2.2.2.3 Harvesting

Particulate emissions from crop production arise from soil cultivation and harvesting. Emissions depend on crop, soil type, cultivation method, and weather conditions before and while working. Environment Canada's national air emissions inventory includes emission quantities and methods for agricultural tilling and wind erosion, but does not specifically include particulate emissions from harvesting.

The emission method from the BC Agricultural Air Emissions Inventory (RWDI, 2014) was used for this inventory. The general emission equation is shown in Equation 6. It is assumed that each crop is harvested only once annually. The PM_{10} emission factors are shown in Table 13. The California Air Resources Board $PM_{2.5}$ to PM_{10} ratio of 0.15 for agricultural harvesting (Countess Environmental, 2006) was used to estimate $PM_{2.5}$. Total PM was assumed to equal $PM_{10.}$ The area by crop type is provided in provided in the detailed method in Appendix 1.

Equation 6: PM_{10} Emissions from Agricultural Harvesting

$$Emissions_{PM_{10}}(kg) = Annual\ crop\ area\ (ha) \times Number\ of\ harvests\ \times Emisison\ factor\ \left(\frac{kg}{ha}\right)$$

Table 13: PM_{10} Emission Factors for Harvesting by Crop Classification Groupings

Crop Classification Category Groupings	PM_{10} Emission Factor (kg/ha)
Corn	0.12
Grass/hay/alfalfa	0.25
Cereal, grain and oilseed	0.47
Pasture	0.00
Peas/beans/early potatoes	0.31
All other vegetables	0.03
Turf	0.00
Tree fruits vines and berries	0.01

2.2.2.4 Wind Erosion

Particulate emissions also result from wind erosion of tilled agricultural lands. Particulate emissions from wind erosion of agricultural lands were calculated using the Wind Erosion Equation (WEQ) shown in Equation 7. The WEQ relies on crop-specific and region-specific factors. Crop specific factors include the surface roughness factor, the unsheltered field width factor and the vegetative factor. Crop-specific factors as developed for the BC Agricultural Air Emission inventory (RWDI, 2014) were used. Region-specific factors including the soil erodibility and climatic factor were developed for the Comox Valley.

Equation 7: Wind Erosion Equation

$$Emissions\ Factor_{PM\,10}\ \left(\frac{ton}{acre\ year}\right) = [Total\ suspended\ particulate\ portion\ (0.025)] \times I\ \left[Soil\ Erodibility\ \left(\frac{ton}{acre\ year}\right)\right] \times K\ [Surface\ roughness\ factor] \times C\ [Climatic\ factor] \times L'^{[Unsheltered\ field\ width\ factor]} \times V'[Vegetative\ cover\ factor]$$

Total PM was broken out into PM_{10} and $PM_{2.5}$ size fractions using factors from the WRAP Fugitive Dust Handbook (Countess Environmental, 2006). The PM_{10}/TPM ratio for wind erosion is 0.5; the $PM_{2.5}$/PM_{10} ratio is 0.15.

A detailed description of the development of the parameters K, C, L' and V' is provided in Appendix 1. Total PM, PM_{10}, and $PM_{2.5}$ emissions were calculated using the monthly emission factors generated from Equation 7 multiplied by the total area per crop. The area of each relevant crop was taken from the 2011 Census of Agriculture and is shown in Table 14.

Table 14: Crop Area by CCS for Wind Erosion Calculations

Wind Erosion Crop Grouping	Census Table	Census Fields	Crop Area (hectares)		
			Comox Valley A	Comox Valley B Lazo North	Comox Valley C Puntledge - Black Creek
Alfalfa	Hay and field crops 2011	Alfalfa_and_alfalfa_mixtures_hectares	284	83	197
Barley	Hay and field crops 2011	Barley_hectares	0	n/a	84
Grain Hays	Hay and field crops 2011	Mixed_grains_hectares	n/a	183	1977
		Canola_rapeseed_hectares			
		Flaxseed_hectares			
		All_other_tame_hay_and_fodder_crops_hectares			
Potatoes	Hay and field crops 2011	Potatoes_hectares	1	n/a	n/a
Vegetables	Vegetables excluding greenhouse	Total vegetables excluding greenhouse vegetables_hectares	19	28	n/a

2.2.2.5 Livestock movements

Particulate emissions from animal production result from animal housing and moving facilities. The emissions methodology for PM from cattle, swine, poultry and horses was selected from the " Review of gricultural ir Emissions Estimates for the Lower Fraser Valley of British Columbia" (Poon & Robbins, 2006). The transfer of methodology from the LFV to CVRD assumes that agricultural livestock production operates similarly in both regions. The number (head) of livestock was taken from the 2011 Census of Agriculture and is shown in Table 15.

Table 15: Number of Livestock by CCS

Livestock	Number of Livestock (head)		
	Comox Valley A	Comox Valley B Lazo North	Comox Valley C Puntledge – Black Creek
Horses	74	19	255
Swine	97	71	603
Poultry	3,857	1,232	18,586
Cattle	48	63	112

The recommended method for deriving emissions from cattle assumes that only cattle in beef feedlots generate significant PM and that the best conservative estimate of the number of cattle in beef feedlots is based on the number of beef steers. The number of steers was taken from the 2011 Census of Agriculture and is shown in Table 15.

The published PM_{10} emission factor is 11 kg/1000 head/day, with particle size multipliers of 3.0 for TPM and 0.15 for $PM_{2.5}$ resulting in the emission factors shown in Table 16. A climate correction factor of 0.572 was generated for the Comox Valley which is equal to fraction of days with less than 2.0 mm of rain in the region.

Equation 8: Particulate Matter Emissions from Cattle

$$PM_A = \frac{Number\ of\ Steers}{1000\ head} \times EF_{PM10,daily} \times Particle\ size\ multiplier_A \times climate\ correction\ factor \times days\ in\ feedlots\ (365)$$

Table 16: Particulate Matter Emission Factors for Cattle

Pollutant	Effective Emission Factor (kg/1000 steer/day)
TPM	33
PM_{10}	11
$PM_{2.5}$	1.65

The recommended methodology for calculating emissions for swine uses Equation 9 with a TPM emission factor of 1.854 mg/hr/kg swine. PM_{10} to TPM and $PM_{2.5}$ to TPM ratios of 0.5 and 0.1 were used. The mass per animal is shown in Table 17.

Equation 9: Particulate Matter Emissions from Swine

$$PM = Number\ of\ swine\ (head) \times Mass\ per\ animal\ (\frac{kg}{head}) \times EF_{PM,hourly} \times Hours\ per\ year\ (8760) \times Particle\ size\ conversion$$

Table 17: Assumed Mass of Animal (Swine)

Census Livestock Category		Number of head	Mass per head kg/head
Swine	Boars_number	9	230
	Sows_and_gilts_for_breeding_number	80	170
	Nursing_and_weaner_pigs_number	270	47
	Grower_and_finishing_pigs_number	412	47

The recommended method for estimating emissions from poultry depends on the length of production cycle and varies for pullets and laying hens versus broilers, turkeys, and other poultry. The emission estimation method was varied between layers (pullets under 19 weeks intended for laying, laying hens19 weeks and over, and layer and broiler breeders) and non-layers (broilers roasters and Cornish, turkeys, and other poultry). The emissions from layers were calculated by bird type using Equation 10. The number of livestock, TPM emission factors, PM_{10} to PM and $PM_{2.5}$ to PM ratios, and hours per production cycle for layers is shown in Table 18.

The emissions from broilers (non-layers) were calculated by bird type using Equation 11. The number of livestock, PM emission factors, PM_{10} to TPM and $PM_{2.5}$ to TPM ratios, and hours per production cycle for broilers (non-layers) is shown in Table 19.

Equation 10: Particulate Matter Emissions from Poultry Layers

$$PM = Number\ of\ birds\ (head) \times Mass\ per\ animal\ (\frac{kg}{head}) \times EF_{PM,production\ cycle}\ (\frac{\frac{mg}{hr}}{kg\ bird}) \times Hours\ of\ production\ per\ year\ (8760) \times Particle\ size\ conversion$$

Equation 11: Particulate Matter Emissions from Poultry Broilers (non-layers)

$$PM = Number\ of\ birds\ (head) \times Mass\ per\ animal\ (\frac{kg}{head}) \times EF_{PM,production\ cycle}\ (\frac{\frac{mg}{hr}}{kg\ bird}) \times Hours\ of\ production\ per\ day\ \times (Days\ of\ production + days\ of\ cleanout) \times cycles\ per\ year \times Particle\ size\ conversion$$

Table 18: Emission Equation Factors for Poultry Layers

Census Livestock Category		Number of head	Mass per head kg/head	EF for production cycle mg/hr/kg	Hours per production hr/yr
Poultry	Pullets under 19 weeks, intended for laying (63)	1605	0.75	1.266	8760
	Laying hens, 19 weeks and over (64)	5215	1.8	1.266	8760
	Layer and broiler breeders (pullets and hens) (65)	333	1.8	1.266	8760

Table 19: Emission Equation Factors for Poultry Broilers (non-layers)

Census Livestock Category		Number of head	Mass per head kg/head	EF for production cycle mg/hr/kg	hours/day hr/day	days production days	cleanout days per cycle days	cycles per year cycles/year
Poultry	Broilers, roasters and Cornish (66)	11870	1	5.61	24	40	2	6.5
	Turkeys (67)	2067	4.9	5.61	24	75	2	3.5
	Other poultry	2585	1.8	5.61	24	75	2	3.5

The recommended method for quantifying emissions from horses separates the animals into those in riding rings versus those in paddocks. This method uses the total number of horses from the Census of Agriculture and assumes a split between horses in riding rings (75%) and horses in paddocks (25%). The assumed splits are based on data from the Lower Fraser Valley with an assumption that the split is similar in the CVRD. The general emission equation is shown in Equation 12 and the emission factors are shown in Table 20.

Equation 12: Particulate Matter Emissions from Horses

$$Emissions\ (kg) = Number\ of\ horses(head) \times EF(\frac{kg}{head})$$

Table 20: Particulate Matter Emission Factors for Horses

Pollutant	Horse Emission Factor (kg/head)	
	Paddocks	Riding Rings
TPM	2.15	1.61
PM_{10}	0.72	0.54
$PM_{2.5}$	0.11	0.08

2.2.2.6 Crop Residue Burning

Open burning is one disposal option for excess vegetation (crop residue) from crop production. Emissions are based on an assumption of the amount of crop residue produced, the proportion of this residue which is disposed of by incineration, and an emission factor. Emissions from the burning of crop residue were calculated using Equation 13. The amount of crop residue produced is calculated using the land area in crops (by crop category) and an assumed rate of residue production (Fuel Loading) per crop type.

Equation 13: Agricultural Waste Burning Equation

$$Emissions\ (kg) = Crop\ area\ (hectares) \times Fuel\ Loading\ \left(\frac{tonne\ residue}{hectare}\right) \times Percentage\ of\ dry\ crop\ residue\ burned\ (\%) \times Emission\ Factor\ \left(\frac{kg}{tonne\ residue}\right)$$

Crop residue production (fuel loadings) were assigned by crop category. The percentage of dry crop residue burned in various regions across the province was developed as part of the BC Agricultural Air Emissions Inventory to be 0.5%. PM emission factors per crop were selected from the California Air Resources Board and grouped into crop categories relevant to BC (California Air Resources Board, 2014). Emission factors and fuel loadings per crop type are shown in Table 21.

Table 21: Crop Residue Burning Emission Factors and Waste Production Rates

Land Cover Category	Emission Factors (kg/tonne)			Fuel Loading (tonnes/hectare)
	TPM	PM_{10}	$PM_{2.5}$	
Corn	5.8	5.7	5.4	9.4
Field Crops - Vegetables	8.7	8.5	8.2	4.7
Orchard Crops	4.0	4.0	3.7	5.1
Vine Crops	3.2	3.2	3.0	4.7
Field Crops - Hay	8.7	8.5	8.2	4.7
Grapes	3.2	3.2	3.0	14.0

The crop area by crop type was taken from 2011 Census of Agriculture for the census consolidated subdivisions (CCSs) within the CVRD. The total area in hectares for each crop category and for each CCS in the CVRD are shown in Appendix 1.

2.2.3 Open Burning

Open burning is a significant source of PM emissions in BC (Environment and Climate Change Canada, 2016). This source can be divided into three sub categories: prescribed & pile burning (land clearing and forestry operations); backyard burning; and, forest fires.

2.2.3.1 Prescribed & Pile Burning

Open burning is a common practice in British Columbia due to the needs of forest management and also disposal of debris related to logging activities and land clearing. Particulate matter emissions from open burning depend on the amount and type of waste burned. Open burns are categorized by their size and nature per the BC Wildfire Regulation, as described in Table 22.

The Ministry of Forest, Lands and Natural Resource Operations (FLNRO) maintains an Open Fire Tracking System (OFTS) through their Wildfire Branch. This inventory keeps track of Category 3 (Pile) and Category 4 (resource management) burns in British Columbia through the issuance of Burn Registration Numbers (BRNs). The BRN data recorded through the Wildfire Branch in the OFTS are the most complete record of open burning activities available in the Province, and thus, were adopted as the activity data for this particular emissions inventory.

Table 22: BC Wildfire Regulation Open Fire Categorization

Open Fire Category	Description
Category 1 (Camp Fires and Backyard Burns)	An open fire that meets both of the following requirements: a) the open fire burns material in one pile no larger than 0.5 m in height and 0.5 m in width; and b) the open fire is lit, fuelled or used: i. by any person for a recreational purpose, or ii. by a first nation for a ceremonial purpose.
Category 2	An open fire, other than a camp fire, that: a) burns material in one pile not exceeding 2 m in height and 3 m in width, b) burns material concurrently in 2 piles each not exceeding 2 m in height and 3 m in width; or c) burns stubble or grass over an area that does not exceed 0.2 ha.
Category 3	An open fire that burns a) material concurrently in 3 or more piles each not exceeding 2 m height and 3 m in width, b) material in one or more piles each exceeding 2 m in height or 3 m in width, c) one or more windrows, or d) stubble or grass over an area exceeding 0.2 ha.
Category 4 (Resource Management Open Fire)	An open fire that: a) burns unpiled slash over an area of any size, or b) is not a campfire or a category 2 or 3 open fire and is lit, fuelled or used for silviculture treatment, forest health management, wildlife habitat enhancement, fire hazard abatement, ecological restoration or range improvement.

Source: Government of British Columbia, 2005.

The OFTS BRN data were obtained from the Ministry for the 2015 calendar year. The records include both pile (in number of piles/windrows) and area (in hectares) burn registrations. The amount of material burned can be estimated using either the number of piles or the area of the burn. The emissions equations for regulated burns by number of pile or by area burned areas are shown in Equation 14 and Equation 15.

Equation 14: Regulated Pile Burn Emissions

$$\textit{Pile Burn Emission (kg)} = \textit{Emission Factor (kg/tonne)} * \textit{Net Mass Per Pile (tonnes)} * \textit{Number of Piles} / 1{,}000$$

Equation 15: Regulated Area Burn Emissions

$$\textit{Area Burn Emission (kg)} = \textit{Emission Factor (kg/tonne)} * \textit{Fuel Loading (tonnes / hectare)} * \textit{Burn Area (hectares)} / 1{,}000$$

The province-wide OFTS BRN data was filtered for regulated burns in the CVRD (using associated latitude / longitude coordinates in ArcGIS) and to remove duplicate entries, resulting in 40 regulated burns in the CVRD in 2015.

For pile burning, a method to categorize the pile burns into different pile classes was adopted from a 2010 BC MOE emissions inventory (McCormick, 2013). The first step of this method was to produce a frequency distribution for the categorization of different pile classes.

Break points were identified at 5 piles and fewer, 5 to 10 piles and more than 10 piles. Pile classes were assigned C (Very Dirty), B (Dirty) and A (Clean), respectively. Pile class statistics within the area of interest are presented in Table 23 and Figure 3. An additional 13 BRN records were classified as area burns.

In addition to the OFTS BRN data, the Denman Island and Cumberland Fire Service areas reported 10 permits for land-clearing each. These additional 10 permits were assumed to be class C piles with an average of 2.25 piles per permit (equal to the number of piles per permit from the BRN data).

Table 23: Pile Burn Statistics from 2014 OFTS BRN Data

Pile Class	Number of BRN Records	Total Number of Piles	Percent of BRNs	Percent of Total Pile Burns	Description
Class A	16	1,620	59%	97%	> 20 piles / BRN
Class B	3	40	11%	2%	5-19 piles / BRN
Class C	8	18	30%	1%	1-5 piles / BRN
Class C from Fire Service District Permits	20*	45	n/a	n/a	Assumed 2.25 piles / Permit

*Both the Denman and Cumberland Fire Services reported 10 permit each for landclearing

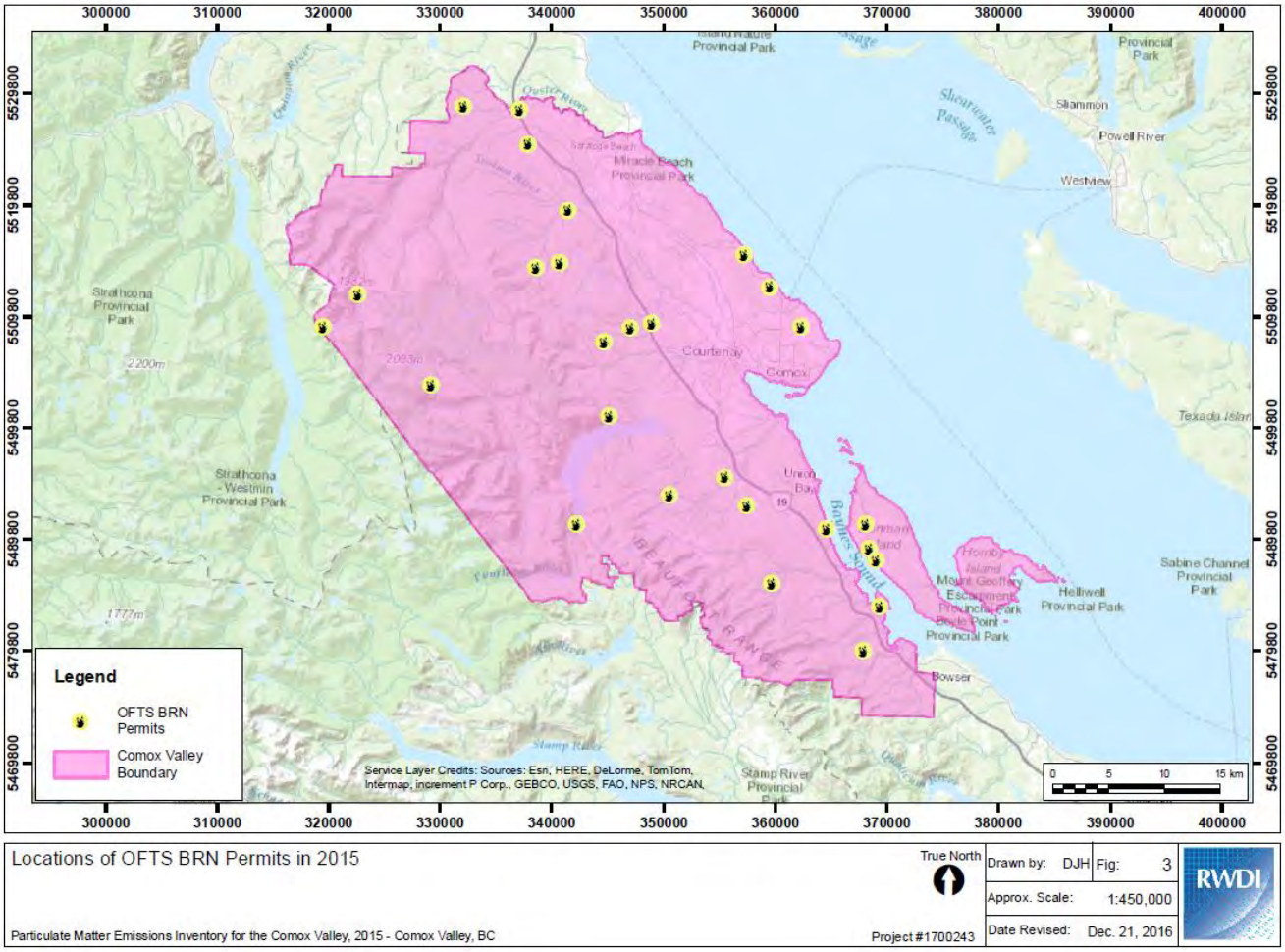

Figure 3: Locations of OFTS BRN Permits in 2015

2.2.3.2 Pile and Area Burn Assumptions

Assumptions were made for pile and area open burns to estimate the amount of material burned as a necessary input for emission calculations. Assumptions for the different pile classes were adapted from the 2010 BC MOE emissions inventory report (McCormick, 2013) and are presented in Table 24. Piles were assumed to be parabolic in shape, with a packing ratio that varied based on the class of pile due to the assumption that operators doing larger numbers of pile burns are typically better at making tight, organized piles. The wood density value is an average calculated from several tree species commonly found in BC forests.

Table 24: Pile Burn Size and Net Mass Assumptions

Pile Class	Pile Height (m)	Pile Width (m)	Pile Volume (m^3)	Packing Ratio	Consumption Factor	Wood Density (lb per ft^3)	Wood Density (kg per m^3)	Net Mass per Pile (tonnes)
Class A	6.0	9.0	190.85	0.25	0.9	27.7	444.63	19.09
Class B	6.0	9.0	190.85	0.15	0.9	27.7	444.63	11.46
Class C	6.0	9.0	190.85	0.10	0.9	27.7	444.63	7.64

The only assumption required for area burns was an estimate of the fuel loading value, which is the estimated number of tonnes of material per hectare. A value of 7.2 tonnes per hectare value was adapted from the US EP ’s P-42 Chapter 2, Section 5 on Open Burning (US EPA, 1992). Most ‘area burns’ in the area of interest were assumed to be resource management burns due to their Category 3 or 4 classifications. As such, the material burned is assumed to be wild grasses and shrub / brush mix. To represent this type of burn material, the fuel loading value for the refuse category “Weeds – Unspecified” was adopted for area burns.

2.2.3.3 Emission Factors

The final emission factor used in the calculation of PM emissions from both pile and area open burn is 0.63 kg per tonnes of mass consumed and is shown in Table 25. This emission factor for burns was referenced from the Metro Vancouver 2005 Lower Fraser Valley Air Emissions Report, Table B.1.2.1 for Burning for the Prescribed Burning category (MV 2010).

Table 25: Open Burning Emission Factors (kg per tonne of mass consumed)

Burn Type / Class	TPM	PM_{10}	$PM_{2.5}$
Class A	11.0	7.8	6.8
Class B	13.5	10.0	8.5
Class C	18.0	14.0	11.9
Area	8.0	5.9	5.1

2.2.3.4 Backyard burning

Backyard burning refers to the burning of clean, untreated wood or other organic materials on residential properties. For this inventory, backyard burning includes Category 1 (camp fires and backyard burns) and Category 2 open fires under the backyard burning category. Category 1 and Category 2 open fires can be regulated and/or tracked by regional and municipal authorities. Fire Chiefs from the local fire districts were contacted to obtain information regarding burning behavior in their respective areas. Each Fire District was asked to provide the number of fire permits issued in 2015 and the number of fires suspected to be lit without a permit. The survey also asked whether backyard burning is banned for part or all of the year. A copy of the survey is provided in Appendix 2.

In the rural areas of the CVRD, it is common practice to burn residential yard waste such as brush, grass clippings or leaf litter. Backyard burning is banned in the City of Courtenay, the Town of Comox and the Village of Cumberland. The Village of Cumberland passed a bylaw on February 27, 2017 to prohibit yard waste fires, previously there had been a spring yard waste burning period. Occasionally household garbage may be burned;

however, it has not been included in this emissions inventory as it is on the prohibited items list of the Open Burning Smoke Control Regulation, and is considered a rare practice.

The CVRD also provided data from Comox Valley Waste Management Centre regarding the amount and types of material collected as well as collection data for the City of Courtenay. The average burnable waste generated per capita was calculated for the City of Courtenay, Comox, and Cumberland for 2015 using the sum of wood, grass, organics and yard waste collected and is shown in Table 26.

Table 26: Yard, Wood, Grass & Leaves and Organic Waste Generated in the Comox Valley by Community

Community	Population	Waste Collected (tonnes)	Waste Generation Rate (kg per capita)
Comox	13,627	1697	124.6
Courtenay	25,744	2365	91.9
Cumberland	3,398	343	100.9

The average of yard waste generation rates for the City of Courtenay (91.9 tonnes/person) was used to estimate the total waste generated in rural areas. This waste generation rate was multiplied times the population in rural areas including Cumberland, and the electoral areas (25,812 people) (Comox Valley Regional District, 2013). The actual amount of waste collected in the rural areas, provided by the CVRD was subtracted and the remainder was assumed to be burned. The values are presented in Table 27.

Table 27: Yard Waste Generated, Collected and Burned (tonnes per year)

2011 CVRD Population	25,812	people
Yard Waste Generation	91.9	kg/capita/year
Estimated Waste Generation	2,371	tonnes/year
Actual Waste Collected	522	tonnes/year
Estimated Yard Waste Burned	1,849	tonnes/year

Using the data from the Comox Valley Waste Management Centre, percentages of the materials collected were calculated and multiplied by the amount of material burned and the PM emission factors from AP-42 Chapter 2, Section 5 on Open Burning (US EPA, 1992). The quantities burned and PM emission factors from backyard burning are listed in Table 28. As the majority of particulate matter is submicron in size (US EPA, 1992), the TPM is equal to the PM_{10} and $PM_{2.5}$ amounts.

Table 28: Particulate Matter Emission Factor and Material Quantities from Backyard Burning

Material	US EPA Category	TPM EF (kg/tonne)	Percentage of Material Collected (%)	Quantity of Material Burned (tonnes)
Yard Waste	Unspecified Weeds	8	81%	1492
Clean Wood Waste	Unspecified forest residue	8	7%	136
Cut Grass & Raked Leaves	Unspecified Leaves	19	12%	221

To verify the amount of waste burned, RWDI contacted nine fire districts and obtained information regarding the number of permits issued in 2015. Each permit was assumed to represent 1.5 piles since most people burn one to two piles per permit. Additionally, the number of fires without a permit (as estimated by each Fire District) was included and assumed to represent a single fire. The amount of material burned was calculated using the same assumptions as opening burning for Class C (1-5 piles) in Table 24 but the pile size was changed to a maximum of 2 m x 3 m as per the BC Wildfire regulation for Category 2 burns (Government of British Columbia, 2005). The estimated amount of material burned is presented in Table 29. This amount (1000 tonnes) is similar in magnitude to the yard waste estimated using the data from CVRD (1849 tonnes), and thus, the emissions from backyard burning are assumed to be reasonable.

Table 29: Estimated Amount of Backyard Burn Material (tonnes per year)

Fire Type	Number of Permits*	Number of Fires	Amount of Material Burned in 2015 (tonnes)
Backyard Burn Permit	1436	2154	460
Burns without a Permit	*	865	195
Recreational Fires	385	385	0.8
Landclearing Fires**	20	45	344
		Total Amount Burned	***999.8***

*The number of fires without a permit was provided by survey with each fire district, thus there is no value for the number of permits
**Emissions from landclearing fires are addressed in section 2.2.3.1 and these amounts have been added into Table 23

2.2.3.5 Wildfire

The BC Wildfire Service collects and publishes several types of data on current and historical wildfires throughout the province. They also published a dynamic list and interactive map of all current wildfires larger than 0.01 hectares for the current year (May 2016-May 2017) for each Fire Service Area. A filter of the Coastal Fire Centre current wildfire list for fire areas 7 and 8 resulted in a list of 6 fires totaling 43.8 hectares, all of which were outside of the Comox Valley.

The BC Wildfire service also produces GIS files with the point locations and sizes (polygons) for wildfires in 2016. The point locations file listed 1,049 individual fires in the province, but the size file only lists sizes for 214 fires. When compared to the Comox Valley, the point locations file listed 10 wildfires, but none of these fires were listed in the size file, meaning the corresponding size of each fire is unknown.

In addition, the BC Wildfire Service publishes historical wildfire data including locations, size, and data in GIS format to the end of 2014. This data source listed two wildfires with a total of 5.3 hectares burned in 2014. This dataset, being the most complete set of recent data, was used for determining emissions from wildfires.

Wildfire emission factors were calculated from data obtained from Wildfire CAC Emission Inventory for 2011 report (McCormick, 2012). The estimated amount (in tonnes) of TPM, PM_{10} and $PM_{2.5}$ emitted were divided by the total area burned for the Coastal Region. The effective emission factors for the Coastal Region and the corresponding emissions estimated for wildfire burns in the CVRD are presented in Table 30.

Table 30: Effective Emission Factors for Wildfire Burning in the Coastal Region (kilogram per hectare)

Emission Factor (kg/ha)		
TPM	**PM_{10}**	**$PM_{2.5}$**
667	481	444

2.2.4 Miscellaneous Sources

Miscellaneous sources of PM include meat cooking, cigarettes, dry cleaning, crematoria, and structural fires. PM emissions from the BC emissions inventory (Environment and Climate Change Canada, 2016) were scaled to the CVRD using human population. PM emissions from the BC emissions inventory are shown in Table 31. Population was taken from BC Statistics (BC Statistics, 2016), the 2014 population for BC used was 4,638,415, and the population for the CVRD for 2015 was 64,634.

Table 31: 2014 BC Emissions from Miscellaneous Sources

Emission Source			2014 BC Emissions (tonnes per year)		
			TPM	**PM_{10}**	**$PM_{2.5}$**
Area	Miscellaneous	Meat Cooking	1,114.0	1,114.0	1,114.0
		Cigarettes	39.0	39.0	39.0
		Dry Cleaning	1.0	1.0	1.0
		Crematorium	1.0	1.0	1.0
		Structural Fires	22.0	22.0	20.0
		Miscellaneous subtotal	***1,177.0***	***1,177.0***	***1,175.0***

2.3 Mobile

Mobile emission sources include on-road vehicles, non-road equipment, marine vessels, locomotives and aircraft. Direct PM emissions from mobile transportation sources are a small portion of the TPM in BC at less than 1% (Environment and Climate Change Canada, 2016).

PM emissions from the BC emissions inventory (Environment and Climate Change Canada, 2016) were scaled to the CVRD using appropriate surrogate data for all mobile sources except marine transportation. Mobile emissions for all of BC are shown in Table 32.

The emission amounts in Table 32 were scaled down to the CVRD region using surrogate data from the 2010 CEEI, the 2011 Census of Agriculture and Statistics Canada. The specific surrogates used for each emission source by the categories used in the 2014 BC air emissions inventory are shown in Table 33. The surrogates used for each mobile emission source are also further discussed in the following sections.

Table 32: Province-Wide (BC) Mobile Source Emissions for 2014

Emission Source				2014 BC Emissions (tonnes per year)		
				TPM	PM_{10}	$PM_{2.5}$
Mobile	On-road	Light-duty	Light-duty diesel trucks	36	36	35
			Light-duty diesel vehicles	33	33	32
			Light-duty gasoline trucks	297	297	273
			Light-duty gasoline vehicles	255	255	235
			Motorcycles	3	3	3
		Heavy-duty vehicles	Heavy-duty diesel vehicles	1181	1181	1146
			Heavy-duty gasoline trucks	61	61	56
	Non-road vehicles		Off-road use of diesel	1225	1225	1200
			Off-road use of gasoline/LPG/CNG	579	557	524
	Marine Vessels		Marine Transportation	2599	2495	2296
	Aircraft		Air Transportation	218	218	196

Table 33: Mobile Emission Scaling Surrogates

Emission Source			BC 2014 Category	BC Value	Comox Valley Value	Scaling Surrogate Name		Surrogate Data Source
Mobile	On-road	Light-duty	Light-duty diesel trucks	73,198,229	1,369,459	Diesel (litres)	Light Trucks, Vans, SUVs	CEEI, 2010
			Light-duty diesel vehicles	35,730,800	1,096,181	Diesel (litres)	Small Passenger Cars	
			Light-duty gasoline trucks	2,404,995,683	40,157,147	Gasoline & hybrid (litres)	Light Trucks, Vans, SUVs	
			Light-duty gasoline vehicles	1,803,891,002	34,484,704	Gasoline & hybrid (litres)	Small Passenger Cars	
			Motorcycles	14,451,157	305,713	Gasoline (litres)	Motorcycles, Mopeds	
		Heavy-duty vehicles	Heavy-duty gasoline trucks	1,212,620,517	9,794,534	Diesel (litres)	Bus	
							Commercial Vehicles	
							Motorhomes	
							Tractor Trailer Trucks	
			Light-duty diesel trucks	341,375,603	4,715,081	Diesel, hybrid, other (litres)	Bus	
							Commercial Vehicles	
							Motorhomes	
							Tractor Trailer Trucks	
	Non-road vehicles		Off-road use of diesel	62,900	1,188	Number Owned & Leased	Total Farm Machinery	Census of Agriculture, 2011
			Off-road use of gasoline/LPG/CNG					
	Non-road vehicles		Off-road use of diesel	13,125,233	147,338	Dollar Value $	Total Building Permits, 2015	BC Statistics
			Off-road use of gasoline/LPG/CNG					
	Aircraft		Air Transportation	1,398,732	21,124	Number	Total, itinerant and local movements (3)	Statistics Canada

2.3.1 On-road vehicles

The 2014 BC emissions inventory estimates for on-road vehicles were scaled from a BC total to the CVRD using the predicted fuel consumption from the 2010 CEEI reports for BC. Fuel consumption by thirteen vehicle class and fuel type combinations from the CEEI were mapped to seven mobile source categories from the BC inventory. Each of the seven mobile source categories was scaled from the Provincial to regional total individually.

2.3.2 Non-road equipment

Non-road equipment can be further divided by sector of use including: agricultural; construction; industrial; commercial; lawn and garden equipment; and, recreational off-road vehicles. However, results from the FVRD have indicated that agricultural and construction equipment contributes to over 85% of the PM from all non-road sources (RWDI, 2016). The 2014 BC emissions inventory estimates for non-road vehicles were therefore scaled to the CVRD using appropriate scaling factors derived from surrogate data for agricultural and construction equipment. BC emissions from non-road equipment were assumed to be split between agriculture and construction at 50% share per sector. Each of these emissions were then downscaled to the CVRD using the surrogates listed in Table 33. The number of vehicles owned and leased as reported to the 2011 Census of Agriculture by census consolidated subdivision (CCS) was used to scale the non-road agricultural equipment emissions. The 2015 annual dollar value in building permits was used to scale the non-road construction equipment emissions.

2.3.3 Marine Vessels

Particulate emissions are expected to be produced by ferries, recreational vessels and fishing vessels in the Comox Valley. For this study, emission estimates from marine vessel movements in 2015 were provided by Environment and Climate Change Canada (ECCC) from earlier results output from the prototype Marine Emission Inventory Tool (MEIT v4.1). It should be noted that the values provided from MEIT have not been fully validated (per ECCC). Emissions from MEIT were provided for the region shown in Figure 4. Emissions over this area are shown in Table 34.

Table 34: Marine Emission Inventory Tool Emissions[1] for the CVRD[2]

Emission Source	2015 MEIT Prototype Emissions (tonnes per year)		
	TPM	PM_{10}	$PM_{2.5}$
Marine Vessels	19.4	19.4	17.8

1. Emissions were extracted from a MEIT prototype and have not been validated yet
2. Emissions from MEIT were provided for a region bounded by a latitude range of -125.555 and a longitude range of -124.570 and 49.921 and 49.404.

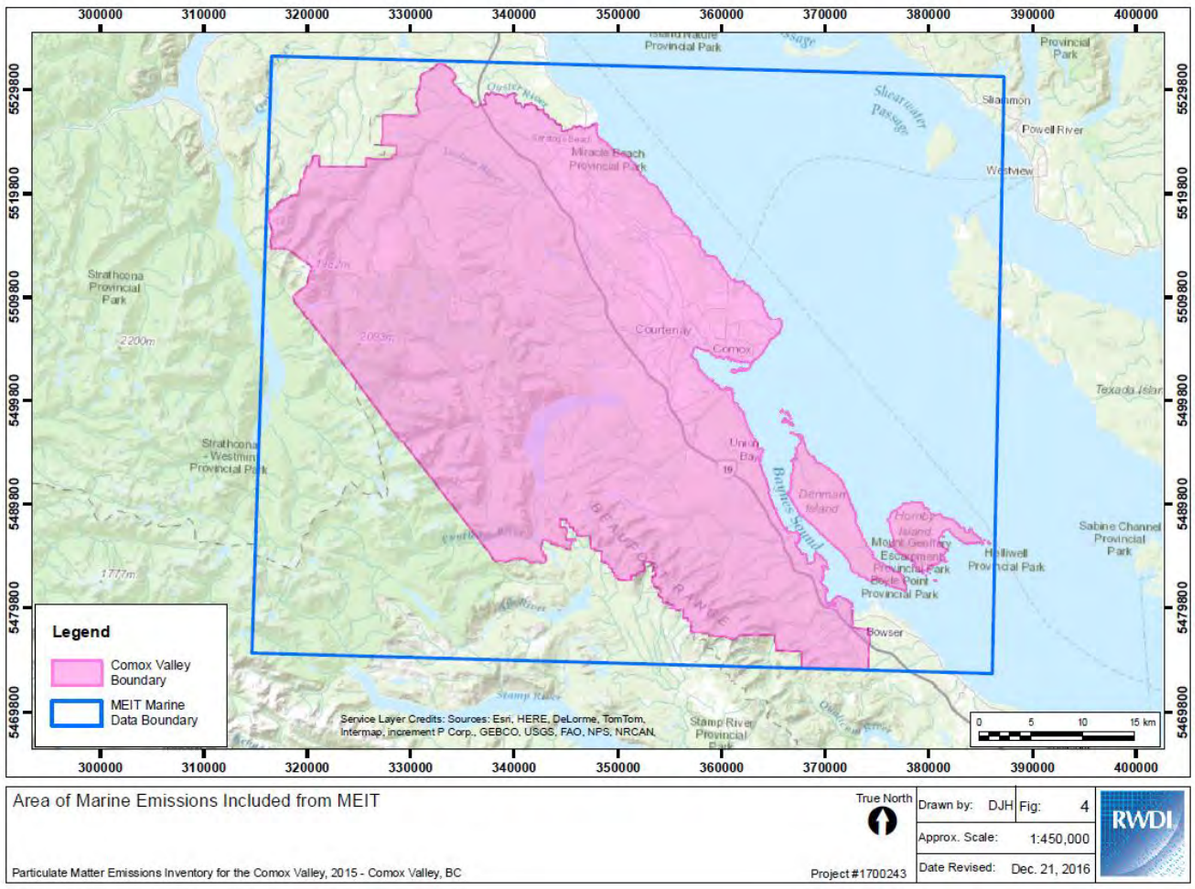

Figure 4: Map of Marine Emissions Included from MEIT

2.3.4 Locomotives and Rail Equipment

All railways within the geographic scope of this project were closed prior to 2011 resulting in zero PM emissions from this source.

2.3.5 Aircraft

RWDI obtained the number of Landings and Take-offs (LTOs) for civilian and military aircraft at the Comox Valley Airport in 2015 from the Royal Canadian Air Force's 19 Wing Comox AFB. A representative from the Comox Valley Airport confirmed that although aircraft movements vary from year to year, traffic did not increase significantly in 2015. Two smaller commuter and recreational airports were contacted by email for information but neither responded. Canada wide aircraft movements were also collected from Statistics Canada for 2014 and are listed in with the Comox totals in Table 35.

Table 35: Total Aircraft Landings and Take-offs (LTOs)

Region	2015 LTOs
Canada	6,085,333
British Columbia	1,398,732
Comox	21,124

The BC emission estimates from aircraft were downscaled to the CVRD using the total aircraft movements from the Comox Valley Airport and the total for all airports in BC as reported by Statistics Canada (Statistics Canada, 2016).

2.4 Fugitive Dust

Fugitive dust emissions result from mobile equipment operating on dust emitting surfaces such as from paved and unpaved roadways, industrial areas, and landfills. Fugitive dust sources included in this section are associate with industrial sources, construction operations, and landfills. Fugitive dust from paved and unpaved roads has been included in a separate section. Emission estimates for fugitive dust from roads are typically large, however, as noted previously, most fugitive road dust is in the coarse (>44 µm) size fraction (Pace, 2005) and thus settles out of the air in close proximity (e.g., within 100 meters) of the emission source (Desert Research Institute, 2000).

2.4.1 Industrial sources

Tayco Paving Company was the only industrial facility within the CVRD to report emissions of fugitive dust to the NPRI in 2014 as shown in Table 36.

Table 36: Fugitive Dust PM Emissions from Industrial Sources reported to the NPRI in 2014

Emission Source			2014 Emissions (tonnes per year)		
			TPM	PM_{10}	$PM_{2.5}$
Fugitive Dust	Industrial Sources	Tayco Paving Company	3.74	1.06	0.11

2.4.2 Construction Operations

Fugitive dust from construction operations were calculated using the method described in Metro Vancouver's 2005 Emission Inventory (Metro Vancouver, 2007), which contains monthly emission factors for 6 different building types. Emission factors were multiplied by the number of dwellings or value of construction built, the assumed number of months of construction, and an average size of building as shown in Table 37. The number of dwellings or value of construction built for each of the 6 building types was extracted from the 2015 Building Permit data from BC Statistics (BC Stats, 2016) as shown in Table 38.

Table 37: Factors for Emissions of Construction Dust

Item	Unit	Conversion Factor (ha/unit)	Duration	Adjusted EF (tonnes TPM and PM_{10}/ha-month)	Adjusted EF (tonnes $PM_{2.5}$/ ha-month)
Single-detached	Dwellings	0.067	4.2	0.014	0.0028
Duplex/Row	Dwellings	0.067	4.2	0.014	0.0028
Apartment	Dwellings	0.02	12	0.049	0.0098
Commercial	$ million	0.55	11	0.085	0.017
Industrial	$ million	0.55	11	0.085	0.017
Institutional	$ million	0.27	11	0.085	0.017

Table 38: Building Permits in Comox Valley Regional District in 2015

Building Types (Units)	Value or Number of Buildings Permitted
Industrial ($000)	4,478
Institutional and Government ($000)	43,070
Commercial ($000)	13,905
Residential Units (total #)	370
Residential Units -single dwelling (#)	163
Residential Units- Row (#)	3
Residential Units- Apartments (#)	195

2.4.3 Landfills

Emissions of fugitive dust from landfills from the BC emissions inventory (Environment and Climate Change Canada, 2016) were scaled based on the total volume of waste predicted and reported from the CEEI for 2010. The 2014 BC emissions inventory reported: 192,022 tonnes of TPM; 57,635 tonnes of PM_{10}; and, 11,542 tonnes of $PM_{2.5}$ for all of BC. The CEEI estimated that 2,386,715 tonnes of solid waste was produced in BC in 2010, and 44,224 tonnes of solid waste was produced in the CVRD in 2010.

2.5 Road Dust

Road Dust emissions are presented in a separate section of this report, in keeping with current emission inventory trends. Fugitive dust from paved and unpaved roads results from traffic movements which suspend material into the atmosphere. Current methods for estimating emissions of road dust include a large degree of uncertainty as estimates are based on a number of site-specific variables which are not known with any certainty without extensive field measurements. Particulate matter that is suspended on roads is typically crustal matter of larger size fractions (e.g., > 44 µm). The largest particles tend to settle out within the first 100 m of the roadway, which provides inherent mitigation of about 75% of emissions (Desert Research Institute 2000). For this reason, road dust emissions are typically highly conservative.

Emissions from paved and unpaved roads were provided by the BC emissions inventory (Environment and Climate Change Canada, 2016) in three categories: tire wear and brake lining; dust from paved roads; and, dust from unpaved roads (see Table 39). The 2014 BC emissions inventory estimates for paved and unpaved roads were scaled from a BC total to the using the predicted fuel consumption from the 2010 CEEI reports for BC as shown in Table 40. Fuel consumption for all vehicle classes and all fuel type combinations from the CEEI were summed to Provincial and regional totals and used to scale emissions from tire wear and brake lining and dust from paved roads. Consumption of diesel fuel was used to scale dust from unpaved roads.

Table 39: 2014 BC Road Dust Emissions

Emission Source	BC 2014 Emission Category	2014 BC Emissions (tonnes)		
		TPM	PM_{10}	$PM_{2.5}$
Paved & Unpaved Roads	Tire wear & Brake Lining	772	772	189
	Dust from Paved Roads	551,352	105,677	25,350
	Dust from Unpaved Roads	347,436	118,543	17,118
Total Road Dust		**899,560**	**224,992**	**42,657**

Table 40: Road Dust Emission Scaling Surrogates

Emission Source	BC 2014 Emission Category	Fuel Consumption (L)		Fuel Type Included
		BC	Comox Valley	
Paved & Unpaved roads	Tire Wear & Brake Lining	5,894,855,894	83,962,333	All fuel
	Dust from Paved Roads			
	Dust from Unpaved Roads	1,321,549,546	12,260,174	Diesel fuel

3 RESULTS

3.1 All Sources

Emissions of TPM, PM_{10}, and $PM_{2.5}$ by source and source sector for 2015 for the CVRD are shown in Table 41. Annual emissions of TPM, PM_{10}, and $PM_{2.5}$ from all sources (excluding road dust) are estimated to be 901, 727, and 608 tonnes, respectively. The relative proportions of TPM, PM_{10}, and $PM_{2.5}$ by major emission source category excluding fugitive dust are shown Figure 5, Figure 6 ,and Figure 7, respectively.

Table 41: Particulate Matter Emissions for the CVRD

Emission Source			2015 Emissions (tonnes per year)		
			TPM	PM_{10}	$PM_{2.5}$
Point	Industrial Sources		1.6	0.6	0.2
	Point Subtotal		***1.6***	***0.6***	***0.2***
Area	Space Heating	Natural Gas - Residential	1.2	1.2	1.2
		Natural Gas - Commercial/Industrial	1.0	1.0	1.0
		Propane	0.2	0.2	0.2
		Wood	225.6	213.0	212.8
		Heating Oil	0.5	0.5	0.5
		Space Heating Subtotal	***228.5***	***215.9***	***215.7***
	Agricultural	Synthetic Fertilizer Application	0.2	0.1	0.03
		Tilling	35.5	35.5	7.5
		Harvesting	0.3	0.3	0.05
		Wind Erosion	51.1	25.6	3.8
		Livestock movements	4.1	1.2	0.2
		Crop Residue Burning	0.9	0.8	0.8
		Agricultural Subtotal	***92.1***	***63.6***	***12.4***
	Open Burning	Provincially Regulated - Pile	348.9	247.8	215.9
		Provincially Regulated - Area	57.5	42.4	36.7
		Municipally Regulated - Pile	6.2	4.8	4.1
		Recreational Fires	0.01	0.01	0.009
		Regional/Municipal - Backyard Burns	17.2	17.2	17.2
		Wildfire	3.5	2.6	2.4
		Open Burning Subtotal	***433.4***	***314.8***	***276.2***
	Miscellaneous	Meat Cooking	15.5	15.5	15.5
		Cigarettes	0.5	0.5	0.5
		Dry Cleaning	0.01	0.01	0.01
		Crematorium	0.01	0.01	0.01
		Structural Fires	0.3	0.3	0.3
		Miscellaneous Subtotal	***16.4***	***16.4***	***16.4***
	Area Subtotal		***770.3***	***610.7***	***520.7***
Mobile	On-road	Light-duty	11.6	11.6	10.8
		Heavy-duty vehicles	10.4	10.4	10.0
	Non-road vehicles		34.1	33.7	32.6
	Marine Vessels		19.4	19.4	17.8
	Aircraft		3.3	3.3	3.0
	Mobile Subtotal		***78.7***	***78.3***	***74.1***
Fugitive Dust	Industrial Sources		3.7	1.1	0.1
	Construction Operations		23.3	23.3	4.7
	Landfills		22.8	12.6	8.4
	Fugitive Dust Subtotal		***49.8***	***36.9***	***13.1***
Total (no road dust)			***900.5***	***726.5***	***608.1***
Paved and unpaved roads			11,087.3	2,615.9	522.6
Total (with Road dust)			***11,987.8***	***3,342.4***	***1,130.7***

Notes: Totals may not equal the sum of components due to rounding.

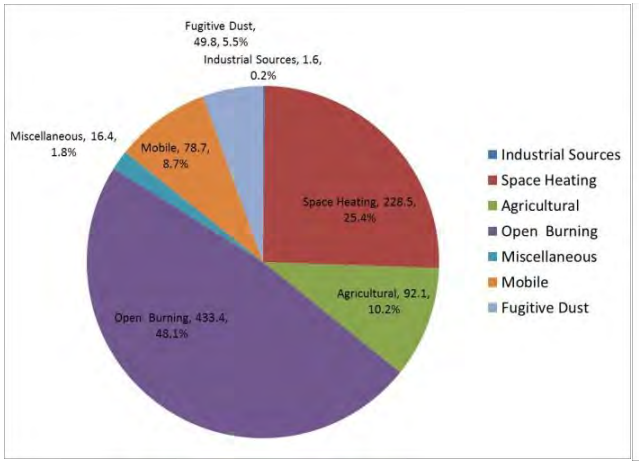

Figure 5: TPM Emissions for the CVRD, tonnes (not including Road Dust)

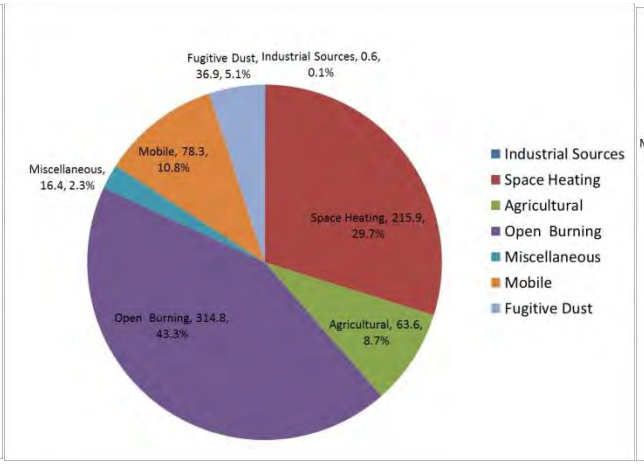

Figure 6: PM_{10} Emissions for the CVRD, tonnes (not including Road Dust)

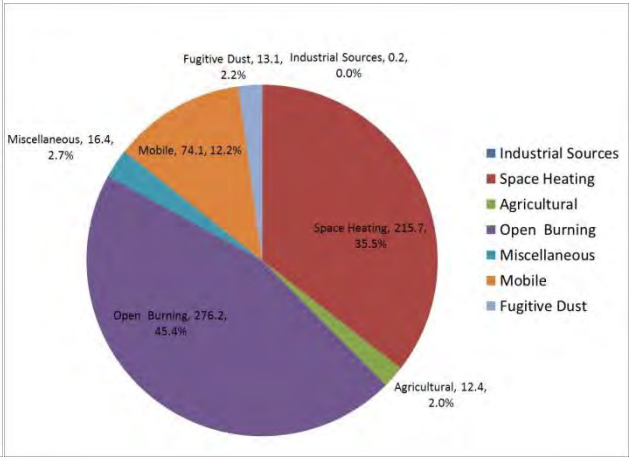

Figure 7: $PM_{2.5}$ Emissions for the CVRD, tonnes (not including Road Dust)

3.2 Industrial Sources

Emissions from industrial sources are shown in Table 42.

Table 42: Particulate Matter Emissions from Industrial Sources

Emission Source		2015 Emissions (tonnes per year)		
		TPM	PM_{10}	$PM_{2.5}$
Point	Tayco Paving Company	1.51	0.65	0.23
	Trueline Masonry and Landscape Products td.	0.01	-	-
	Hyland Precast Inc.	0.07	-	-
Total		***1.59***	***0.65***	***0.23***

3.3 Area Sources

Emissions from area sources by source and type are shown in Table 43. Emissions from wood used for space heating and provincially regulated pile burns make up the majority of the area source emissions, contributing 25% and 48% of the TPM, respectively. The relative proportions of TPM, PM_{10}, and $PM_{2.5}$ emissions from area sources by emission source category are shown Figure 8, Figure 9, and Figure 10, respectively

Table 43: Particulate Matter Emissions from Area Sources

Emission Source			2015 Emissions (tonnes per year)		
			TPM	PM_{10}	$PM_{2.5}$
Area	Space Heating	Natural Gas - Residential	1.2	1.2	1.2
		Natural Gas - Commercial/Industrial	1.0	1.0	1.0
		Propane	0.2	0.2	0.2
		Wood	225.6	213.0	212.8
		Heating Oil	0.5	0.5	0.5
		Space Heating Subtotal	***228.5***	***215.9***	***215.7***
	Agricultural	Synthetic Fertilizer Application	0.2	0.1	0.03
		Tilling	35.5	35.5	7.5
		Harvesting	0.3	0.3	0.05
		Wind Erosion	51.1	25.6	3.8
		Livestock movements	4.1	1.2	0.2
		Crop Residue Burning	0.9	0.8	0.8
		Agricultural Subtotal	***92.1***	***63.6***	***12.4***
	Open Burning	Provincially Regulated - Pile	348.9	247.8	215.9
		Provincially Regulated - Area	57.5	42.4	36.7
		Municipally Regulated - Pile	6.2	4.8	4.1
		Recreational Fires	0.01	0.01	0.009
		Regional/Municipal - Backyard Burns	17.2	17.2	17.2
		Wildfire	3.5	2.6	2.4
		Open Burning Subtotal	***433.4***	***314.8***	***276.2***
	Miscellaneous	Meat Cooking	15.5	15.5	15.5
		Cigarettes	0.5	0.5	0.5
		Dry Cleaning	0.01	0.01	0.01
		Crematorium	0.01	0.01	0.01
		Structural Fires	0.3	0.3	0.3
		Miscellaneous Subtotal	***16.4***	***16.4***	***16.4***
	Area Subtotal		***770.3***	***610.7***	***520.7***

Note: Totals may not equal the sum of components due to rounding.

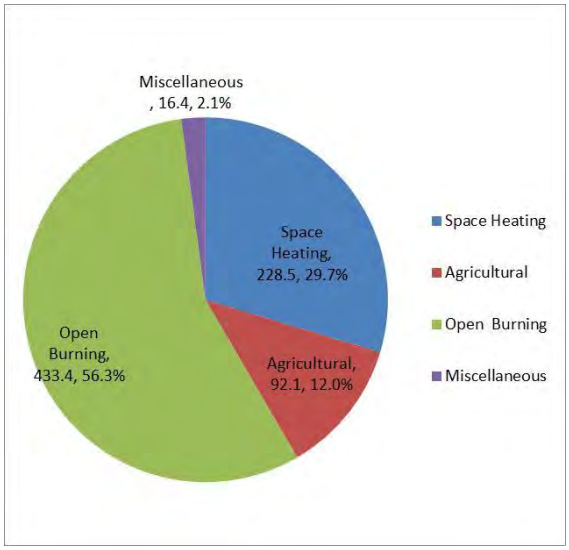

Figure 8: TPM Emissions from Area sources in the CVRD, tonnes

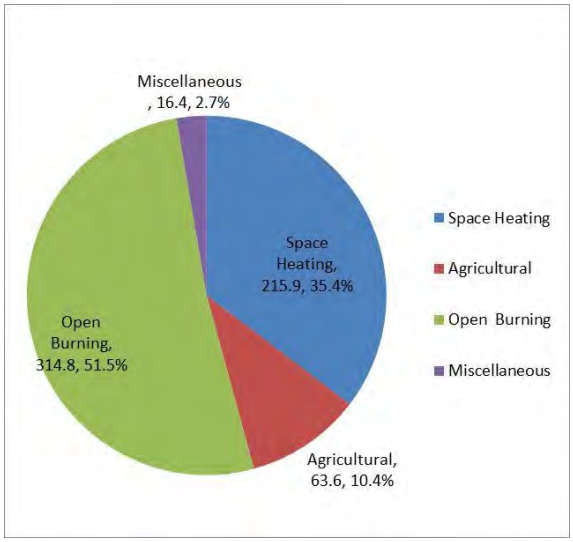

Figure 9: PM_{10} Emissions from Area Sources in the CVRD, tonnes

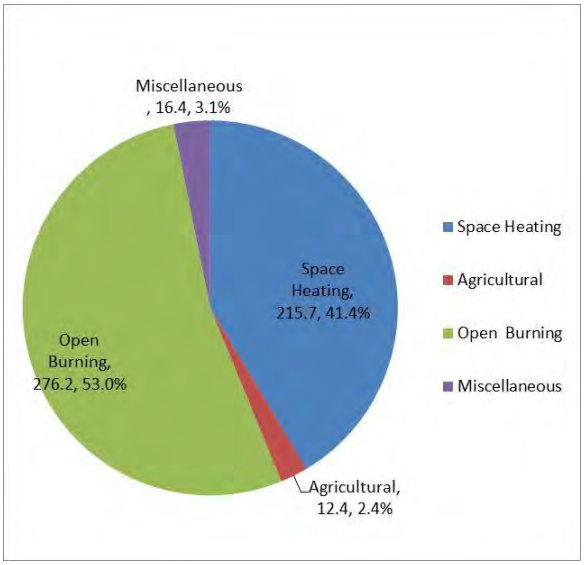

Figure 10: $PM_{2.5}$ Emissions from Area Sources in the CVRD, tonnes

3.3.1 Space Heating

Space heating emissions by fuel type are shown in Table 44, Emissions from wood burning equipment are listed in Table 45.

Table 44: Particulate Matter Emissions from Space Heating Sources by Fuel Type

Emission Source		2015 Emissions (tonnes per year)		
		TPM	PM_{10}	$PM_{2.5}$
Space Heating	Natural Gas - Residential	1.2	1.2	1.2
	Natural Gas - Commercial/Industrial	1.0	1.0	1.0
	Propane	0.2	0.2	0.2
	Wood	225.6	213.0	212.8
	Heating Oil	0.5	0.5	0.5
	Space Heating Total	***228.5***	***215.9***	***215.7***

Table 45: Particulate Matter Emissions from Wood Burning Equipment (tonnes per year)

Appliances Type	Fireplace; Advanced	Fireplace; Conventional Without glass doors	Central Furnace/Boiler (inside)	Central Furnace/Boiler	Central Furnace/Boiler (outside)	Fireplace Insert; Advanced Technology	Fireplace Insert; Catalytic	Fireplace Insert; Conventional	Woodstove; Advanced	Woodstove; Catalytic	Woodstove; Conventional	Pellet	Total Wood burning Equipment
TPM	9.5	34.4	8.5	0.1	2.2	17.2	1.6	34.0	66.8	2.0	44.9	4.3	***225.6***
PM_{10}	9.0	33.0	8.0	0.1	2.0	16.2	1.5	32.1	62.9	1.9	42.3	4.0	***213.0***
$PM_{2.5}$	9.0	32.8	8.0	0.1	2.0	16.2	1.5	32.1	62.9	1.9	42.3	4.0	***212.8***

Note: Totals may not equal the sum of components due to rounding.

3.3.2 Agricultural Sources

Emissions from agricultural sources are shown in Table 46.

Table 46: Particulate Matter Emissions from Agricultural Area Sources by Emission Sources and CCS

Emission Source			2015 Emissions (tonnes per year)		
			TPM	PM_{10}	$PM_{2.5}$
Agricultural	Synthetic Fertilizer Application	Comox Valley A	0.04	0.02	0.01
		Comox Valley B Lazo North	0.03	0.01	0.00
		Comox Valley C Puntledge - Black Creek	0.14	0.07	0.02
	Synthetic Fertilizer Application Subtotal		***0.21***	***0.10***	***0.03***
	Tilling	Comox Valley A	7.71	7.71	1.62
		Comox Valley B Lazo North	5.65	5.65	1.19
		Comox Valley C Puntledge - Black Creek	22.14	22.14	4.65
	Tilling Subtotal		***35.50***	***35.50***	***7.45***
	Harvesting	Comox Valley A	0.10	0.10	0.02
		Comox Valley B Lazo North	0.04	0.04	0.01
		Comox Valley C Puntledge - Black Creek	0.16	0.16	0.02
	Harvesting Subtotal		***0.31***	***0.31***	***0.05***
	Wind Erosion	Comox Valley A	5.83	2.91	0.44
		Comox Valley B Lazo North	5.49	2.74	0.41
		Comox Valley C Puntledge - Black Creek	39.82	19.91	2.99
	Wind Erosion Subtotal		***51.13***	***25.57***	***3.83***
	Livestock movements	Comox Valley A	0.71	0.22	0.03
		Comox Valley B Lazo North	0.56	0.19	0.03
		Comox Valley C Puntledge - Black Creek	2.79	0.83	0.13
	Livestock movements Subtotal		***4.07***	***1.24***	***0.20***
	Crop Residue Burning	Comox Valley A	0.17	0.17	0.16
		Comox Valley B Lazo North	0.08	0.08	0.07
		Comox Valley C Puntledge - Black Creek	0.61	0.60	0.57
	Crop Residue Burning Subtotal		***0.86***	***0.85***	***0.81***
Agricultural Total			***92.08***	***63.55***	***12.37***

Note: **Totals may not equal the sum of components due to rounding**

3.3.3 Open Burning

Emissions from open burning sources are shown in Table 47 and illustrated in Figure 11.

Table 47: Particulate Matter Emissions from Open Burning Sources by Emission Sources and CCS

Emission Source			2015 Emissions (tonnes per year)		
			TPM	PM_{10}	$PM_{2.5}$
Open Burning	Provincially Regulated - Pile	Class A	340.2	241.3	210.3
		Class B	6.19	4.58	3.89
		Class C	2.47	1.92	1.64
		Provincially Regulated - Pile Subtotal	***348.9***	***247.8***	***215.9***
	Provincially Regulated - Area	Area	57.5	42.4	36.7
		Provincially Regulated - Area Subtotal	***57.5***	***42.4***	***36.7***
	Municipally Regulated - Pile	***Municipally Regulated - Pile Subtotal***	***6.2***	***4.8***	***4.1***
	Recreational Fires	***Recreational Fires Subtotal***	***0.01***	***0.01***	***0.009***
	Backyard Burning	Yard Waste	11.9	3.77	3.77
		Clean Wood Waste	1.1	0.04	0.04
		Cut Grass & Raked Leaves	4.2	0.14	0.14
		Backyard Burning Subtotal	***17.2***	***3.9***	***3.9***
	Wildfire	Wildfire subtotal	3.53	2.55	2.36
		Wildfire Subtotal	***3.53***	***2.55***	***2.36***
Open Burning Total			***433.4***	***314.8***	***276.2***

Note: Totals may not equal the sum of components due to rounding.

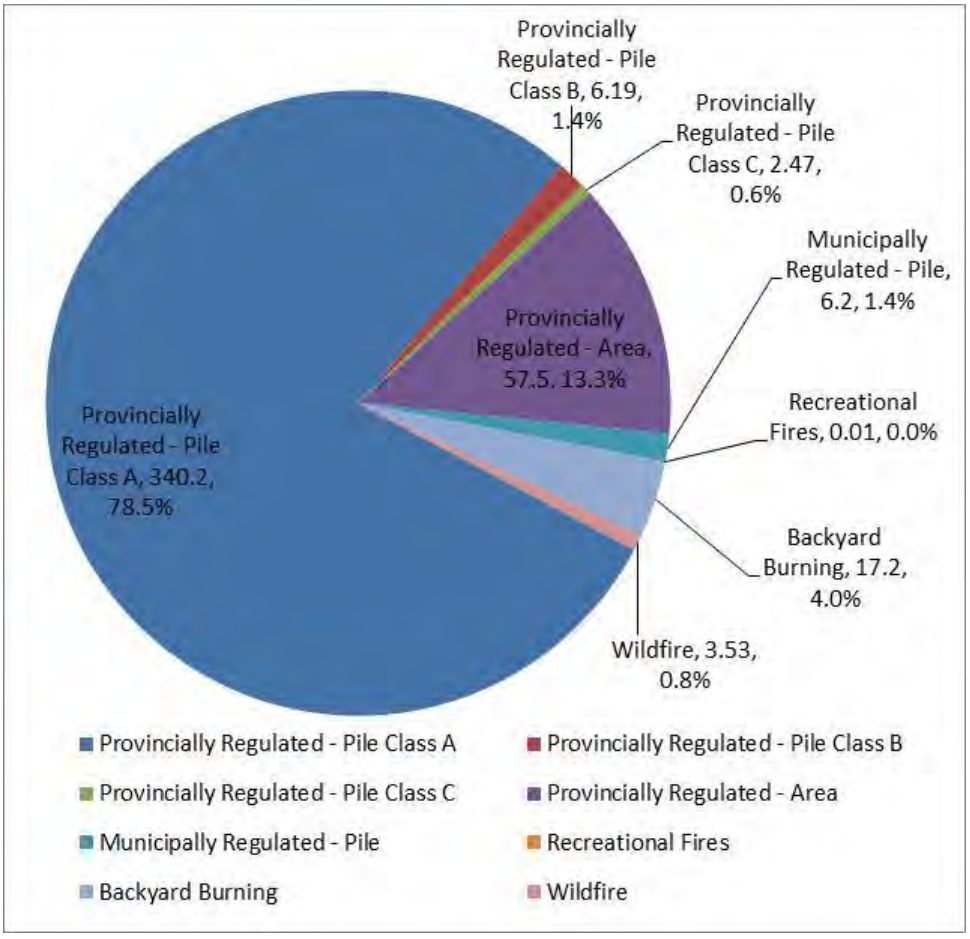

Figure 11: Particulate Matter Emissions from Open Burning Sources in the CVRD, tonnes

3.3.4 Miscellaneous Sources

Emissions from miscellaneous sources are shown in Table 48.

Table 48: Particulate Matter Emissions from Miscellaneous Sources

Emission Source		2015 Emissions (tonnes per year)		
		TPM	PM_{10}	$PM_{2.5}$
Miscellaneous	Meat Cooking	15.5	15.5	15.5
	Cigarettes	0.5	0.5	0.5
	Dry Cleaning	0.0	0.0	0.0
	Crematorium	0.0	0.0	0.0
	Structural Fires	0.3	0.3	0.3
	Miscellaneous Subtotal	***16.4***	***16.4***	***16.4***

3.4 Mobile

Emissions from mobile sources by source are shown in Table 49. Emissions from mobile sources collectively contribute only 7.4% of the TPM in the CVRD (excluding fugitive dust).

Table 49: Particulate Matter Emissions from Mobile Sources

Emission Source			2015 Emissions (tonnes per year)		
			TPM	PM_{10}	$PM_{2.5}$
Mobile	On-road	Light-Duty	11.58	11.58	10.75
		Heavy-Duty Vehicles	10.38	10.38	10.03
	Non-Road Vehicles		34.07	33.66	32.56
	Marine Vessels		19.4	19.4	17.8
	Aircraft		3.29	3.29	2.96
	Mobile Subtotal		***78.7***	***78.3***	***74.1***

3.5 Fugitive Dust

Emissions from fugitive sources by source are shown in Table 50.

Table 50: Particulate Matter Emissions from Fugitive Dust Sources

Emission Source		2015 Emissions (tonnes per year)		
		TPM	PM_{10}	$PM_{2.5}$
Fugitive Dust	Industrial Sources	3.7	1.1	0.1
	Construction Operations	23.3	23.3	4.7
	Landfills	22.8	12.6	8.4
	Fugitive Dust Subtotal	***49.8***	***36.9***	***13.1***

Note: Totals may not equal the sum of components due to rounding.

3.6 Road Dust

Emissions of from road dust are shown in Table 51. Emissions from fugitive dust (shown in Table 52) contribute to 93% of the TPM, 80% of the PM_{10}, and 47% of the $PM_{2.5}$.

Table 51: Particulate Matter Emissions from Fugitive Dust Sources

Emission Source		2015 Emissions (tonnes per year)		
		TPM	PM_{10}	$PM_{2.5}$
Road Dust	Paved & Unpaved Roads	11,087.3	2,615.9	522.6

Table 52: Particulate Matter Emissions from Fugitive Dust and Other Sources

Emission Source	2015 Emissions (tonnes per year)		
	TPM	PM_{10}	$PM_{2.5}$
Point	1.6	0.6	0.2
Area	770.3	610.7	520.7
Mobile	78.7	78.3	74.1
Fugitive Dust	49.8	36.9	13.1
Total (no Road dust)	***900.5***	***726.5***	***608.1***
Road Dust	11,087.3	2,615.9	522.6
Total (with Road dust)	***11,987.8***	***3,342.4***	***1,130.7***

Note: Totals may not equal the sum of components due to rounding.

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APPENDIX 1: DETAILED AGRICULTURAL EMISSIONS INVENTORY METHOD

4.1 Agricultural Sources

Particulate matter is produced from agricultural activities including the addition of synthetic fertilizers, tilling and harvesting of crops, wind erosion on fields, livestock husbandry, and the use of agricultural on- and non-road vehicles and equipment. Agricultural non-road vehicles and equipment has been discussed in section 2.3.2.

The Canadian Census of Agriculture provides the land in crops by crop type and the head of livestock (on a particular date) by Census Consolidated subdivision (CCS) every five years. The most current Census of Agriculture is from 2011, the 2016 Census data are not expected to be available until 2017 at the earliest. The base quantities used for the emissions from agricultural sources in this inventory were all extracted from the 2011 Census of Agriculture for the CCSs for Comox Valley: Comox Valley A (5926021), Comox Valley B (Lazo North) (5926022), and Comox Valley C (Puntledge - Black Creek) (5926024). Census consolidated subdivisions (CCSs) within the CVRD are shown in Figure 12.

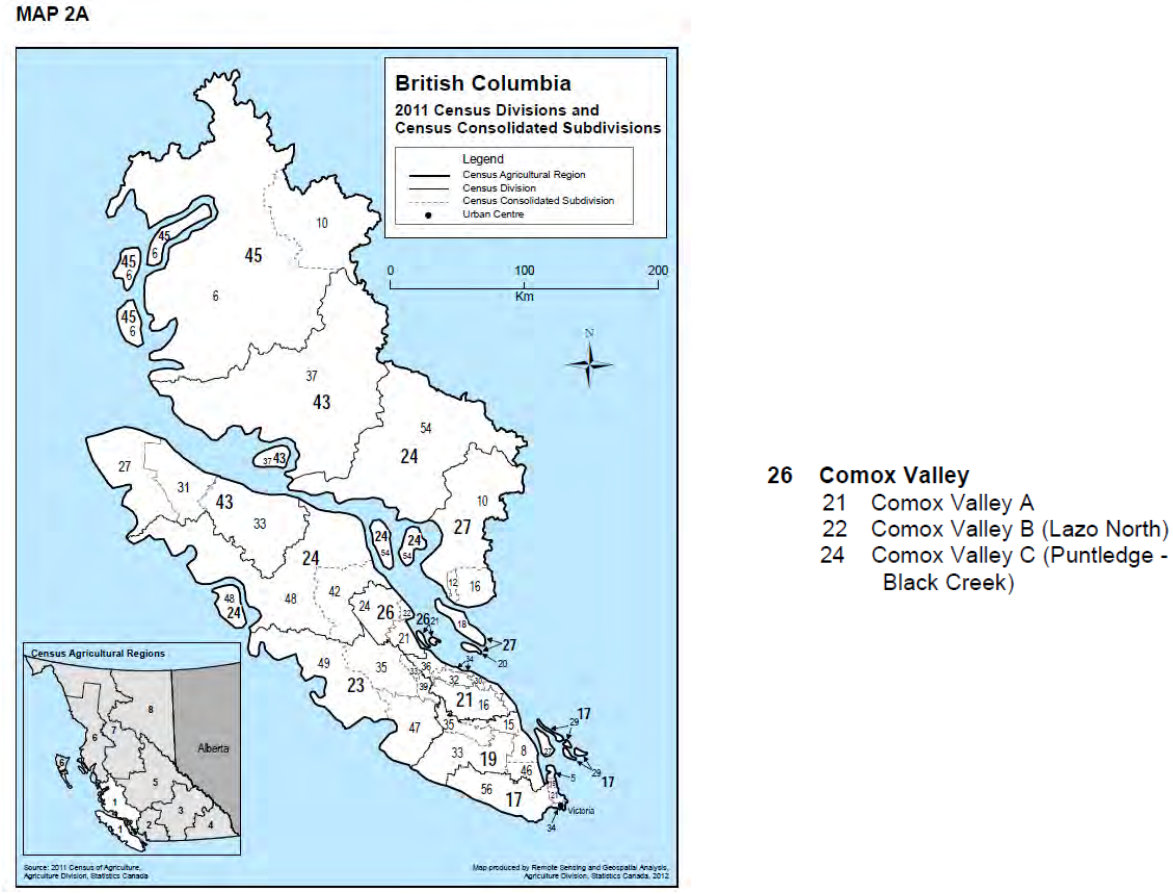

Figure 12: BC Census Division 1 (Vancouver Island-Coast) Showing Consolidated Subdivisions and the CVRD.

4.1.1 Synthetic Fertilizer Application

Particulate emissions were based on the method used by Environment Canada to calculate PM emissions from fertilizer application as part of the national emissions inventory. The emissions of PM are based on the quantity of fertilizer applied with global emission factors that account for the handling and storage as well as the spreading of fertilizers (Environment Canada, 2006). The general emission equation is shown in Equation 16. PM emission factors per tonne of fertilizer applied are shown in Table 53. The amount of fertilizer applied (summed per crop type) is equal to the area of land per crop multiplied by a fertilizer application density which varies by crop.

Equation 16: Particulate Matter Emissions from Fertilizer Application

$$PM\ Emissions\ (kg) = Area\ of\ land\ per\ crop\ (hectare) \times Amount\ of\ Fertilizer\ applied\ per\ crop\ \left(\frac{kg}{ha}\right) \times PM\ Emission\ Factor\ \left(\frac{kg}{tonne}\right)$$

Table 53: Particulate Matter Emission Factors for Fertilizer Application

Pollutant	Emission Factor (kg/t Fertilizer)
PM	2.23
PM_{10}	1.09
$PM_{2.5}$	0.31

A detailed method for estimating monthly emissions of ammonia from fertilizer application was developed by Sheppard *et al.* (Sheppard, Bittman, & Bruulsema, 2009). This method includes calculating the fertilizer application rate for 37 different crop types by four different fertilizer solution groupings (15 of these crop types are relevant to the CVRD). The work completed by Sheppard *et al.* (Sheppard, Bittman, & Bruulsema, 2009) used fertilizer sales data from the Canadian Fertilizer Institute (CFI) to partition nitrogen fertilizer amounts into four main forms: urea, nitrogen solutions (typically urea ammonium nitrate), anhydrous ammonia, and 'others'. The fertilizer application rate by census crop and fertilizer type are shown in Table 54 and the crop area by CCS is shown in Table 55.

Table 54: Fertilizer Application Density by Census Crop and Fertilizer Type

Census Field	Fertilizer Application Rates (kg/ha)			
	Anhydrous	Other	UAN	Urea
Alfalfa_and_alfalfa_mixtures_hectares	0.28	0.54	0.00	1.44
Blueberries_total_area_hectares	26.24	50.43	0.02	134.36
Carrots_hectares	31.46	60.47	0.02	161.12
Census_All_131_Barley_hectares	21.08	40.52	0.01	107.95
Corn_for_silage_hectares	14.07	27.05	0.01	72.07
Fall_rye_hectares	10.39	19.98	0.01	53.23
Green peas_hectares	15.73	30.24	0.01	80.56
Mixed_grains_hectares	17.30	33.26	0.01	88.62
Other vegetables 48_hectares	13.62	26.19	0.01	69.77
Potatoes_hectares	20.20	38.82	0.01	103.43
Raspberries_total_area_hectares	19.07	36.66	0.01	97.68
Spring_rye_hectares	10.39	19.98	0.01	53.23
Spring_wheat_excluding_durum_hectares	21.39	41.12	0.01	109.56
Sweet corn_hectares	35.11	67.49	0.02	179.82
Tomatoes_hectares	41.85	80.45	0.03	214.35

Table 55: Crop Area by CCS and Crop Type

Census Crop	Crop Area by CCS (ha)		
	Comox Valley A	Comox Valley B Lazo North	Comox Valley C Puntledge – Black Creek
Alfalfa_and_alfalfa_mixtures_hectares	284.0	83.0	197.0
All_other_tame_hay_and_fodder_crops_hectares	412.0	183.0	1977.0
Blueberries_total_area_hectares	4.0	2.0	15.0
Carrots_hectares	1.0	1.0	0.0
Census_All_131_Barley_hectares	0.0	30.0	84.0
Corn_for_silage_hectares	74.7	0.0	261.3
Fall_rye_hectares	23.0	0.0	23.0
Forage_seed_for_seed_hectares	0.0	0.0	243.0
Green peas_hectares	1.0	0.0	0.0
Mixed_grains_hectares	5.0	0.0	0.0
Oats_hectares	4.8	0.0	14.3
Other vegetables 48_hectares	7.0	1.0	3.0
Potatoes_hectares	1.0	26.9	67.1
Raspberries_total_area_hectares	1.0	1.0	10.0
Spring_rye_hectares	13.0	0.0	0.0
Spring_wheat_excluding_durum_hectares	0.0	0.0	1.0
Sweet corn_hectares	11.5	3.5	4.0
Tomatoes_hectares	1.0	0.0	1.0

The method used by Environment Canada is based on a technique for Phosphorous-based fertilizers developed in 1973. Environment Canada is one of the few agencies that incudes PM from fertilizer application in their emissions inventory. The US EPA currently states that "emission factors are not presently available for PM" (*from fertilizer application*) (US EPA, 1995).

4.1.2 Tilling

Particulate matter is released from the disturbance of soils during the tilling of fields and harvesting of crops. The EPA method for agricultural tilling was used with local improvements (Poon & Robbins, 2006). Tilling emissions are dependent on crop-specific and region-specific factors. Crop-specific factors including the area tilled and the number of tills per year (often expressed as the years between renovations). Region-specific factors include the moisture reduction factor (an expression of the local precipitation pattern) and the local silt content.

The general emission equation is shown in Equation 17. Emissions of PM, PM_{10}, and $PM_{2.5}$ are calculated per crop type and per season. Emissions are based on the crop area (in hectares), the number of tillings (passes), and an emission factor calculated specifically for the region and season. The area per crop for each CCS is shown in Table 56.

Equation 17: Tilling Emission Equation

$$Emissions\ per\ crop\ per\ season\ _{(PM,PM_{10},PM_{2.5})} = Area\ per\ crop\ (ha) \times Number\ of\ tillings\ per\ crop\ and\ per\ season\ \times Emission\ Factor_{(PM,PM_{10},PM_{2.5})} \times Tillage\ Factor(unitless)$$

Table 56: Crop Area by CCS and Crop Type for Tilling and Harvesting

Census Crop	Crop Area by CCS (ha)		
	Comox Valley A	Comox Valley B Lazo North	Comox Valley C Puntledge – Black Creek
Alfalfa_and_alfalfa_mixtures_hectares	284.0	83.0	197.0
All_other_tame_hay_and_fodder_crops_hectares	412.0	183.0	1977.0
Apples_total_area_hectares	12.0	7.0	4.0
Beets_hectares	0.0	1.0	0.0
Blueberries_total_area_hectares	4.0	2.0	15.0
Broccoli_hectares	0.0	2.0	0.0
Cabbage_hectares	0.0	0.3	0.7
Carrots_hectares	1.0	1.0	0.0
Cauliflower_hectares	1.3	0.7	0.0
Census_All_131_Barley_hectares	0.0	30.0	84.0
Census_All_131_Total_corn_44_hectares	74.7	0.0	261.3
Cherries_sweet_total_area_hectares	0.0	0.3	1.7
Corn_for_silage_hectares	74.7	0.0	261.3
Cranberries_total_area_hectares	5.3	16.0	10.7
Cucumbers_hectares	0.0	0.0	1.0
Dry onions yellow Spanish cooking etc _hectares	1.0	0.0	0.0
Fall_rye_hectares	23.0	0.0	23.0
Forage_seed_for_seed_hectares	0.0	0.0	243.0
Grapes_total_area_hectares	7.0	13.0	5.0
Green peas_hectares	1.0	0.0	0.0
Lettuce_hectares	2.4	0.6	1.0
Mixed_grains_hectares	5.0	0.0	0.0
Oats_hectares	4.8	0.0	14.3
Other vegetables 48_hectares	7.0	1.0	3.0
Other_field_crops_46_hectares	2.3	0.0	0.8
Other_fruits_berries_and_nuts_total_area_47_hectares	14.0	2.0	42.0
Pears_total_area_hectares	2.0	2.0	1.0
Peppers_hectares	0.0	0.0	1.0
Plums_and_prunes_total_area_hectares	1.0	2.0	0.0
Potatoes_hectares	1.0	26.9	67.1
Pumpkins_hectares	2.0	0.7	0.3
Raspberries_total_area_hectares	1.0	1.0	10.0
Saskatoons_total_area_hectares	0.5	0.0	0.5
Shallots and green onions_hectares	0.0	0.4	0.6
Spinach_hectares	0.8	0.3	0.0
Spring_rye_hectares	13.0	0.0	0.0
Spring_wheat_excluding_durum_hectares	0.0	0.0	1.0
Squash and zucchini_hectares	1.0	1.0	1.0
Strawberries_total_area_hectares	2.0	0.0	2.0
Sweet corn_hectares	11.5	3.5	4.0
Tomatoes_hectares	1.0	0.0	1.0
Total vegetables excluding greenhouse vegetables_hectares	19.0	28.0	16.0
Total_area_of_fruits_berries_and_nuts_hectares	43.0	57.0	85.0
Total_rye_45_hectares	0.7	0.0	0.3
Total_wheat_43_hectares	0.0	0.0	2.0

The number of tills per crop is based on the census agricultural region and the month. The number of tills (passes) for each region has been developed with expertise from Ministry of Agriculture staff as part of the BC Agricultural Air Emissions Inventory (RWDI, 2014). The number of tills per month is shown in Table 57**Error! Reference source not found.**, no tilling is done in January or December. The number of tills per season were provided by BC Ministry of Agriculture staff and divided over the months within the season or year. The tillage factor is assumed to 100% minus the percentage of area managed with no-till or zero-till practices. For the CVRD, the tillage factor was set to 76%.

Table 57: Tilling Practices per Season by Crop Category for Vancouver Island

Census Crop	Number of Tills per month									
	February	March	April	May	June	July	August	September	October	November
Alfalfa_and_alfalfa_mixtures_hectares	0.25	0.25	0.25	0.25	0.00	0.00	0.00	0.13	0.13	0.13
Apples_total_area_hectares	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Apricots_total_area_hectares	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Asparagus non-producing_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Asparagus producing_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Beets_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Blueberries_total_area_hectares	0.22	0.22	0.22	0.22	0.00	0.00	0.00	0.00	0.00	0.00
Broccoli_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Brussels sprouts_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Buckwheat_hectares	0.63	0.63	0.63	0.63	0.00	0.00	0.00	0.50	0.50	0.50
Cabbage_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Canary_seed_hectares	0.25	0.25	0.25	0.25	0.00	0.00	0.00	0.13	0.13	0.13
Canola_rapeseed_hectares	0.63	0.63	0.63	0.63	0.00	0.00	0.00	0.50	0.50	0.50
Caraway_seed_hectares	0.63	0.63	0.63	0.63	0.00	0.00	0.00	0.50	0.50	0.50
Carrots_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Cauliflower_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Celery_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Census_All_131_Barley_hectares	0.63	0.63	0.63	0.63	0.00	0.00	0.00	0.50	0.50	0.50
Census_All_131_Total_corn_44_hectares	0.75	0.75	0.75	0.75	0.00	0.00	0.00	0.25	0.25	0.25
Cherries_sour_total_area_hectares	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Cherries_sweet_total_area_hectares	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Chick_peas_hectares	1.25	1.25	1.25	1.25	1.00	1.00	1.00	0.00	0.00	0.00
Chinese cabbage_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Cucumbers_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Dry onions yellow Spanish cooking etc hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67

Census Crop	Number of Tills per month									
	February	March	April	May	June	July	August	September	October	November
Dry_field_peas_hectares	1.25	1.25	1.25	1.25	1.00	1.00	1.00	0.00	0.00	0.00
Dry_white_beans_hectares	1.25	1.25	1.25	1.25	1.00	1.00	1.00	0.00	0.00	0.00
Durum_wheat_hectares	0.25	0.25	0.25	0.25	0.00	0.00	0.00	0.13	0.13	0.13
Fall_rye_hectares	0.63	0.63	0.63	0.63	0.00	0.00	0.00	0.50	0.50	0.50
Flaxseed_hectares	0.63	0.63	0.63	0.63	0.00	0.00	0.00	0.50	0.50	0.50
Grapes_total_area_hectares	0.22	0.22	0.22	0.22	0.00	0.00	0.00	0.00	0.00	0.00
Green and wax beans_hectares	1.25	1.25	1.25	1.25	1.00	1.00	1.00	0.00	0.00	0.00
Green peas_hectares	1.25	1.25	1.25	1.25	1.00	1.00	1.00	0.00	0.00	0.00
Lentils_hectares	0.63	0.63	0.63	0.63	0.00	0.00	0.00	0.50	0.50	0.50
Lettuce_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Mixed_grains_hectares	0.63	0.63	0.63	0.63	0.00	0.00	0.00	0.50	0.50	0.50
Mustard_seed_hectares	0.63	0.63	0.63	0.63	0.00	0.00	0.00	0.50	0.50	0.50
Oats_hectares	0.63	0.63	0.63	0.63	0.00	0.00	0.00	0.50	0.50	0.50
Other vegetables 48_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Other_dry_beans_hectares	1.25	1.25	1.25	1.25	1.00	1.00	1.00	0.00	0.00	0.00
Other_field_crops_46_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Other_fruits_berries_and_nuts_total_area_47 _hectares	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Peaches_total_area_hectares	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Pears_total_area_hectares	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Peppers_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Plums_and_prunes_total_area_hectares	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Potatoes_hectares	1.25	1.25	1.25	1.25	1.00	1.00	1.00	0.00	0.00	0.00
Pumpkins_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Radishes_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Raspberries_total_area_hectares	0.30	0.30	0.30	0.30	0.19	0.19	0.19	0.65	0.65	0.65
Rutabagas and turnips_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67

Census Crop	Number of Tills per month									
	February	March	April	May	June	July	August	September	October	November
Shallots and green onions_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Soybeans_hectares	1.25	1.25	1.25	1.25	1.00	1.00	1.00	0.00	0.00	0.00
Spinach_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Spring_rye_hectares	0.25	0.25	0.25	0.25	0.00	0.00	0.00	0.13	0.13	0.13
Spring_wheat_excluding_durum_hectares	0.63	0.63	0.63	0.63	0.00	0.00	0.00	0.50	0.50	0.50
Squash and zucchini_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Sugar_beets_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Sweet corn_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Tomatoes_hectares	1.50	1.50	1.50	1.50	0.50	0.50	0.50	0.67	0.67	0.67
Total_rye_45_hectares	0.63	0.63	0.63	0.63	0.00	0.00	0.00	0.50	0.50	0.50
Total_wheat_43_hectares	0.63	0.63	0.63	0.63	0.00	0.00	0.00	0.50	0.50	0.50
Triticale_hectares	0.63	0.63	0.63	0.63	0.00	0.00	0.00	0.50	0.50	0.50
Winter_wheat_hectares	0.63	0.63	0.63	0.63	0.00	0.00	0.00	0.50	0.50	0.50

The tillage emission factor equation is shown in Equation 5. The base equation includes an empirically derived constant (5.38) multiplied by a moisture reduction factor, particle size multiplier, and the silt content. The particle size multiplier is used to estimate the fraction of PM that is PM_{10} or $PM_{2.5}$. The particle size multiplier is typically assumed to be 0.21 for PM_{10} and 0.042 for $PM_{2.5}$.

Equation 18: Tilling Emission Factor Equation

$$Emission\ Factor_{(PM,PM_{10},PM_{2.5})} = 5.38 \times Moisture\ reduction\ factor\ per\ season \times Particle\ size\ multiplier_{(PM,PM_{10},PM_{2.5})} \times Silt\ content\ per\ region\ (\%)^{0.6}$$

The moisture reduction factor reflects the precipitation accumulation which decreases the likelihood of particles becoming airborne. Moisture reduction factors were generated by month for each of the eight agricultural regions (based on the Census of Agriculture regions) for the detailed agricultural emissions inventory for the MoA. The moisture reduction factors for Vancouver Island – Coast was used for the CVRD and are shown in Table 58.

Table 58: Moisture Reduction Factors for Tilling Emission Factor Equation

Month	Moisture Reduction Factor (unitless)
January	0.00
February	0.00
March	0.00
April	0.20
May	0.50
June	0.50
July	0.75
August	0.50
September	0.50
October	0.00
November	0.00
December	0.00

The silt content is a percentage based on typical soil type. The silt content values for each CCS were developed using data from the Soil Landscapes of Canada version 3.2, developed by Agriculture and Agri-Food Canada and shown in Table 12.

Table 59: Silt Content by CCS

CCS	Silt content (%)
Comox Valley A	35.0
Comox Valley B Lazo North	43.6
Comox Valley C Puntledge - Black Creek	48.4

4.1.3 Harvesting

Particulate emissions from crop production arise from soil cultivation and harvesting. Emissions depend on crop, soil type, cultivation method, and weather conditions before and while working. Environment Canada's national air emissions inventory includes emission quantities and methods for agricultural tilling and wind erosion, but does not specifically include particulate emissions from harvesting.

The emission method from the BC Agricultural Air Emissions Inventory (RWDI, 2014) was used for this inventory. The general emission equation is shown in Equation 19. It is assumed that each crop is harvested only once annually. The PM_{10} emission factors are shown in Table 60. The California Air Resources Board $PM_{2.5}$ to PM_{10} ratio of 0.15 for agricultural harvesting (Countess Environmental, 2006) was used to estimate $PM_{2.5}$. And total PM was assumed equal to PM_{10}. The area by crop type is provided inTable 56.

Equation 19: PM_{10} Emissions from Agricultural Harvesting

$$Emissions_{PM_{10}}(kg) = Annual\ crop\ area\ (ha) \times Number\ of\ harvests\ \times Emisison\ factor\ \left(\frac{kg}{ha}\right)$$

Table 60: PM_{10} Emission Factors for Harvesting by Crop Classification Groupings

Crop Classification Category Groupings	PM_{10} Emission Factor (kg/ha)
Corn	0.12
Grass/Hay/Alfalfa	0.25
Cereal, Grain & Oilseed	0.47
Pasture	0.00
Peas/Beans/Early Potatoes	0.31
All Other Vegetables	0.03
Turf	0.00
Tree Fruits Vines & Berries	0.01

4.1.4 Wind Erosion

Particulate emissions result from wind erosion of tilled agricultural lands. Particulate emissions from wind erosion of agricultural lands were calculated using the Wind Erosion Equation (WEQ) shown in Equation 20. The WEQ relies on crop-specific and region-specific factors. Crop specific factors include the surface roughness factor, the unsheltered field width factor and the vegetative factor. Crop-specific factors as developed for the BC Agricultural Air Emission inventory (RWDI, 2014) were used. Region-specific factors including the soil erodibility and climatic factor were developed readily for the Comox Valley.

Equation 20: Wind Erosion Equation

$$Emissions\ Factor_{PM_{10}}\ \left(\frac{ton}{acre\ year}\right) =$$
$$[Total\ suspended\ particulate\ portion\ (0.025)] \times I\ \left[Soil\ Erodibility\ \left(\frac{ton}{acre\ year}\right)\right] \times$$
$$K\ [Surface\ roughness\ factor] \times C\ [Climatic\ factor] \times L'^{[Unsheltered\ field\ width\ factor]} \times$$
$$V'[Vegetative\ cover\ factor]$$

Total PM was speciated to PM_{10} and $PM_{2.5}$ using factors from the WRAP Fugitive Dust Handbook (Countess Environmental, 2006). The PM_{10}/PM ratio for wind erosion is 0.5. The $PM_{2.5}$/PM_{10} ratio for windblown fugitive dust is 0.15.

s an aid in understanding the mechanics of this equation, the soil erodibility factor or “I”, may be thought of as the basic erodibility of a flat, very large, bare field in a climate highly conducive to wind erosion (i.e., high wind speeds and high temperature with little precipitation). This factor was initially established for the WEQ for a large, flat, bare field in Kansas that has relatively high winds along with hot summers and low precipitation. The parameters K, C, L’ and V’ may be thought of as reduction factors for a ridged surface, a climate less conducive to wind erosion, smaller-sized fields, and vegetative cover, respectively, to adjust the equation for applicability to field conditions that differ from the original Kansas field.

Individual land parcels were assigned soil textural classes (Table 61) using a standard soil texture triangle, shown in Figure 13 (Soil Classification Working Group, 2013) and soil erodibility factor, “I”, using GIS. The percentage of particles in three size groupings: silt, sand and clay were extracted from Agriculture and Agri-Food Canada’s Soil Landscapes of Canada National Soil DataBase (Agriculture and Agri-Food Canada, 2010). Area-weighted erodibility factors, “I”, were determined in GIS for each of the three CCSs and are shown in Table 61.

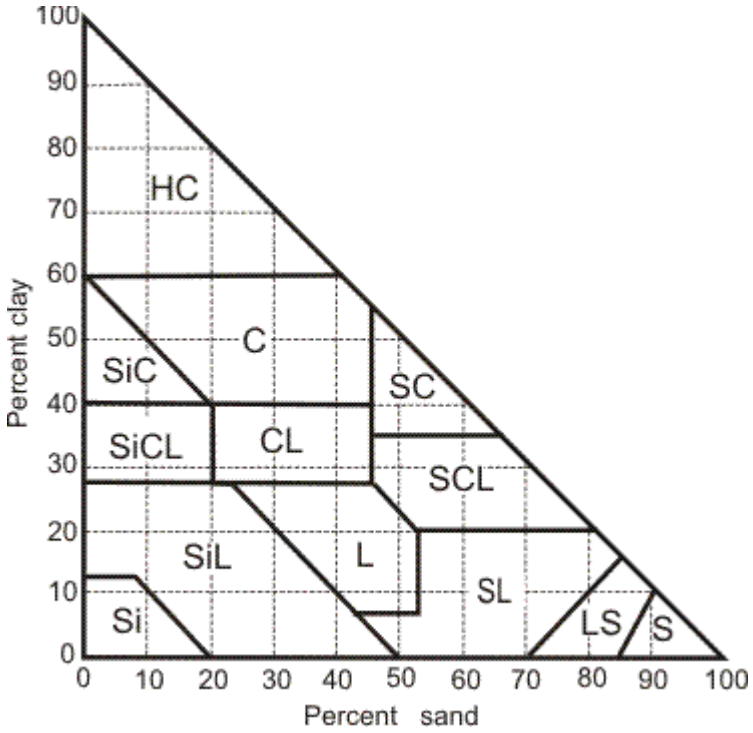

Figure 13: Soil Texture Triangle

Table 61: Soil Erodibility, I, for Various Soil Textural Classes

Predominant Soil Textural Class	Erodibility (tons/acre-year)
Sand	220
Loamy Sand	134
Sandy Loam, Clay, Silty Clay	86
Loam, Sandy Clay Loam, Sandy Clay	56
Silty Loam, Clay Loam	47
Silty Clay Loam, Silt	38

Table 62: Erodibility Factor, I per CCS

CCS	Erodibility factor (tons per year)
Comox Valley A	84
Comox Valley B Lazo North	65
Comox Valley C Puntledge - Black Creek	56

The surface roughness factor (K), unsheltered field width (L'), and vegetative cover (V') were assigned by crop type using values developed by the US EPA (US EPA, 1974), as shown in Table 63.

Table 63: Wind Erosion Variables by Crop (USA EPA, 1974)

Crop	K	L, ft.	V, lb/acre	L*, ft.
Alfalfa	1	1000	3000	250
Barley	0.6	2000	1100	500
Beans	0.5	1000	250	250
Corn	0.6	2000	500	500
Grain Hays	0.8	2000	1250	500
Oats	0.8	2000	1250	500
Potatoes	0.8	1000	400	250
Rye	0.6	2000	1250	500
Vegetables	0.6	500	100	125
Wheat	0.6	2000	1350	500

Monthly climatic factors, C, were taken from the BC Agricultural Air Emissions Inventory (RWDI, 2014) for Vancouver Island - Coast and are shown in Table 64.

Table 64: Wind Erosion Equation, Monthly climatic factor, C

Month	Climatic Factor, C
January	0
February	0
March	0
April	0.01
May	0.02
June	0.04
July	0.14
August	0.06
September	0.01
October	0
November	0
December	0

Total particulate matter (PM), PM_{10}, and $PM_{2.5}$ emissions are calculated using the monthly emission factors generated from Equation 7 multiplied times the area per crop. The area of each relevant crop was taken from the 2011 Census of Agriculture and is shown in Table 65.

Table 65: Crop Area by CCS for Wind Erosion Calculations

Wind Erosion Crop Grouping	Census Table	Census Fields	Crop Area (hectares)		
			Comox Valley A	Comox Valley B Lazo North	Comox Valley C Puntledge – Black Creek
Alfalfa	Hay and field crops 2011	Alfalfa_and_alfalfa_mixtures_hectares	284	83	197
Barley	Hay and field crops 2011	Barley_hectares	0		84
Grain Hays	Hay and field crops 2011	Mixed_grains_hectares		183	1977
		Canola_rapeseed_hectares			
		Flaxseed_hectares			
		All_other_tame_hay_and_fodder_crops_hectares			
Potatoes	Hay and field crops 2011	Potatoes_hectares	1		
Vegetables	Vegetables excluding greenhouse	Total vegetables excluding greenhouse vegetables_hectares	19	28	

4.1.5 Livestock Movements

Particulate emissions from animal production result from animal housing and moving facilities. The emissions methodology for PM from cattle, swine, poultry and horses was selected from the " Review of gricultural ir Emissions Estimates for the Lower Fraser Valley of British Columbia" (Poon & Robbins, 2006). The transfer of methodology from the LFV to CVRD assumes that agricultural livestock production operates similarly across the West Coast of BC. The number of livestock was taken from the 2011 Census of Agriculture and is shown in Table 66.

Table 66: Number of Livestock by CCS

Livestock	Number of Livestock (head)		
	Comox Valley A	Comox Valley B Lazo North	Comox Valley C Puntledge – Black Creek
Horses	74	19	255
Swine	97	71	603
Poultry	3,857	1,232	18,586
Cattle	48	63	112

The recommended method for cattle assumes that only cattle in beef feedlots generate significant PM and that the best conservative estimate of the number of cattle in beef feedlots is based on the number of beef steers. The number of steers was taken from the 2011 Census of Agriculture and is shown in Table 66

The published PM_{10} emission factor is 11 kg/1000 head/day, with particle size multipliers of 3.0 for PM and 0.15 for $PM_{2.5}$ resulting in the emission factors shown in Table 67. A climate correction factor of 0.572 was generated for the Comox Valley which is equal to fraction of days with less than 2.0 mm of rain in the region.

Equation 21: Particulate Matter Emissions from Cattle

$$PM_A = \frac{Number\ of\ Steers}{1000\ head} \times EF_{PM10,daily} \times Particle\ size\ multiplier_A \times climate\ correction\ factor \times days\ in\ feedlots\ (365)$$

Table 67: Particulate Matter Emission Factors for Cattle

Pollutant	Effective Emission Factor (kg/1000 steer/day)
PM	33
PM_{10}	11
$PM_{2.5}$	1.65

The recommended methodology for swine uses Equation 22 with a PM emission factor of 1.854 mg/hr/kg swine. PM_{10} to PM and $PM_{2.5}$ to PM ratios of 0.5 and 0.1 were used. The mass per animal is shown in Table 68.

Equation 22: Particulate Matter Emissions from Swine

$$PM = Number\ of\ swine\ (head) \times Mass\ per\ animal\ (\frac{kg}{head}) \times EF_{PM,hourly} \times Hours\ per\ year\ (8760) \times Particle\ size\ conversion$$

Table 68: Assumed Mass of Animal (Swine)

Census Livestock Category		Number of head	Mass per head kg/head
Swine	Boars_number	9	230
	Sows_and_gilts_for_breeding_number	80	170
	Nursing_and_weaner_pigs_number	270	47
	Grower_and_finishing_pigs_number	412	47

The recommended method for poultry depends on the length of production cycle and varies for pullets and laying hens versus broilers, turkeys, and other poultry. The emission method varied between layers (pullets under 19 weeks intended for laying, laying hens19 weeks and over, and layer and broiler breeders) and non-layers (broilers roasters and Cornish, turkeys, and other poultry). The emissions from layers were calculated by bird type using Equation 10. The number of livestock, PM emission factors, PM_{10} to PM and $PM_{2.5}$ to PM ratios, and hours per production cycle for layers is shown in Table 69.

The emissions from broilers (non-layers) were calculated by bird type using Equation 24. The number of livestock, PM emission factors, PM_{10} to PM and $PM_{2.5}$ to PM ratios, and hours per production cycle for broilers (non-layers) is shown in Table 70.

Equation 23: Particulate Matter Emissions from Poultry Layers

$$PM = Number\ of\ birds\ (head) \times Mass\ per\ animal\ (\frac{kg}{head}) \times EF_{PM,production\ cycle}\ (\frac{\frac{mg}{hr}}{kg\ bird}) \times Hours\ of\ production\ per\ year\ (8760) \times Particle\ size\ conversion$$

Equation 24: Particulate Matter Emissions from Poultry Broilers (non-layers)

$$PM = Number\ of\ birds\ (head) \times Mass\ per\ animal\ (\frac{kg}{head}) \times EF_{PM,production\ cycle}\ (\frac{\frac{mg}{hr}}{kg\ bird}) \times Hours\ of\ production\ per\ day\ \times (Days\ of\ production + days\ of\ cleanout) \times cycles\ per\ year \times Particle\ size\ conversion$$

Table 69: Emission Equation Factors for Poultry Layers

Census Livestock Category		Number of Head	Mass per Head kg/head	EF for Production Cycle mg/hr/kg	Hours per Production hr/yr
Poultry	Pullets under 19 weeks, intended for laying (63)	1605	0.75	1.266	8760
	Laying hens, 19 weeks and over (64)	5215	1.8	1.266	8760
	Layer and broiler breeders (pullets and hens) (65)	333	1.8	1.266	8760

Table 70: Emission Equation Factors for Poultry Broilers (non-layers)

Census Livestock Category		Number of Head	Mass per Head kg/head	EF for Production Cycle mg/hr/kg	Hours/Day hr/day	Days Production Days	Cleanout Days per Cycle Days	Cycles per Year Cycles/Year
Poultry	Broilers, roasters and Cornish (66)	11870	1	5.61	24	40	2	6.5
	Turkeys (67)	2067	4.9	5.61	24	75	2	3.5
	Other poultry	2585	1.8	5.61	24	75	2	3.5

The recommended method for horses separates the animals into horses in riding rings and in paddocks. This method uses the total number of horses from the Census of Agriculture and assumes a split between horses in riding rings (75%) and horses in paddocks (25%). The assumed splits are based on data from the Lower Fraser Valley with an assumption that the CVRD has similar splits. The general emission equation is shown in Equation 25 and the emission factors are shown in Table 71.

Equation 25: Particulate Matter Emissions from Horses

$$Emissions\ (kg) = Number\ of\ horses(head) \times EF(\frac{kg}{head})$$

Table 71: Particulate Matter Emission Factors for Horses

Pollutant	Horse Emission Factor (kg/head)	
	Paddocks	Riding Rings
PM	2.15	1.61
PM_{10}	0.72	0.54
$PM_{2.5}$	0.11	0.08

4.1.6 Crop Residue Burning

Open burning is one disposal option for excess vegetation (crop residue) from crop production. Emissions are based on an assumption of the amount of crop residue produced, the proportion of this residue which is disposed of by incineration, and an emission factor. Emissions from the burning of crop residue were calculated using Equation 26. The amount of crop residue produced is calculated using the land area in crops (by crop category) and an assumed rate of residue production (also called the fuel loading) per crop type.

Equation 26: Agricultural Waste Burning Equation

$$Emissions\ (kg) = Crop\ area\ (hectares) \times Fuel\ Loading\ \left(\frac{tonne\ residue}{hectare}\right) \times Percentage\ of\ dry\ crop\ residue\ burned\ (\%) \times Emission\ Factor\ \left(\frac{kg}{tonne\ residue}\right)$$

Crop residue production (fuel loadings) were assigned by crop category. The percentage of dry crop residue burned in various regions across the province was developed as part of the BC Agricultural Air Emissions Inventory to be 0.5%. PM emission factors per crop were selected from the California Air Resources Board and grouped into crop categories relevant to BC (California Air Resources Board, 2014). Emission factors and fuel loadings per crop type are shown in Table 72.

Table 72: Crop Residue Burning Emission Factors and Waste Production Rates

Land Cover Category	Emission Factors (kg/tonne)			Fuel Loading (tonnes/hectare)
	PM	PM_{10}	$PM_{2.5}$	
Corn	5.8	5.7	5.4	9.4
Field Crops - Vegetables	8.7	8.5	8.2	4.7
Orchard Crops	4.0	4.0	3.7	5.1
Vine Crops	3.2	3.2	3.0	4.7
Field Crops - Hay	8.7	8.5	8.2	4.7
Grapes	3.2	3.2	3.0	14.0

The crop area by crop type was taken from 2011 Census of Agriculture for the census consolidated subdivisions (CCSs) within the CVRD. Crop areas for specific crop fields and tables were grouped into crop categories matching the emission factors as shown in Table 73. The total area in hectares for each crop category and for each CCS in the CVRD are shown in Table 74.

Table 73: 2011 Census Tables and Fields per Crop Categories

Land Cover Category	Census Table	Census Fields	
Orchard Crops	Fruits Berries Nuts	Apples_total_area_hectares	Cherries_sour_total_area_hectares
		Pears_total_area_hectares	Peaches_total_area_hectares
		Plums_and_prunes_total_area_hectares	Apricots_total_area_hectares
		Cherries_sweet_total_area_hectares	
Grapes	Fruits Berries Nuts	Grapes_total_area_hectares	
Corn	Hay and Fieldcrops	Total_corn_44_hectares	
Field Crops - Vegetables	Vegetables excluding greenhouses	Total vegetables excluding greenhouse vegetables_hectares	
Field Crops - Hay	Hay and Fieldcrops	Total_wheat_43_hectares	Alfalfa_and_alfalfa_mixtures_hectares
		Oats_hectares	All_other_tame_hay_and_fodder_crops_hectares
		Barley_hectares	Forage_seed_for_seed_hectares
		Mixed_grains_hectares	Potatoes_hectares
		Total_rye_45_hectares	Mustard_seed_hectares
		Canola_rapeseed_hectares	Sunflowers_hectares
		Soybeans_hectares	Canary_seed_hectares
		Flaxseed_hectares	Ginseng_hectares
		Chick_peas_hectares	Buckwheat_hectares
		Lentils_hectares	Sugar_beets_hectares
		Dry_field_peas_hectares	Caraway_seed_hectares
		Dry_white_beans_hectares	Triticale_hectares
		Other_dry_beans_hectares	Other_field_crops_46_hectares
Vine Crops	Fruits Berries Nuts	Strawberries_total_area_hectares	Blueberries_total_area_hectares
		Raspberries_total_area_hectares	Saskatoons_total_area_hectares
		Cranberries_total_area_hectares	Other_fruits_berries_and_nuts_total_area_47_hectares

Table 74: Crop Area by Crop Category and CCS

CCS	Land Cover Category						Fuel Loading (tonnes/ hectare)
	Corn	Field Crops - Vegetables	Orchard Crops	Vine Crops	Field Crops - Hay	Grapes	
Comox Valley A	74.7	19	15	26.8	707.4	7	9.4
Comox Valley B (Lazo North)	0	28	11.3	21	322.9	13	4.7
Comox Valley C (Puntledge - Black Creek)	261.3	16	6.6	80.2	2584.7	5	5.1

APPENDIX 2: FIRE SURVEY REQUEST

Questions	Response
Does your fire service area allow open/backyard burning at some point during the year (or is it completely banned)?	*Yes/No*
If yes, please continue	
Does your fire service area allow open/backyard burning **without** a permit?	*Yes/No*
If so, which months is this allowed?	*Provide a range of months*
Can you estimate the amount of burning that occurs **without** a permit during this time?	*Use whatever description is most useful (e.g. "about twice the amount that occurs in months requiring permit", "about 100 fires", etc.)*
Does your fire service area issue permits for open/backyard burning?	*Yes/No*
If yes, during what months are these permits issued	*Provide a range of months*
If yes, how many permits were issued in **2015**?	*If exact values are not available please provide an estimate of the typical number of permits issued.*
If yes, how many permits were issued in **2014**?	*If exact values are not available please provide an estimate of the typical number of permits issued.*
Does this fire service area have any other specific burning requirements?	*e.g. restrictions on pile size, ventilation index, etc.*
Approximately how many complaints or reports of illegal burning do you receive per year?	
Given your experience, can you estimate about how many piles (with and without permit) are burned in your fire service area annually?	*Burns without permit:*
	Burns with permit:
Do you have any additional comments or insights on burning behaviours in your fire service area?	

What types of material do you typically observe being burned in your fire service area? (check all that apply and write in additional)	***Yes*** ✓	***No*** ✓
Wood or wood by-products (brush, waste wood)		
Grass or leaf litter (leaves, clippings, old grass)		
Landclearing (trees, bushes, fields)		
Agricultural waste (crop cover, trimmings/prunings)		
Residential garbage (including newspaper and cardboard)		
Hazardous domestic waste (plastics, paint, rubber)		
Other (please specify): _____		