Draft

2001 and 2002 Inventory of Particulate Matter Emissions for the Bulkley Valley – Lakes District Airshed

Prepared By
Ben Weinstein
Air Resources Technician
British Columbia Ministry of Water, Land and Air Protection
Skeena Region
Smithers, BC

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Abstract

An emission inventory is an accounting of all sources of air emissions within a defined geographic area. Emission inventories are essential management tools. A micro-emissions inventory is a localized inventory of emissions on a ‘small scale’, which in the case of the Bulkley Valley – Lakes District (BVLD), is 35,000 km^2. This report describes the methods and calculations used to compile emission totals for the BVLD for the years 2001 and 2002. It includes emissions from seven categories, identified by the Community Working Groups of the Bulkley Valley – Lakes District’s Airshed Management Plan as significant contributors of pollution in the BVLD. Only particulate matter emissions in the form of TPM, PM_{10}, and $PM_{2.5}$ are included in this micro-emissions inventory, as it is accepted that this pollutant is the typical driver of air quality degradation in the airshed.

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Comments

We welcome any comments you might have. Please send them care of:

Benjamin Weinstein, BSc
Air Resources Technician
Ministry of Water, Land and Air Protection
Box 5000, 3726 Alfred Avenue
Smithers, B.C. V0J 2N0
Phone: 250.847.7224
Toll free: 1866.362.4986
Fax: 250.847.7591
Ben.Weinstein@gems1.gov.bc.ca

Or

Ian D. Sharpe, RPBio
Head Environmental Quality Section
WLAP Environmental Protection Division
Box 5000 Smithers BC V0J 2N0
Phone (250) 847-7251
Cell (250) 877-9237
Fax (250) 847-7591
Ian.Sharpe@gems5.gov.bc.ca

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List of Acronyms

AEIBC – Air and Emissions Information of British Columbia
AMP – Airshed Management Plan
BFP – Babine Forest Products
BRN – burn reference number
BVLD – Bulkley Valley – Lakes District
Canfor – Canadian Forest Products
CFFPIWC – Conversion Factors for the Forest Products Industry in Western Canada
CFP – Cheslatta Forest Products
CWG – Community Working Group
DLFP – Decker Lake Forest Products
EIIP – Emission Inventory Improvement Program
EIIS – Emission Inventory Improvement Strategy
FD – forest district
FERA – Fire and Environmental Research Applications Team
HFP – Houston Forest Products
HHV – higher heating value
MCD – moisture content dry basis
MCW – moisture content wet basis
MOF – the Ministry of Forests
NPRI – National Pollutant Release Inventory
PFP – permit fee parameter
PIR – Pacific Inland Resources
PM – particulate matter
PM_{10} – particulate matter with a diameter less than or equal to 10 micrometers
$PM_{2.5}$ – particulate matter with a diameter less than or equal to 2.5 micrometers
RWBEBC – Residential Wood Burning Emissions in British Columbia
TPM – total suspended particulate matter of all sizes
US EPA – the United States Environmental Protection Agency
USFS – the United States Forest Service
WLAP – the Ministry of Water, Land and Air Protection

1) Introduction

The Ministry of Water, Land and Air Protection (WLAP) initiated the airshed planning process for the Bulkley Valley – Lakes District (BVLD) in the fall of 2002. Community Working Groups (CWGs) were formed in 4 communities to identify and address local air quality concerns related to particulate matter (PM) emissions. In total, the CWGs consisted of approximately 80 active and "information only" stakeholders from a variety of different interest groups including government, industry, small business, non-governmental organizations and the general public. Additional working groups were subsequently formed which led to a Resource Management Burning Subcommittee and a Road Dust Forum to assist in addressing these source-specific concerns raised by the CWGs on an airshed wide basis. As of the spring 2004, the airshed planning process entered a 5-year implementation phase. More information, including the BVLD Airshed Management Plan (AMP) entitled *Community Action Plan for Clean Air*, can be obtained from www.bvldamp.ca.

The CWGs identified seven source categories as significant contributors of PM emissions in the BVLD. The selection of these seven categories was based on both scientific evidence and local view points derived from observation.

These seven categories, as outlined in the BVLD AMP are

1. Beehive Burners
2. Other Regulated Industrial Sources
3. Forest Harvest Debris Burning
4. Agricultural, Land Development and Small Sawmill Debris Burning
5. Residential and Commercial Space Heating
6. Backyard Burning
7. Road Dust (from traction materials used on paved roads)

In order to understand more of the 'science' behind these emission sources it was necessary to compile a micro-emissions inventory (MEI) for the BVLD. In the MEI, all permitted sources have been combined, reducing the number of categories to six. Emission estimates for the years 2001 and 2002 (referred to as 'the inventory period') are grouped into the following categories:

1. Major Licensee Resource Management Debris Burning
2. Small Licensee, Agricultural and Land Development Debris Burning
3. All Permitted Source Emissions (including the beehive burners)
4. Residential Wood Burning
5. Road Dust (paved roads)
6. Backyard Burning

Only these source categories are currently included in the BVLD MEI. Other sources may be included at a later time. Unlike other emission inventories, the MEI focuses solely on emissions of PM. While sources in the MEI emit more than just PM, air quality in the BVLD is typically driven by this pollutant. This is a stand alone document but does have other uses. Once assembled, information in this inventory can be used for ambient assessment, airshed management and also dispersion modelling with CALPUFF.

As dispersion modelling was a major driver behind the need to develop a MEI, temporal and spatial allocation methodology (referred to as 'distribution') are included in each chapter. While distribution does not exclusively pertain to modelling, recommendations of how to properly utilize emission estimates from each source for dispersion modelling (specifically CALPUFF) are included in the 'Distribution' Section of each chapter. Dispersion modelling input data (in Microsoft Excel format) for each source in the MEI is available on a CD accompanying this report. Copies of this CD can be obtained from any of the names in the MEI's 'Comments' Section (page iv).

This MEI follows the principal guidelines outlined in the RWDI West Inc. 2003 report *Bulkley Valley – Lakes District Emission Inventory Improvement Strategy*. (RWDI 2003) It also involves collaboration with WLAP's Water, Air and Climate Change Branch in Victoria, especially for home heating emission estimates, road dust estimates and aspects of the permitted source emission estimates. Source background information, data development methodology (referred to as 'Summary of Source Development') as well as temporal and spatial allocation methodology (referred to as 'Distribution') are all included in the MEI.

It is important to understand that results obtained in this MEI are estimates and not irrefutable data. Indeed, some source category estimates are highly variable. Results presented should be analysed collectively as relative proportions and not as specific or exact numbers.

a) Study Area

At 35,000 km^2, the Bulkley Valley – Lakes District Airshed is very large. It is the largest airshed in the province for which dispersion modelling is currently being performed.

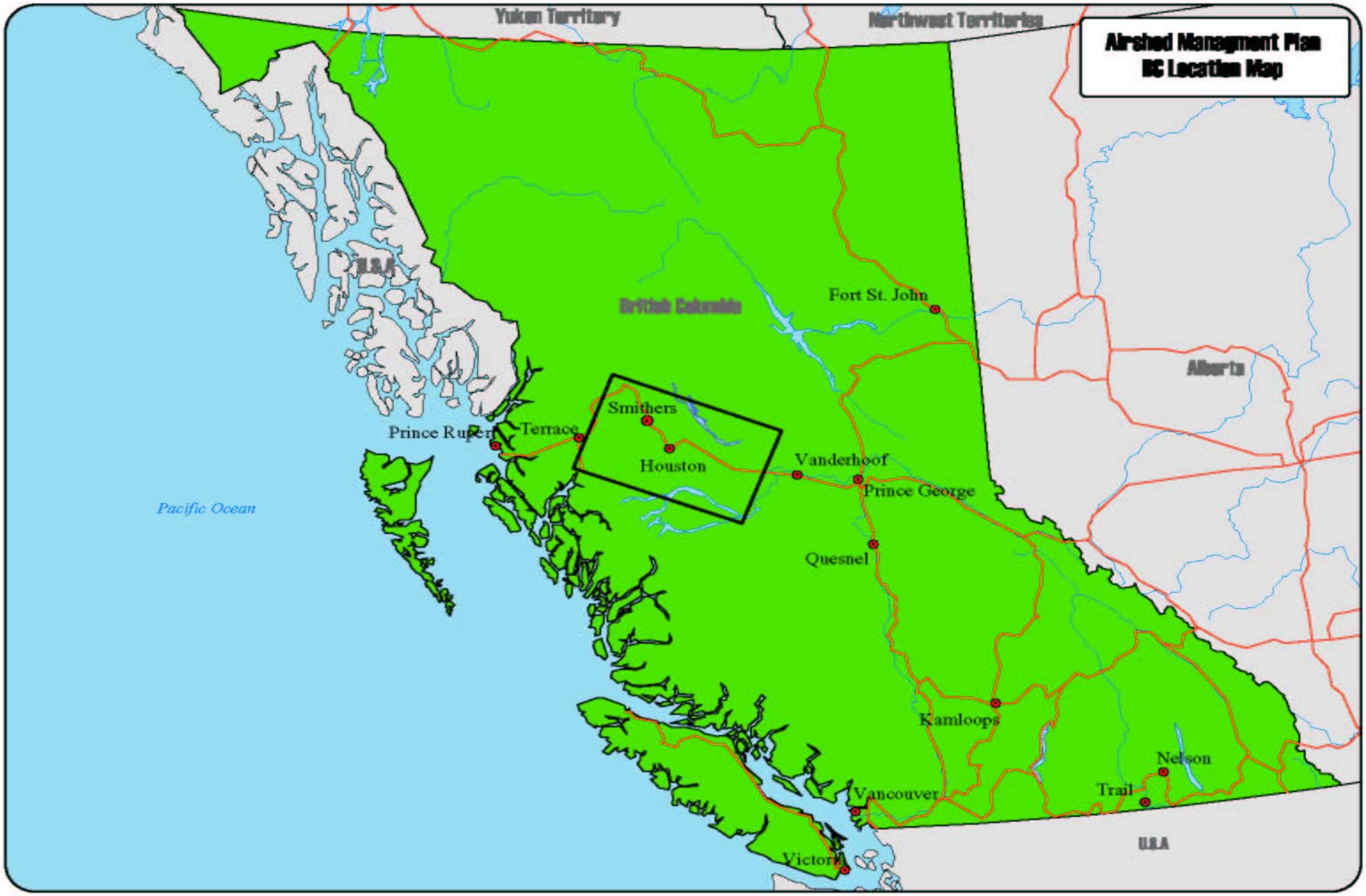

Figure 1 – The BVLD in British Columbia

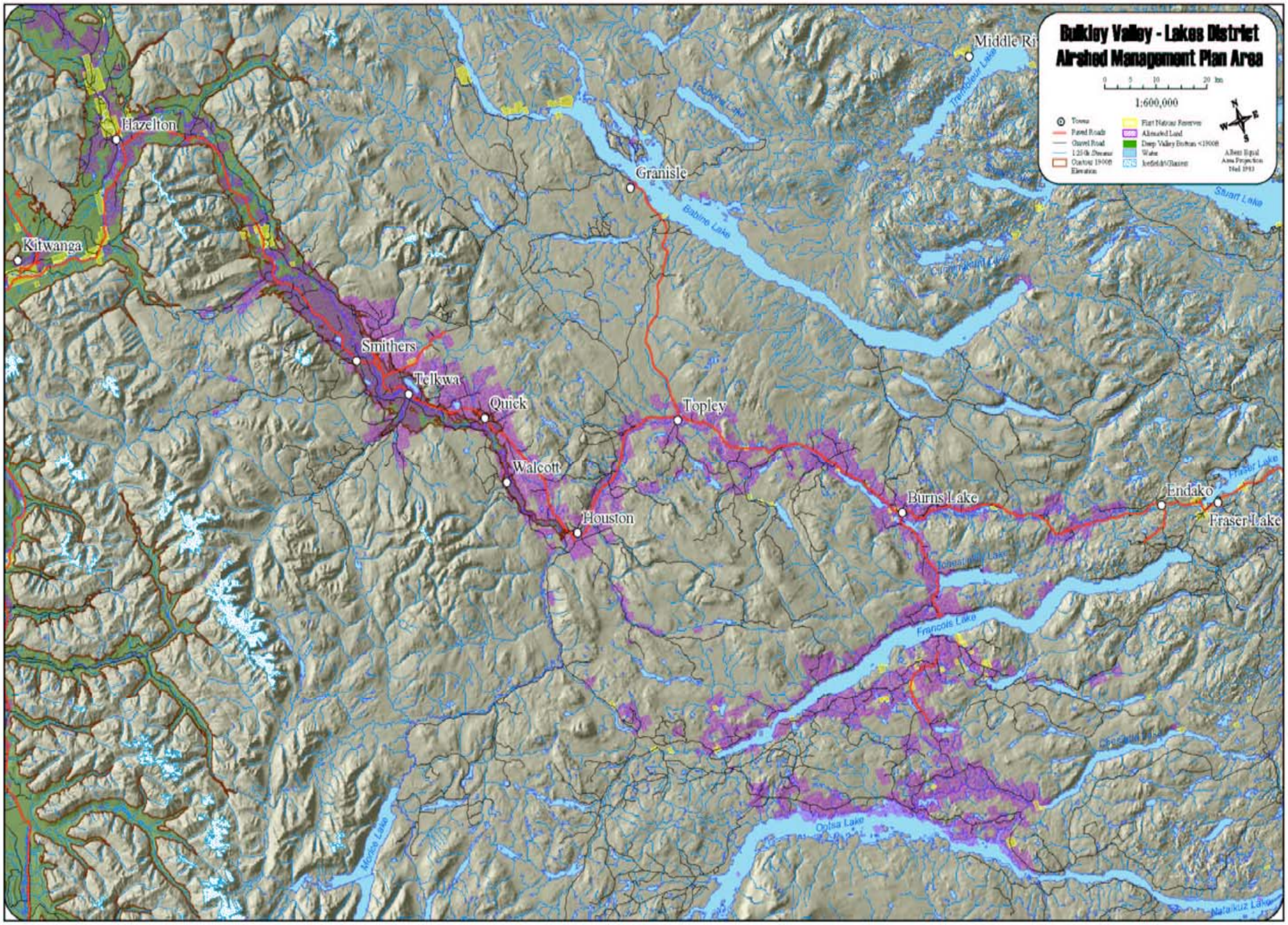

Figure 2 – The BVLD close up

b) Contaminants Inventoried

Emissions of PM including total particulate matter (TPM), PM_{10} and $PM_{2.5}$ are the only pollutants currently included in the MEI. Environment Canada's National Pollutant Release Inventory (NPRI)[1] and WLAP's *2000 British Columbia Emissions Inventory of Criteria Air Contaminants: Methods and Calculations* (Wakelin 2004) define the above pollutants as:

- **i)** **Total particulate matter**, **TPM** (also called TSP or Part), is defined as total suspended particulate matter of all sizes,
- **ii)** **PM_{10}**, particulate matter with aerodynamic diameters less than or equal to 10 micrometers (can be considered inhalable particulate) and
- **iii)** **$PM_{2.5}$**, particulate matter with aerodynamic diameters less than or equal to 2.5 micrometers.[2] $PM_{2.5}$, also known as fine particulate "is the fraction of particulate matter recognized as having the greatest effect on human health."[3]

TPM values in the MEI include the size fractions for PM_{10} as well as $PM_{2.5}$. Similarly, PM_{10} values in the MEI include the size fractions for $PM_{2.5}$.

PM exists in either solid or liquid form. Large PM can be seen and is often identified as dust or dirt, while small, fine particles must be identified with a microscope. PM can be emitted directly into the atmosphere from combustion sources such as wood burning but can also result from non-combustive sources like road dust or tire wear.[4] When inhaled, the finer fractions of PM, defined above as $PM_{2.5}$ as well as the courser fraction PM_{10} have been associated with many adverse cardio-respiratory health effects such as increased risk of heart attacks, risk of pneumonia, aggravation of chronic lung disease, increased risk of lung cancer and reduced survival.[5]

Chapter 2 of the BVLD AMP is entitled Fine Particulate Pollution. For more information visit the BVLD AMP Website at www.bvldamp.ca. All chapters of *Community Action Plan for Clean Air* can be downloaded from http://www.bvldamp.ca/html/current.htm.

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[1] NPRI's Criteria Air Contaminants online glossary, http://www.ec.gc.ca/pdb/cac/cac_gloss_e.cfm.
[2] Wakelin, 2004, p3
[3] BVLD AMP, 2004, 1-1
[4] U.S. EPA, Understanding Particle Pollution, http://www.epa.gov/airtrends/pm.html.
[5] BVLD AMP, 2004, 2-1

c) General Emissions Formula

In most cases, emissions are calculated through the formula:

$$(1.1)\ E_{PM} = BQ \times \frac{EF_{PM}}{1000}$$

where $E_{PM}(t)$ are the emissions of PM (either TPM, PM_{10} or $PM_{2.5}$),

$BQ(t)$ is the base quantity (of fuel burned) and

$EF_{PM}\left(\frac{kg}{t}\right)$ is the emission factor of PM (either TPM, PM_{10} or $PM_{2.5}$).

It should be noted that there are uncertainties in both the base quantities and emission factors for every source in the MEI, but that these uncertainties have been minimized as much as possible.

d) Final Emissions Breakdown

Emission values presented below (in Tables 1 & 2 as well as Figures 3-8) represent each chapter's most comprehensive totals. Refer to the individual chapters for detailed emission outlines.

Table 1 – 2001 emission totals for the BVLD airshed (tonnes)

2001 Emission Totals For the BVLD Airshed	TPM	PM_{10}	$PM_{2.5}$
Major Licensee Resource Management Debris Burning	2104	1491	1270
Small Licensee, Agricultural and Land Clearing Debris Burning	564	402	348
Permitted Sources (other than Beehive Burners)	2971	1676	703
Beehive Burners	1654	905	665
Residential Heating	572	540	540
Road Dust	9,726	1,864	446
Backyard Burning	15.6	12.5	11.4
Total	TPM	PM_{10}	$PM_{2.5}$
	17607	6890	3983

Table 2 – 2002 emission totals for the BVLD airshed (tonnes)

2002 Emission Totals For the BVLD Airshed	TPM	PM_{10}	$PM_{2.5}$
Major Licensee Resource Management Debris Burning	2370	1679	1430
Small Licensee, Agricultural and Land Clearing Debris Burning	964	693	598
Permitted Sources (other than Beehive Burners)	2853	1625	675
Beehive Burners	1760	963	708
Residential Heating	572	540	540
Road Dust	9,726	1,864	446
Backyard Burning	15.6	12.5	11.4
Total	TPM	PM_{10}	$PM_{2.5}$
	18260	7376	4408

2001 Emission Totals for the BVLD Airshed

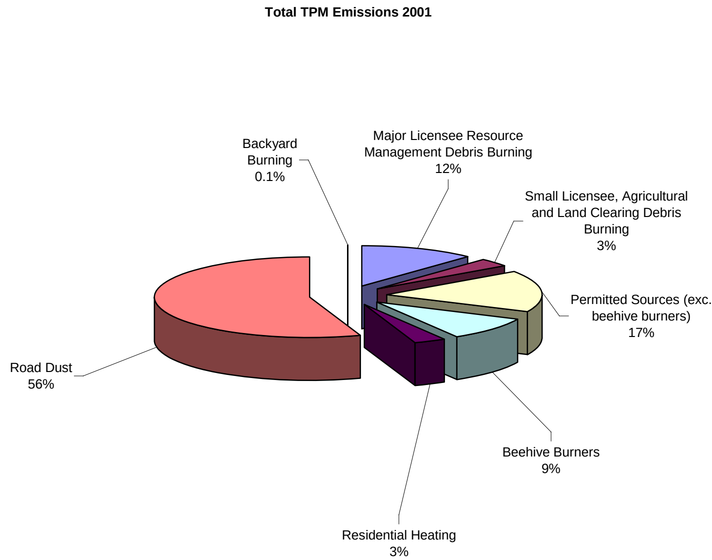

Figure 3 – Total TPM emissions in 2001

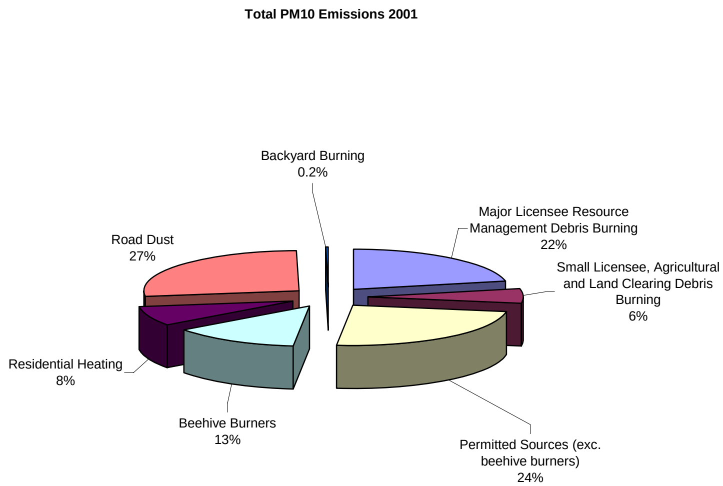

Figure 4 – Total PM10 emissions in 2001

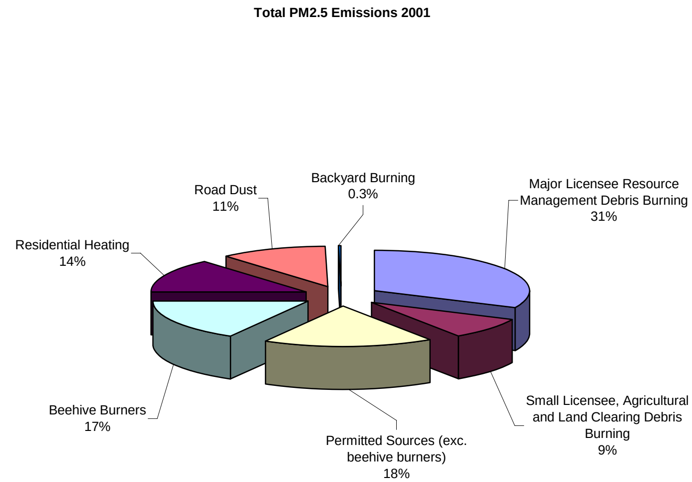

Figure 5 – Total PM2.5 emissions in 2001

2002 Emission Totals for the BVLD Airshed

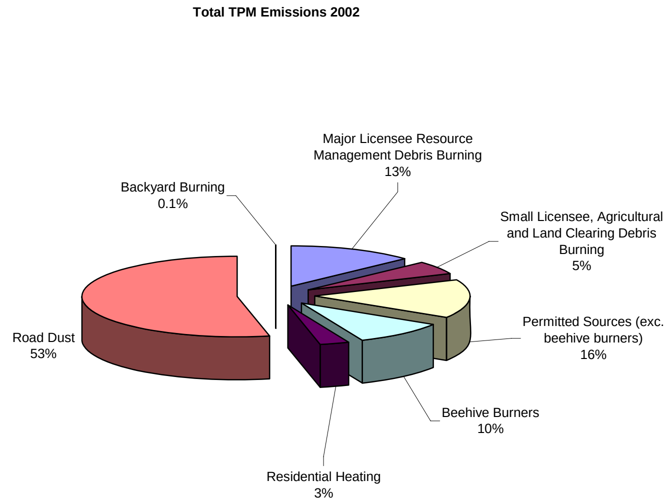

Figure 6 – Total TPM emissions in 2002

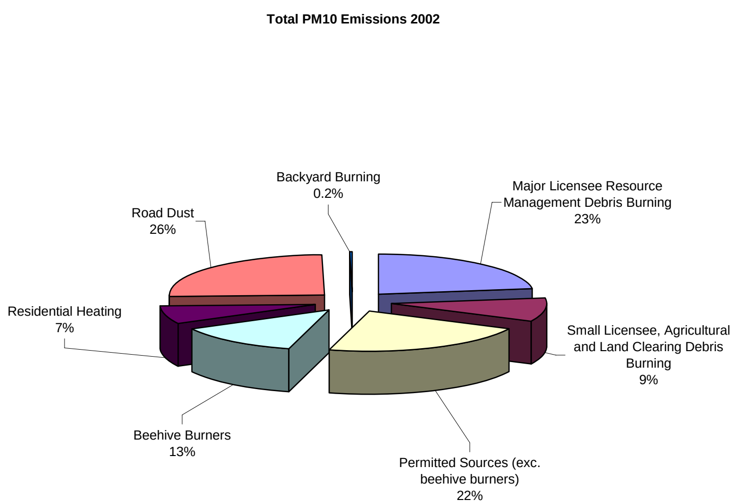

Figure 7 – Total PM10 emissions in 2002

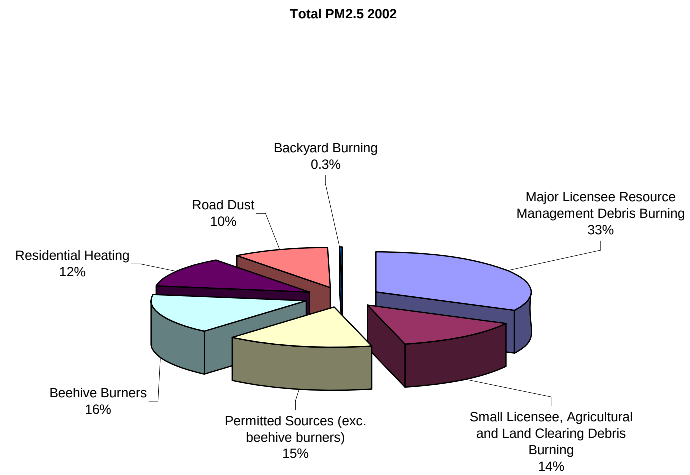

Figure 8 – Total PM2.5 emissions in 2002

2) Major Licensee Resource Management Debris Burning

a) Background

Economics and operational practicalities of the forestry sector dictate that not all wood harvested in cut blocks can be removed for processing. Tree limbs, tops and rotten wood are examples of residual debris created from the logging process that is not removed from the land it originated on. As this wood creates fire and insect hazards the Ministry of Forests (MOF) requires it to be disposed of practically, and burning it safely is simple and economic.[6]

There are four major licensees currently operating in the BVLD: Pacific Inland Resources (PIR), Canadian Forest Products (Canfor), Houston Forest Products Company (HFP) and Babine Forest Products (BFP). Resource management debris burning from these four licensees accounts for the majority of the open burning activity in the BVLD. A round number estimate would place the total number of piles burned each fall by these licensees at 11,000 piles total, most of which have an estimated base area of $100m^2$, and height of 5 metres.[7]

During the fall burning season it is understood that resource management debris burning is a major contributor to air quality in the BVLD. Emissions from these burns are the largest contributor of fine particulate matter to the airshed on an annual basis. For this reason, the CWGs felt it was necessary to closely examine emissions from this source.

b) Summary of Source Development

Following the recommendation by RWDI West Inc (RWDI 2003), the United States Forest Service (USFS) Consume v2.1 model was used to estimate total emissions from resource management debris burning activity. Some aspects of the model needed to be changed to reflect local needs, which were done by extracting Consume v2.1 into Microsoft Excel format and manually changing some input variables.

[6] BVLD AMP, 2004, 6-1
[7] Annual total based on reports from the 4 major licensees for the year 2002. Area estimates based on resource management burning subcommittee meetings, 2004.

Uses of this model as well as the changes made to it are elaborated in great detail in Appendix A, "The Consume v2.1 Model".

Two methods were used in conjunction with Consume v2.1 (henceforth to be called 'Consume') to estimate emissions from major licensee resource management debris burns. The first used data submitted directly from the four licensees for the year 2002. This detailed information included:

- block numbers and sizes,
- latitudes and longitudes,
- number of piles and
- treatment dates (dates piles were burned).

In some cases the blocks were further divided into tree species composition for the purpose of calculating average pile density. It was assumed that piles were paraboloids, with dimensions 10m x 10m x 5m. (Note, for PIR the pile estimates were corrected to 15m x 15m x 5m piles, as pile numbers were estimated using this set of dimensions.) In most cases pile numbers were reported, while for the remainder pile numbers were estimated using the formula of 2- 10m x 10m debris piles per hectare harvested. Missing or absent data was interpolated on a case by case basis. Only data for the year 2002 was available from the four licensees for this method and therefore only estimates from the year 2002 were calculated. Estimates for the year 2001 were interpolated through the fraction of 2001 / 2002 emissions from the methodology used to estimate emissions from the MOF's Open Fire Tracking System, outlined in the section below. The formula for estimating 2001 emissions from data supplied by the licensees can be written as

$$(1.2)\ E_{PM_{Licensees\,2001}} = E_{PM_{Licensees\,2002}} \times \frac{E_{PM_{OFTS\,2001}}}{E_{PM_{OFTS\,2002}}}$$

where $E_{PM_{Licensees\,2001}}(t)$ and $E_{PM_{Licensees\,2002}}(t)$ are the PM (either TPM, PM_{10} or $PM_{2.5}$) emissions estimated from data supplied by the licensees for the years 2001 and 2002 respectively and $E_{PM_{OFTS\,2001}}(t)$ and $E_{PM_{OFTS\,2002}}(t)$ are the PM (either TPM, PM_{10} or $PM_{2.5}$) emissions estimated from data obtained through the OFTS for the years 2001 and 2002 respectively.

The second method used to estimate emissions from resource management debris burning for the four major licensees was performed using Consume in conjunction with the MOF's Open Fire Tracking System (OFTS). The OFTS tracks burn reference numbers (BRNs), which all operators must obtain from the MOF prior to open burning of any kind (with the exception of backyard burns and small grass fires).

An in-detail explanation of the OFTS can be found in Appendix B, "the Open Fire Tracking System". Data obtained from the OFTS included:

- location of burns and
- approximate number of piles burned.

The system also provided either a two week window in which the BRN was active (if winter burning conditions were not in effect), or a window which started whenever a BRN was issued and ended on the following March 31st (if winter burning conditions were in effect). To estimate the burn date, the exact middle date of this window was taken, provided that not more than 500 piles were burned on one day in one reference number. In cases where 500 piles would have been burned in one day, these burns were spread over a two day period. Pile sizes for major licensee burns were all estimated to be 10m x 10m x 5m, to be consistent with size estimates given by the Resource Management Burning Subcommittee.

Results represent estimates based on the methods described above and a variety of emission factors, taken from Consume.[8] Note that the formula used to calculate these emissions deviates slightly from the general emissions equation(1.1), outlined in Chapter 1, Section C:

(1.1) $$E_{PM} = BQ \times \frac{EF_{PM}}{1000}$$

where $E_{PM}(t)$ are the emissions of PM (either TPM, PM_{10} or $PM_{2.5}$),

$BQ(t)$ is the base quantity (of wood burned) and

$EF_{PM}\left(\frac{kg}{t}\right)$ is the emission factor of PM (either TPM, PM_{10} or $PM_{2.5}$).

As explained in Appendix A, there is a reduction for the proportion of wood burned (Consume assumes only 90% of the base quantity combusts) as well as a percentage subtraction for soil in the pile which does not burn (estimated predominantly at 5%).

(1.3) $$E_{PM} = BQ \times \frac{PpnMassConsumed}{100} \times \frac{EF_{PM}}{1000}\left(1 - \frac{\%soil}{100}\right)$$

where *PpnMassConsumed* is the percentage of fuel that fully combusts and

$\left(1 - \frac{\%soil}{100}\right)$ is the adjustment for soil content in the pile (estimated predominantly at 5%).

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[8] Ottmar, 2000, p146

Table 3 – 2001 resource management debris burning emission estimates from large licensees based on Consume v2.1 emission factors and data supplied by the licensees

Company Name	Total Wood Burned (t)	Emission Factors (kg/t)			Total Emissions (t)		
	(90% of BQ)	TPM	PM_{10}	$PM_{2.5}$	TPM	PM_{10}	$PM_{2.5}$
PIR	*	10.94	7.75	6.74	*	*	*
Canfor	*	10.94	7.75	6.74	*	*	*
HFP	*	10.94	7.75	6.74	*	*	*
BFP	*	10.94	7.75	6.74	*	*	*
	Total Wood Burned				Total TPM	Total PM_{10}	Total $PM_{2.5}$
	202,518				2104	1491	1270

*Note the absence of data for the year 2001. Due to the potential for high variability, only annual totals were estimated using the fraction of 2001 / 2002 emissions from the methodology used to estimate emissions from the MOF's Open Fire Tracking System (equation(1.2)).

Table 4 – 2002 resource management debris burning emission estimates from large licensees based on Consume v2.1 emission factors and data supplied by the licensees

Company Name	Total Wood Burned (t)	Emission Factors (kg/t)			Total Emissions (t)		
	(90% of BQ)	TPM	PM_{10}	$PM_{2.5}$	TPM	PM_{10}	$PM_{2.5}$
PIR	25,747	10.94	7.75	6.74	268	190	165
Canfor	80,487	10.94	7.75	6.74	837	593	515
HFP	69,641	10.94	7.75	6.74	724	513	446
BFP	52,153	10.94	7.75	6.74	542	384	334
	Total Wood Burned				Total TPM	Total PM_{10}	Total $PM_{2.5}$
	228,027				2370	1679	1430

Table 5 – 2001 resource management debris burning emission estimates from large licensees based on Consume v2.1 emission factors and data obtained through the OFTS

Company Name	Total Wood Burned (t)	Emission Factors (kg/t)			Total Emissions (t)		
	(90% of BQ)	TPM	PM_{10}	$PM_{2.5}$	TPM	PM_{10}	$PM_{2.5}$
PIR	27,627	10.94	7.75	6.74	287	203	177
Canfor	106,979	10.94	7.75	6.74	1112	788	685
HFP	2055	10.94	7.75	6.74	21	15	13
BFP	5539	10.94	7.75	6.74	58	41	36
	Total Wood Burned				Total TPM	Total PM_{10}	Total $PM_{2.5}$
	142,200				1478	1047	911

Table 6 – 2002 resource management debris burning emission estimates from large licensees based on Consume v2.1 emission factors and data obtained through the OFTS

Company Name	Total Wood Burned (t)	Emission Factors (kg/t)			Total Emissions (t)		
	(90% of BQ)	TPM	PM_{10}	$PM_{2.5}$	TPM	PM_{10}	$PM_{2.5}$
PIR	40,426	10.94	7.75	6.74	420	298	259
Canfor	26,913	10.94	7.75	6.74	280	198	172
HFP	28,674	10.94	7.75	6.74	298	211	184
BFP	64,099	10.94	7.75	6.74	666	472	410
	Total Wood Burned				Total TPM	Total PM_{10}	Total $PM_{2.5}$
	160,112				1664	1179	1025

It should be noted that there is great discrepancy between results from data submitted by the licensees and the data obtained through the OFTS, especially when emissions are separated by licensee. Pile numbers submitted to the MOF to obtain a BRN are estimates only while data submitted from the licensees is collected while the burning is being completed. The information submitted by the licensees themselves is likely more accurate in pile quantity, location and date of treatment. It is thought that the OFTS is better capable of managing smaller scale operations like small licensees, ranchers or farmers because pile quantities are likely estimated more accurately.

c) Distribution

Temporal and spatial distribution can be facilitated by treating each burn as an individual event, as separate latitudes, longitudes and dates are all known. In terms of CALPUFF dispersion modelling, for the year 2001 only data obtained through the OFTS can be modelled, while for 2002 data submitted by the licensees can be modelled as well as data obtained through the OFTS. Resource management debris burns meet all the requirements of an area source in CALPUFF (base area, latitude, longitude, emission rate and energy release rate) and can be modelled as such. Each burn was estimated to occur over a 48 hour period, with a constant emission rate for the entire length of the burn. While it is known that emission rates change through the different phases of a burn (pre-heating, flaming, smouldering), until an easy to use emission rate formula is developed, a constant emission rate is a good staring point for modelling.

3) Small Licensee, Agricultural and Land Development Debris Burning

a) Background

This chapter describes the remainder of non-permitted open burning emissions, including emissions from small licensees, agricultural and land development debris burning. Small licensees include any BC Timber Sales, Woodlot licensee or company that are not one of the four major licensees.

While they do constitute resource management debris burns, small licensee, agricultural and land development debris burning differ from major licensee resource management debris burning because in many cases burns occur in valley bottoms and close to populated areas. As a result, these burns have increased potential for noticeable local impacts.[9] While overall emissions from these sources are an order of magnitude less than from the major licensees, their simple proximity to populated areas means they are an important contributor to air quality.

b) Summary of Source Development

Estimating emissions from small licensee, agricultural and land development debris burning was performed using Consume in conjunction with the MOF's OFTS. As mentioned in the previous chapter, the OFTS tracks BRNs, which operators must obtain from the MOF prior to open burning of any kind (with the exception of backyard burns). It should be noted that because small licensee and land development burns are resource management based the OFTS cannot positively distinguish one from the other. Agricultural based burns however, are not considered resource management and are usually classified separately (if they are properly registered). One can make broad assumptions through the definitions of the burn categories that agricultural debris burns are spread throughout categories 3-5, while small licensee and land development burns all fall into category 7. This assumption has been confirmed from MOF officials through correspondence. An in-detail explanation of the OFTS, including

[9] BVLD AMP, 2004, 7-1.

definitions of the different burn categories can be found in Appendix B, "the Open Fire Tracking System".

Results presented represent estimates based on the OFTS and a variety of emission factors, taken from Consume.[10] Similar to the previous chapter, the formula used to calculate these emissions deviates slightly from equation(1.1):

$$(1.1)\ E_{PM} = BQ \times \frac{EF_{PM}}{1000}.$$

As previously mentioned, there is a reduction for the proportion of wood burned (Consume assumes only 90% of the base quantity combusts) as well as a percentage subtraction for soil in the pile which does not burn (estimated predominantly at 5%). Recall equation(1.3):

$$(1.3)\ E_{PM} = BQ \times \frac{PpnMassConsumed}{100} \times \frac{EF_{PM}}{1000}\left(1 - \frac{\%soil}{100}\right).$$

Table 7 – 2001 emission estimates from small licensee, agricultural and land development debris burning based on Consume v2.1 emission factors and data obtained through the OFTS

Ministry of Forests Burn Category	Total Wood Burned (t)	Emission Factors (kg/t)			Total Emissions (t)		
	(90% of BQ)	TPM	PM_{10}	$PM_{2.5}$	TPM	PM_{10}	$PM_{2.5}$
3	908	13.48	10.02	8.49	11.6	8.6	7.3
4	139	17.99	14.01	11.82	2.4	1.8	1.6
5	532	13.48	10.02	8.49	6.8	5.1	4.3
6	68 *	13.48	12.02	8.49	0.9	0.7	0.6
7-Person	2616	13.48	10.02	8.49	33.5	24.9	21.1
7-Small Licensee	48,962	10.94	7.75	6.74	508.9	360.5	313.5
7-Major Licensee (from previous chapter)	142,200	10.94	7.75	6.74	1477.9	1046.9	910.5
8	No Activity Reported						
2001 Totals (t) excluding Category 7 – Major Licensees	53,225				564.0	401.6	348.3
2001 Totals (t) including Category 7-Major Licensees	195,425				2041.9	1448.5	1258.8

Note that for OFTS Category 6 grass burns it was assumed that 95% of the fuel fully combusted.

[10] Ottmar, 2000, p146

Table 8 – 2002 emission estimates from small licensee, agricultural and land development debris burning based on Consume v2.1 emission factors and data obtained through the OFTS

Ministry of Forests Burn Category	Total Wood Burned (t)	Emission Factors (kg/t)			Total Emissions (t)		
	(90% of BQ)	TPM	PM_{10}	$PM_{2.5}$	TPM	PM_{10}	$PM_{2.5}$
3	2207	13.48	10.02	8.49	28.3	21.0	17.8
4	213	17.99	14.01	11.82	3.6	2.8	2.4
5	3390	13.48	10.02	8.49	43.4	32.3	27.3
6	624 *	13.48	12.02	8.49	8.0	5.9	5.0
7-Person	16,610	13.48	10.02	8.49	212.7	158.1	134.0
7-Small Licensee	64,227	10.94	7.75	6.74	667.5	472.9	411.2
7-Major Licensee (from previous chapter)	160,112	10.94	7.75	6.74	1664.0	1178.8	1025.2
8	No Activity Reported						
2002 Totals (t) excluding Category 7 – Major Licensees	87,270				963.5	693.0	597.8
2002 Totals (t) including Category 7-Major Licensees	247,381				2627.5	1871.8	1623.0

Note that for OFTS Category 6 grass burns it was assumed that 95% of the fuel fully combusted.

c) Distribution

Temporal and spatial distribution for small licensee, agricultural and land development debris burns can be achieved in the same fashion as major licensee resource management debris burns. It should be noted that only burns originating in the Lakes, Morice, Bulkley and Kispiox Forest Districts (FDs) were included in the MEI. While the boundaries of the BVLD airshed do extend into the Fort St. James, Vanderhoof and Kalum FDs, these burns were not considered. Burns from these districts (especially the Vanderhoof FD) can be inserted at a later date.

4) Permitted Sources (including the beehive burners)

a) Background

This section of the MEI covers emissions from all permitted sources including emissions from the beehive burners, their respective mills, mines, small sawmills (including open burning), winter fall and burn emissions and all other permitted sources. Combined, permitted sources (including the beehive burners) are the largest contributors of PM_{10} and $PM_{2.5}$ on an annual basis to the airshed.

b) Summary of Source Development

Because the nature of emissions differs from one type of permit to another (some permits involve non-combustive emissions, others include combustive and non-combustive emissions while some pertain exclusively to combustive emissions.), permits have been grouped into four different categories:

1. Beehive burners and their respective mills,
2. Mines,
3. Small sawmills, open burning (at sawmills) and fall and burn programs and
4. Miscellaneous (all other types of permits).

Emission data for permitted sources was determined in a variety of different ways. To reflect the multiple methods for emission estimation, in all cases more than one estimate is presented. Having a range of estimates allows for examination of 'worst case scenarios'. Most often these 'worst cases' involve the company's permitted emission limits, as permitted emission rates are designed to represent maximum possible emissions for any given source and often overestimate actual emissions.[11]

For each permit category emission estimates presented are from at least 2 different sources, one of which has both actual as well as a maximum estimates. These two sources are

[11] Wakelin, 2004, p5

1) The permit fee parameters (PFP), verified by WLAP's WASTE permit fee calculation program.

Primary Crusher and Conveyor	**Lime Silo Vent**	**Molydenum dryer/packer operation**	**Bucking room (lab sized jaw crusher, cone crusher, pulverizer and splitter)**
Lat	Lat	Lat	Lat
Long	Long	Long	Long
Permitted Rate of Discharge	Permitted Rate of Discharge	Permitted Rate of Discharge	Permitted Rate of Discharge
(m3/min) 285	(m3/min) 25	(m3/min) 72	(m3/min) 100
(hours/day) 24	(hours/MONTH) 8	(hours/day) 24	(hours/day) 10
(days/year) 365	(MONTH/year) 12	(days/year) 365	(days/year) 365
Discharge Characteristics (TPM)	Discharge Characteristics (TPM)	Discharge Characteristics (TPM)	Discharge Characteristics (TPM)
(mg/m3) 50	(mg/m3) 50	(mg/m3) 229	(mg/m3) 50
Schedule:	Schedule:	Schedule:	Schedule:
Start Up: Monday 00:00:00	Start Up: Monday Not Applicable	Start Up: Monday 00:00:00	Start Up: Monday 07:00:00
Shut Down Sunday 23:59:59	Shut Dowr Friday	Shut Down Sunday 23:59:59	Shut Down Monday 17:00:00
Total Time (hours) 168	Total Time (hours)	Total Time (hours) 168	Total Time (hours) 70
(min) 10080	(min)	(min) 10080	(min) 4200
Emissions Correction 1.00	Emissions Correction 1.00	Emissions Correction 1.00	Emissions Correction 1.00
Total Hourly Particulate Emissions	Total Hourly Particulate Emissions	Total Hourly Particulate Emissions	Total Hourly Particulate Emissions
(kg) 0.86	(kg) 0.08	(kg) 0.99	(kg) 0.30
Total Daily Particulate Emissions	Total MONTHLY Particulate Emissions	Total Daily Particulate Emissions	Total Daily Particulate Emissions
(kg) 20.52	(kg) 0.60	(kg) 23.74	(kg) 3.00
Total Weekly Particulate Emissions		Total Weekly Particulate Emissions	Total Weekly Particulate Emissions
(kg) 143.64		(kg) 166.20	(kg) 21.00
Total Annual Particulate Emissions	Total Annual Particulate Emissions	Total Annual Particulate Emissions	Total Annual Particulate Emissions
(kg) 7489.80	(kg) 7.20	(kg) 8666.09	(kg) 1095.00
(tonnes) 7.49	(tonnes) 0.01	(tonnes) 8.67	(tonnes) 1.10
Total Annual PM10 Emissions	Total Annual PM10 Emissions	Total Annual PM10 Emissions	Total Annual PM10 Emissions
(kg)	(kg)	(kg)	(kg)
(tonnes) 3.82	(tonnes) 0	(tonnes) 4.42	(tonnes) 0.56
Total Annual PM2.5 Emissions	Total Annual PM2.5 Emissions	Total Annual PM2.5 Emissions	Total Annual PM2.5 Emissions
(kg)	(kg)	(kg)	(kg)
(tonnes) 1.12	(tonnes) 0	(tonnes) 1.30	(tonnes) 0.16

Grand Total Annual Particulate Emissions

TPM	(tonnes)	17.3
PM10	(tonnes)	8.8
PM2.5	(tonnes)	2.6

Figure 9 – Emission estimates based on permit fee parameters

Annual PFP emissions are estimated based on the equation

$$(1.4)\sum_{i=1}^{n} E_{TPM_i} = \left(\frac{60}{1,000,000,000} \times R_{PD_i} \times C_{PD_i}\right) \times H_{D_i} \times D_{Y_i}$$

where *i* is an individual section of a permit,

n is the number of sections in a permit,

$E_{TPM}\left(t\right)$ is the annual emissions of TPM,

$R_{PD}\left(\frac{m^3}{\min}\right)$ is the rate of permitted discharge,

$C_{PD}\left(\frac{mg}{m^3}\right)$ is the characteristics of permitted discharge,

$H_D\left(hours\right)$ is the number of daily permitted discharge hours,

$D_Y\,(days)$ is the number of annual permitted discharge days of TPM and

$\frac{60}{1,000,000,000}$ converts emissions of $\frac{mg}{\min}$ into $\frac{t}{a}$.

PM_{10} and $PM_{2.5}$ emission estimates are determined based on a ratio to TPM emissions and depend on the source. For example, for the molybdenum dryer/packer operation listed above, the PM_{10} and $PM_{2.5}$ ratios are $E_{PM_{10}} = 0.51 \times E_{TPM}$ and $E_{PM_{2.5}} = 0.15 \times E_{TPM}$. Emission ratios are listed for most permitted sources in Appendix D, "Permitted Point Source Normalized Emission Ratios".

2) Air and Emissions Information of British Columbia (AEIBC)[12]
   a. Actual emissions and
   b. Maximum emissions.

FACILITY:	HUCKLEBERRY MINES LTD.		
Criteria Air			
PERM_NO:	14800		
LAT_N:	53.674		
LON_W:	-127.1611		
PERM_NO:	14800		
Actual		Maximum	
CO:	0	CO:	0
NOX:	0	NOX:	0
NH3:	0		
SOX:	0	SOX:	0
VOC:	0	VOC:	0
PARTICULAT:	16.91	PARTICULAT:	17.26
PM_10:	8.63	PM_10:	8.8
PM_25:	2.54	PM_25:	2.59
DESCRIPTOR:	UNDER 200		
Coordinate Position			
BC Albers:	923823, 963076		
Geographic:	127°9' W		
	53°40' N		
UTM:	621856, 5948060		
	(zone 9)		

Figure 10 – Emission estimates based on Air and Emissions Information of British Columbia

It should be noted that AEIBC's reported 'actual' emissions are taken from *2000 British Columbia Emissions Inventory of Criteria Air Contaminants: Methods and Calculations*. (Wakelin 2004)

It should also be noted that while final values often do not always match, AEIBC's maximum emissions section are a reflection of the sum of all components in a permit. Reasons why PFPs and AEIBCs may not match include

[12] AEIBC can be accessed online at http://imf.geocortex.net/mapping/air/index.html.

- Changes to a permitted emission source (increased hours of operations, increased emission limits, etc.) between the years 2000 (when AEIBC estimations were developed) and 2001 or 2002,
- Addition of a new source to an existing permit between 2000 and 2001 or 2002,
- Cancellation of a permit between 2000 and 2001 or 2002 or
- Adjustment factors applied to certain sources in a permit in AEIBC.

Further emission estimation is presented in certain cases where more research was carried out. For example, emission estimates for the beehive burners based on the SENES Consulting Ltd. report *Critique of the Air Quality Assessment of Beehive Burner Emissions – Bulkley Valley, BC* (SENES 2000) are also included in the report. Where permits require stack testing for certain sources (volcano energy recovery systems, Newpro dryer stacks, etc), modified emission estimates are also presented. In cases where permits involve open burning of wood, the Consume v2.1 emission model was also used to estimate emissions. For a complete list of emission estimates, refer to Appendix C, “Emissions by Permit and Estimation Type”.

i) Beehive Burners and their Respective Mills

A summary of beehive burner and associated mill emissions has been provided from multiple sources for the seven mills that operated throughout the inventory period. Where possible, some ‘fine tuning’ of estimates was performed, mostly to adjust beehive burner emissions from permitted wood residue throughput to actual reported throughput.

PM estimates from four sources are reported for each of the beehive burners and their associated sawmills:

1) Emission estimates based on PFPs,
2) AEIBC reporting for the year 2000 (reports actual as well as maximum estimates),
3) Estimates based on the SENES consulting methodology for the beehive burners using permitted throughput (with permit fee estimates for all other sources) and
4) The SENES consulting reporting methodology corrected for actual throughput to the beehive burners as well as emission stack testing result corrections for hog boilers/volcano energy recovery systems (with permit fee estimates for all remaining sources).

Table 9 – Beehive burner and sawmill emission totals (tonnes)

	2001				2002		
	Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
Based on PFPs	6331.5	3205.5	2050.9		6817.5	3475.7	2250.3
AEIBC (Actual)	3436.5	1841.8	1172.7		3266.8	1751.7	1114.6
AEIBC (Maximum)	8653.3	4666.6	3162.8		6838.5	3688.3	2478.5
SENES Method for Beehive Burners and Permit Fees for Others	4279.0	2256.4	1389.6		4442.7	2349.0	1462.7
SENES Method Corrected for Reported Throughput, Stack Test Results and Permit Fees	3617.0	1844.0	1073.7		3684.0	1883.5	1106.6

Emission estimates for the seven beehive burners operating throughout the inventory period are also reported. Provided estimates are based on

1) Permitted levels for 2001 and 2002 and
2) Revised estimates based on SENES consulting methodology and reported burner throughput (where possible) or permitted levels.

For detailed information on how beehive burner emissions are calculated refer to Appendix E, “Beehive Burner Emissions and Calculations”.

Table 10 – Beehive burner emissions (tonnes)

1) Based on PFPs							
	2001				2002		
	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
Canfor (PA 01543)	1256.0	690.7	502.4		1256.0	690.7	502.4
PIR (PA 01691)	968.0	532.3	387.2		968.0	532.3	387.2
HFP (PA 05339)	761.6	418.8	304.6		761.6	418.8	304.6
DLFP (PA 03019)	528.8	290.8	211.5		528.8	290.8	211.5
BFP (PA 04122)	485.8	267.1	194.3		485.8	267.1	194.3
SCI Carnaby (PA 07748)	184.0	101.2	73.6		0.0	0.0	0.0
CFP (PA 16903)	41.1	22.6	16.4		750.0	412.4	300.0
	Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
	4225.3	2323.5	1690		4750.2	2612.1	1900

2) Based on SENES Consulting methodology for beehive burner emissions corrected for throughput to burner where available (marked with '*')							
	2001				2002		
	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
Canfor (PA 01543) *	590.6	323.4	239.1		588.4	322.2	238.2
PIR (PA 01691) *	242.0	132.5	98.0		113.7	62.2	46.0
HFP (PA 05339) *	226.6	124.1	91.7		194.3	106.4	78.7
DLFP (PA 03019) *	213.1	116.6	83.3		279.2	152.7	109.1
BFP (PA 04122)	229.5	125.7	92.9		229.5	125.7	92.9
SCI Carnaby (PA 07748)	132.5	72.5	51.8		0.0	0.0	0.0
CFP (PA 16903)	19.4	10.6	7.9		354.4	194.1	143.4
	Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
	1653.7	905.4	664.7		1759.5	963.3	708.3

Note that PA 07748 ceased operations in March 2001 and has been closed since. Also, PA 16903 began operating in December 2001 and was fully operational in 2002.

ii) Mines

Mine emissions from the two mines operating in the BVLD (Thompson Creek Mining Ltd. and Huckleberry Mines Ltd.) during the inventory period are reported from two sources,

1) Emission estimates based on PFPs and
2) AEIBC reporting for the year 2000.

Table 11 – Mine emission totals (tonnes)

	2001				2002		
	Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
Based on PFPs	557.8	549.4	193.4		557.8	549.4	193.4
AEIBC (Actual)	426.8	418.5	147.2		426.8	418.5	147.2
AEIBC (Maximum)	501.3	492.8	173.5		501.3	492.8	173.5

iii) Small Sawmills, Open Burning (at Sawmills) and Fall and Burn Permits

This section incorporates emissions from small sawmills (those that do not have beehive burners), open burning at sawmills and fall and burn permits. As source development for each category differs, each section is treated individually.

- **Permitted Small Sawmill Emissions**

Permitted sawmill emissions from the four permitted sawmills operating in the inventory period (Kitwanga Lumber Co. Ltd., Skeena Cellulose Inc., Burns Lake Specialty Wood Ltd. and Kispiox Forest Products Ltd.) are reported from two sources,

1) Emission estimates based on PFPs and
2) AEIBC reporting for the year 2000.

Table 12 – Permitted sawmill emission totals (tonnes)

	2001				**2002**		
	Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
Based on PFPs	87.46	35.69	18.57		7.77	3.08	1.61
AEIBC (Actual)	35.66	16.12	6.99		5.81	2.32	1.16
AEIBC (Maximum)	46.55	21.05	9.12		7.77	3.11	1.55

- **Permitted Sawmill Open Burning**

During the inventory period Boo Flat Lumber Ltd., Merkley Enterprises and Ootsa Lake Sawmill Ltd. had permits allowing for open burning of waste wood. Emissions for these permits are reported from three sources,

1) Emission estimates based on PFPs,
2) AEIBC reporting for the year 2000 and
3) Emission estimates based on Consume.

Estimates from Consume were adjusted based on consultation with the permitees regarding the wood species burned and whether or not burning actually took place during the inventory period.

Table 13 – Sawmill open burning emission totals (tonnes)

	2001				2002		
	Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
Based on PFPs	7.94	6.27	3.57		7.94	6.27	3.57
AEIBC (Actual)	3.02	20.3	1.88		3.02	20.3	1.88
AEIBC (Maximum)	7.94	5.29	4.94		7.94	5.29	4.94
Consume v2.1 and Contact with Permittees	1.82	1.29	1.12		1.41	1.00	0.87

- **Fall and Burn Permits**

There are three fall and burn permits, two of which belong to Canadian Forest Products Ltd. (Canfor, formerly Northwood Pulp and Timber) and one which belongs to West Fraser Mills Ltd. Emission estimates are reported from three sources,

1) Emission estimates based on permit fee parameters,
2) AEIBC reporting for the year 2000 and
3) Emission estimates based on Consume and consultation with the permitees.

Table 14 – Fall and burn emission totals (tonnes)

	2001				2002		
	Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
Based on PFPs	25.60	20.22	11.52		25.60	20.22	11.52
AEIBC (Actual)	28.10	18.80	17.50		28.10	18.80	17.50
AEIBC (Maximum)	44.80	29.87	27.92		44.80	29.87	27.92
Consume v2.1 and Contact with Permittees	6.74	4.77	4.15		7.41	5.25	4.56

iv) Miscellaneous Permitted Sources

There are a variety of other permitted sources in the BVLD that don't fall into any specific category. The largest one in terms of annual emissions is a panelboard manufacturing plant, Newpro (Northern Engineering Wood Products Inc.). There are also two permits for natural gas compression stations under Westcoast Energy Inc., two permits for asphalt plants under LB Paving Ltd. (one stationary and one mobile) and one permit for the Chemical Lime Company of Canada Ltd., a lime storage facility.

Emissions for these miscellaneous permits are reported from two sources,

1) Emission estimates based on PFPs and
2) AEIBC reporting for the year 2000.

For permit PA 06099 (Newpro), emission testing is performed annually for its major stacks (the inside and outside dryers). An emission summary for these tests combined with their other permitted sources is included separately in the tables below. For the LB Paving permits some data is missing due to limited permit information.

Table 15 – Miscellaneous permitted sources emission totals (tonnes)

	2001				2002		
	Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
Based on PFPs	406.1	182.7	102.3		406.1	182.7	102.3
AEIBC (Actual)	247.1	135.4	73.6		247.1	135.4	73.6
AEIBC (Maximum)	340.8	182.7	96.4		340.8	182.7	96.4
Permit Fees and also Considering Emission Testing on 2 Stacks at Newpro	354.1	145.7	76.5		354.1	145.7	76.5

v) Permitted Source Totals

Table 16 – permitted source totals (tonnes)

	2001				2002		
	Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
Based on PFPs	7416.4	3999.8	2380.3		7822.7	4237.4	2562.7
AEIBC (Actual)	4177.2	2450.9	1419.8		3977.6	2347.0	1355.9
AEIBC (Maximum)	9594.7	5398.3	3474.7		7741.1	4402.1	2782.9
Permit Fees and Consideration of Special Cases (refinement)	4624.9	2580.9	1367.4		4612.5	2587.9	1383.5

c) Distribution

Temporally, a source's emissions take place within the limits of its permit. For example, in one permit some sections allow for discharge 24 hours per day, 7 days per week, even while other sections of the same permit only allow for discharge 8 hours per day 5 days per week. Emissions can be temporally resolved based on these limits using permit fee estimates with the notable exception of sources where emission refinement took place. Refinement occurred for

a) the beehive burner estimates,
b) the hog fuel or volcano energy recovery system estimates,
c) Newpro's 2 dryer stacks and
d) sawmill open burning and fall and burn open burning estimates.

For these sources other estimates have been developed, either through external reports such as the SENES Consulting report, stack testing or through the use of Consume. Emission refinement includes specialized emission rates and in some cases modifications to the temporal parameters of a permit.

Spatially, most permits must be modelled as area sources because permit information is not extensive enough to meet the requirements of point sources in CALPUFF. Where possible, on-site GPS measurements were taken to establish a 4-cornered base area for each permitted source, however, where this was not the case a standard area approximation was made assuming properties were either $1km^2$ or $0.5km^2$. Some permits do have point source components, namely the special cases where emission refinement was performed. For these special cases enough information was collected to allow point source development.

5) Residential Home Heating

a) Background

In the BVLD there are many people who heat their homes with wood. Wood is an economical, reliable and relatively safe fuel source. Improperly used, however, the combination of unseasoned wood and older-technology appliances are known to cause air quality impacts.[13] In the BVLD there is a 'wood heating' season, during which air quality can be driven by the combination of meteorology and home heating smoke. Emission reduction strategies including "Burn it Smart" workshops and wood stove exchange programs have been put in place in the BVLD in an effort to curb wood appliance emissions and impacts. To date these programs have had relatively good levels of success. The CWGs felt it was necessary to examine emissions from this source because of the high quantity of wood appliances in both the urban and rural areas of the BVLD.

b) Summary of Source Development

In the summer of 2003 WLAP conducted a province-wide (with the exception of the Lower Mainland and Kamloops) telephone survey regarding home heating practices, with a focus on developing statistics pertaining to residential heating with wood products (either wood or wood pellets). Data was summarized by region and airshed into a document called *Residential Wood Burning Emissions in British Columbia* (RWBEBC). (Rensing 2004) Survey results for Skeena Region as well as the BVLD are reported in the MEI. Note that Skeena Region's results exclude the BVLD.

Table 17 – Number of households surveyed

	Complete Responses			**Simple Yes/ No Query**		
Region	User	Non-User	Total Valid	Yes to Wood/ Wood Pellets	No to Wood/ Wood Pellets	Total Interviews
BVLD	106	51	157	124	129	253
Other Skeena	127	64	191	147	543	690

[13] BVLD AMP, 2004, 8-1

Table 18 – Wood appliance types by region

Region	Total Number of Appliances	Fireplace; Advance Technology	Fireplace; Conventional Without Glass Doors	Central Furnace/ Boiler (inside)	Central Furnace/ Boiler (outside)	Fireplace Insert; Advance Technology	Fireplace Insert; Catalytic	Fireplace Insert; Conventional	Woodstove; Advance Technology	Woodstove; Catalytic	Woodstove; Conventional	Pellet Stoves
BVLD	8124	2%	7%	11%	5%	0%	0%	2%	14%	4%	29%	26%
Other Skeena	5592	1%	14%	13%	1%	3%	0%	1%	20%	6%	35%	6%

Table 19 – Regional base quantities by appliance type (tonnes of wood/year)

Region	Fireplace; Advance Technology	Fireplace; Conventional Without Glass Doors	Central Furnace/ Boiler (inside)	Central Furnace/ Boiler	Central Furnace/ Boiler (outside)	Fireplace Insert; Advance Technology	Fireplace Insert; Catalytic	Fireplace Insert; Conventional	Woodstove; Advance Technology	Woodstove; Catalytic	Woodstove; Conventional	**Regional Total**
BVLD	392.3	1689.3	7537.5	(0)	4838.1	(0)	(0)	1212.5	6211.7	1620.1	12212.4	**35714.0**
Other Skeena	212.6	1806.7	4197.3	(0)	208.8	306.4	(0)	315.4	5831.1	1505.5	9018.6	**23402.6**

Table 20 – Wood burning appliance emission factors (kg/tonne)

Emission Factor	Fireplace; Advance Technology	Fireplace; Conventional Without Glass Doors	Fireplace; Conventional With Glass Doors	Central Furnace/ Boiler (inside)	Central Furnace/ Boiler	Central Furnace/ Boiler (outside)	Fireplace Insert; Advance Technology	Fireplace Insert; Catalytic	Fireplace Insert; Conventional	Woodstove; Advance Technology	Woodstove; Catalytic	Woodstove; Conventional	Woodstove; Conventional, Not Air-Tight	Woodstove; Conventional, Air-Tight	Pellet Stove	Other Equipment
TPM	5.1	19.3	13.5	14.1	14.1	14.1	5.1	5.1	14.4	5.1	5.1	24.6	24.6	14.4	1.2	14.4
PM_{10}	4.8	18.5	13	13.3	13.3	13.3	4.8	4.8	13.6	4.8	4.8	23.2	23.2	13.6	1.1	13.6
$PM_{2.5}$	4.8	18.4	12.9	13.3	13.3	13.3	4.8	4.8	13.6	4.8	4.8	23.2	23.2	13.6	1.1	13.6

Table 21 – Total emissions from wood burning appliances and pellet stoves in Skeena Region and the BVLD (tonnes/year)

	Wood Burning Appliances				**Pellet Stoves**			
Region	Fuel	TPM	PM_{10}	$PM_{2.5}$	Base Quantity	TPM	PM_{10}	$PM_{2.5}$
BVLD	35714.0	566.9	535.1	535.0	4277.6	5.1	4.7	4.7
Other Skeena	23402.6	363.5	343.3	343.1	807.6	1.0	0.9	0.9

Table 22 – Total BVLD residential home heating emission estimates (tonnes) for the years 2001, 2002

2001, 2002 BVLD Residential Home Heating Emission Estimates					
	Description		**Total TPM**	**Total PM_{10}**	**Total $PM_{2.5}$**
	Residential Home Heating		**572.0**	**539.8**	**539.7**

For more information regarding RWBEBC, refer to WLAP's web page: http://wlapwww.gov.bc.ca/air/particulates/, or download it directly from http://wlapwww.gov.bc.ca/air/airquality/pdfs/wood_emissions.pdf.

Originally it was thought that data from this survey could be separated into urban and rural categories, as one of the first survey questions asks whether the respondent lives in a rural setting. (The classification of an urban area is defined as living inside an incorporated municipality.) It is thought (though not statistically proven) that home heating with wood is more common in rural settings than urban areas due to many factors, one being the lack of availability of natural gas outside urban boundaries. After lengthy data analysis however, it was concluded that the survey methodology of disproportionate sampling did not permit for the separation of urban and rural practices, and therefore conclusions of that sort could not be made. Based on the survey's results it must be assumed that wood use in the BVLD is solely a 'per capita' issue and not an urban vs. rural one.

It should be noted that some statistical data in RWBEBC differs from the rest of the MEI. For example, population data used in RWBEBC was based upon Canada Post dwelling count summaries, where for the MEI population counts were based upon 2001 census data, 2002 regional district data and 2002 local health area data. Also, data for wood densities used in the RWBEBC differs from wood density data in the remainder of the MEI, as both documents use different data sources[14].

c) Distribution

All of the temporal and spatial distribution research was completed prior to the realization that urban and rural practices could not be separated. The temporal distribution needs no updating; the spatial distribution does though, as emissions are currently based on separate urban and rural per capita values instead of one non-differentiating urban and rural per capita basis. However, since final emission values from the original methodology (which differentiated between urban and rural usage) were within 12% of the survey emission estimates, it is recommended that fixing this error not be a priority.

The United States Environmental Protection Agency (US-EPA) has standard seasonal (monthly), hebdomadal and diurnal normalized emission profiles that show out of a possible 100% (annual total emissions) how much weight should be distributed to each month, day of the week and hour. The hebdomadal profile which placed equal weight on each day of the week was accepted for the MEI, while

[14] Wood densities for RWBEBC can be found in (Alden 1997), while in the MEI wood densities are taken from (Nielson 1985).

the seasonal and diurnal profiles needed to be adjusted for use in the BVLD airshed. Methodologies for deriving the customized diurnal and seasonal emission profiles are outlined in Appendix F, “Derivation of the Hourly and Monthly Emissions Profiles for Residential Wood Appliances”.

Allocating annual total emissions to the appropriate hour, day and month allows for temporal modelling to occur with CALPUFF. Spatially, urban domains were created for the incorporated towns, districts and villages of Burns Lake, Granisle, Houston, Telkwa, Smithers, Hazelton and New Hazelton, while the remaining (rural) domain was separated into three sections, namely Upper Skeena, Rural Smithers and Rural Burns Lake. Emissions can be apportioned linearly by population based on the original data that differentiated between urban and rural wood usage.

6) Road Dust (paved roads)

a) Background

Road dust can be a significant contributor to air quality, particularly in (though not limited to) the spring when the snow melts and all of the deposits from winter traction promotion are still on the road's surface. Of all the months in the year, the highest recorded PM_{10} levels typically occur during the month of March. Also, March has the highest frequency of days in which air quality advisories are in effect.[15] The 'road dust season' tends to last for 3-5 weeks per spring and ends when all of the previous winter's aggregate is removed from the roads.

Road dust emission estimates are highly variable. It has been reported that the US-EPA has overestimated fugitive road dust emissions by 50-75 %, due to the lack of differentiation between suspendable and transportable material[16]. This dilemma is outlined in detail in the BVLD EIIS as well as in the SENES Consulting Ltd. report *Critique of the Air Quality Assessment of Beehive Burner Emissions – Bulkley Valley, BC* (SENES 2004). Both these reports play down the importance of road dust impacts to air quality:

> ….based on the SENES assessment, the factors discussed above, and direct discussion with experts in the field, it is unlikely that fugitive road dust is significant in the context of elevated PM.
>
> -BVLD EIIS, 2003, p20

However, while it is true that much of the dust during the spring road dust season is not transportable material and does not travel more than a few hundred metres from its source, it is known that there are air quality episodes attributable to road dust, especially in urbanized areas with increased road traffic. Also, as road dust is the highest contributor of TPM to the airshed, for the purpose of quantifying annual totals in an emissions inventory, its contribution cannot be ignored.

[15] BVLD AMP, 2004, 3-2
[16] RWDI, 2003, p20

b) Summary of Source Development

Environment Canada, using methods outlined by the US EPA, developed road dust emission estimates for *2000 British Columbia Emissions Inventory of Criteria Air Contaminants: Methods and Calculation*". (Wakelin 2004) These estimates for the entire Skeena Region are displayed below.[17]

Table 23 – Skeena Region road dust emission estimates (tonnes) for the year 2000

Year 2000 Provincial Emissions Inventory - Skeena Region					
	Description		Total TPM	Total PM_{10}	Total $PM_{2.5}$
	Paved Road Dust		28,363	5,436	1,300

One method of allocating emissions from the above total to the BVLD is through population distribution. 2001 census data gave Skeena Region a population of approximately 91,741. (BC Stats a, b, c 2004) (Note that this number is slightly high, due to the inclusion of small communities near Bella Bella which are not in Skeena Region.) The population of the BVLD in 2001 based on similar census data (BC Stats a, b 2003) was 31,461. Therefore the BVLD had 34.29% of Skeena Region's population. Correcting the above estimated figures by this percentage gives road dust estimates in the BVLD for the years 2001 and 2002, assuming no population change in Skeena Region between the years 2000 and 2002.

Table 24 – Total BVLD paved road dust emission estimates (tonnes) for the years 2001, 2002

2001, 2002 BVLD Road Dust Emission Estimates					
	Description		**Total TPM**	**Total PM_{10}**	**Total $PM_{2.5}$**
	Paved Road Dust		**9,726**	**1,864**	**446**

c) Distribution

It has been shown that precipitation has an effect on road dust emissions, such that emissions fall to zero during and for a period after a rainfall event.[18] To facilitate temporal representation, historical climate data containing hourly weather observations including periods of precipitation was obtained from Environment Canada for the Smithers airport. It was assumed that weather conditions in Smithers were

[17] Road dust emission estimates for Skeena Region provided by Environment Canada through Tony Wakelin.
[18] Kuhns, 2003, p4577

representative of weather conditions across the BVLD. It was also assumed that for the month of March and the first half of April road dust occurred 24 hours after the end of a significant precipitation event until the beginning of the next significant precipitation event. A significant precipitation event was defined as 3 consecutive hours of rain (or snow) or 6 consecutive hours of rain (or snow) showers. Annual road dust totals were allocated equally over the total number of hours meeting these criteria.

As described above, road dust consists mainly of non-transportable material which rarely travels higher that 2m above ground and a few hundred metres (horizontally) from its source[19]. Spatially, it can be assumed that road dust from paved roads occurs only in the urbanized (incorporated) areas of Burns Lake, Granisle, Houston, Telkwa, Smithers, New Hazelton and Hazelton. The spatial grid for road dust can be the same as the grid used in the "Residential Heating" and "Back Yard Burning" Chapters. It can be assumed that road traffic through all of these urban areas is proportional to their population and therefore road dust totals from can be apportioned linearly based on 2001 census population.

[19] SENES, 2000, p50

7) Back Yard Burning

a) Background

Back yard burning emissions represent the smallest emission source in the MEI, approximately two orders of magnitude less than resource management debris burning emissions or permitted emissions. However, while annual emissions are relatively low the potential for strong localized impacts is significant because of the proximity which with back yard burns occur relative to neighbouring residences. For this reason, back yard burning emissions were identified by the CWGs as one which required further study.

Back yard burning activity data is highly variable. Final emission estimates use recommendations outlined in the US EPA's Emission Inventory Improvement Program (EIIP) documents regarding back yard burning. (Eastern Research Group Inc. 2001 b.) The EPA identifies two different types of back yard burning:

- Residential Yard Waste Burning and
- Residential Household Waste Open Burning.

As the names suggest, 'Residential Yard Waste' deals strictly with yard waste burning, while 'Residential Household Waste' involves the burning of household garbage. As both activity data and emission factors differ from one type to another, methods for developing emission estimates are separate.

b) Summary of Source Development

i) Residential Yard Waste Burning

According to the US EPA, 0.2584 kg of yard waste is generated per person per day. Total estimated waste is composed of 25 % leaves, 25 % brush and 50 % grass. Furthermore, of all the waste generated only 28% is burned. While the EPA assumes that grass burning is not a common practice and is not reflected in their national emission inventory, this assumption is not made for the MEI because grass burning has been observed to be common practice in the BVLD.

The EPA employs correction factors for yard waste burning based on the percentage of forestation in each county, assuming that the smaller the forest content the less yard waste burned. However, since the burning of grass is included in the MEI, one cannot readily assume that smaller forestation percentages correspond to less yard waste burning. Therefore, this final correction step was omitted in the MEI.

Corrections for local back yard burning bylaws were taken into account where such restrictions were in place. During the inventory period, only the Town of Smithers had a bylaw in place prohibiting back yard burning. Therefore, BQ data for Smithers was set to 0.

EPA TPM emission factors for unspecified leaf species, unspecified forest residues and unspecified weeds and grass were 19, 8.5 and 7.5 kg/tonne respectively[20]. PM_{10} and $PM_{2.5}$ emission factors were estimated using the formulas $EF_{PM_{10}} \approx 0.8 \times EF_{TPM}$ and $EF_{PM_{2.5}} \approx 0.731 \times EF_{TPM}$.[21]

Table 25 – Urban yard waste emission estimates (tonnes) 2001, 2002

2001, 2002 Urban Yard Waste Emissions								
Yard Waste Burning Population		8778						
Daily Yard Waste Generation (t)		2.27						
Annual Yard Waste Generation (t)		828						
Percent of Waste Burned (%)		28						
Composition	Percentage of Yard Waste	Waste Burned (t)	Emission Factors (kg/t)			Emissions (t)		
	(%)		TPM	PM_{10}	$PM_{2.5}$	TPM	PM_{10}	$PM_{2.5}$
Leaves	25	57.99	19	15.2	13.9	1.102	0.881	0.806
Brush	25	57.99	8.5	6.8	6.2	0.493	0.394	0.360
Grass	50	115.97	7.5	6	5.5	0.870	0.696	0.638
Totals (t)		232.0				**2.5**	**2.0**	**1.8**

Table 26 – Rural yard waste emission estimates (tonnes) 2001, 2002

2001, 2002 Rural Yard Waste Emissions								
Yard Waste Burning Population		16973						
Daily Yard Waste Generation (t)		4.39						
Annual Yard Waste Generation (t)		1602						
Percent of Waste Burned (%)		28						
Composition	Percentage of Yard Waste	Waste Burned (t)	Emission Factors (kg/t)			Emissions (t)		
	(%)		TPM	PM_{10}	$PM_{2.5}$	TPM	PM_{10}	$PM_{2.5}$
Leaves	25	112.12	19	15.2	13.9	2.130	1.704	1.558
Brush	25	112.12	8.5	6.8	6.2	0.953	0.762	0.695
Grass	50	224.24	7.5	6	5.5	1.682	1.345	1.233
Totals (t)		448.5				**4.8**	**3.8**	**3.5**

[20]US EPA, 1992 a, 2.5-10
[21] US EPA, 1992 a, 2.5-11

ii) Residential Household Waste Open Burning

According to the EPA, an average of 1.501 kg of household waste is generated per person per day. Removing grass (0.258 kg/day) (initially, the EPA includes grass in both household waste and yard waste generation) and non-combustible material (0.24 kg/day), this figure reduces to 1.003 kg of household waste per person per day. Again, the EPA assumes an average of 28% of household waste was burned though, only 66% of the burned waste combusts. These figures apply only to those residing in a 'rural' setting (because of garbage collection in urban areas), which in the case of the MEI refers to the population of the BVLD living outside municipal boundaries.

Emission factor data originates from *Evaluation of Emissions from the Open Burning of Household Waste in Barrels* (Lemieux 1998), summarized online at http://www.epa.gov/ttn/atw/burn/trashburn1.pdf. As a generalization PM_{10} and $PM_{2.5}$ emission factors were set to 5.8 and 5.3 kg/tonne respectively. The TPM emission factor was estimated based on the formula $EF_{TPT} \approx 1.25 \times EF_{PM_{10}}$.[22]

Table 27 – Urban household waste burning emission estimates (tonnes) 2001, 2002

Urban Household Waste Emissions 2001, 2002								
Household Waste Burning Population		0						
Daily Household Waste Generation (t)		0						
Annual Household Waste Generation (t)		0						
Percent of Waste Burned (%)		28						
Composition	Waste Burned (t)	Percent Combusted	Emission Factors (kg/t)			Emissions (t)		
		(%)	TPM	PM_{10}	$PM_{2.5}$	TPM	PM_{10}	$PM_{2.5}$
Waste	0	66.7	7.25	5.8	5.3	0.0	0.0	0.0
			Totals (t)			**0.0**	**0.0**	**0.0**

Table 28 – Rural household waste burning emission estimates (tonnes) 2001, 2002

Rural Household Waste Emissions 2001, 2002								
Household Waste Burning Population		16973						
Daily Household Waste Generation (t)		17.024						
Annual Household Waste Generation (t)		6214						
Percent of Waste Burned (%)		28						
Composition	Waste Burned (t)	Percent Combusted	Emission Factors (kg/t)			Emissions		
		(%)	TPM	PM_{10}	$PM_{2.5}$	TPM	PM_{10}	$PM_{2.5}$
Waste	1740	66.7	7.25	5.8	5.3	8.410	6.728	6.148
			Totals (t)			**8.4**	**6.7**	**6.1**

[22] US EPA, 1992 a, 2.5-11

Table 29 – Total BVLD back yard burning emission estimates (tonnes) for the years 2001, 2002

2001, 2002 BVLD Back Yard Burning Emission Estimates					
	Description		**Total TPM**	**Total PM_{10}**	**Total $PM_{2.5}$**
	Back Yard Burning		**15.7**	**12.5**	**11.4**

c) Distribution

Developing distribution data for this emission source represents a challenge. Aside from assuming that no yard waste burning occurs in the winter, it is conceivable that yard waste burning is a 3 season activity while household waste burning is a 4 season activity. As no temporal or spatial estimation method exists for this source and due to the low overall annual emissions, it is recommended that emission modelling not take place for back yard burning.

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APPENDICES

Appendix A: The Consume v2.1 Model

Using Consume to estimate emissions from resource management debris burning is recommended in the BVLD EIIS. Consume is produced by the United States Forest Service's Fire and Environmental Research Applications Team (FERA), and can be readily downloaded from the internet at http://www.fs.fed.us/pnw/fera/products/consume.html.

FERA produce a number of management tools geared at emission estimation, but Consume was the most applicable and available at the time.

> Consume is a user-friendly computer program designed for resource managers with some working knowledge of Microsoft Windows® applications. The software predicts the amount of fuel consumption and emissions from the burning of logged units, piled debris, and natural fuels based on weather data, the amount and fuel moisture of fuels, and a number of other factors. Using these predictions, the resource manager can accurately determine when and where to conduct a prescribed burn to achieve desired objectives while reducing impacts on other resources. Consume can be used for most forest, shrub and grasslands in North America.
>
> \- http://www.fs.fed.us/pnw/fera/products/consume.html

Consume was used to estimate emissions in three chapters of the MEI:

- The "Major Licensee Resource Management Debris Burning" Chapter,
- The "Small Licensee, Agricultural and Land Development Debris Burning" Chapter and also
- The "Permitted Sources" chapter for the
  - Permitted Open Burning section and
  - Fall and Burn sections section.

Consume is a relatively easy program to use and become accustomed to. It can handle various burn scenarios, namely those of "activity- non-piled units", "activity-piled units" and "natural units". As the name suggests, "activity-piled" units concern consumption and emissions from piled burns and therefore it was used as the primary tool for estimating emissions. Consume requires a number of input parameters to function, namely:

a) Pile tree species (the program allows for primary and secondary species),

b) Pile shape (the program allows for a number of different pile shapes),
c) Pile dimensions,
d) Packing ratio (3 types of packing ratios are provided which allow for a variety of tree trunk sizes),
e) Percent of soil in the pile,
f) Pile quality (a reference to the pile's cleanliness) and
g) Number of piles in a block.

Once the parameters are properly inputted into the program, it is possible to view reports listing the emission factors, fuel consumed, TPM, PM_{10} and $PM_{2.5}$ emissions. As described in Chapters 2 and 3, the required parameters were estimated either by experts in the field or the MOF's OFTS.

Benefits of Consume

Consume's user friendliness made it a useful tool for the MEI. Modifying the model and transposing it into Microsoft Excel format made estimating emissions even easier, allowing for the amalgamation of Consume's requirements with those of spatial and temporal resolution. The Consume equation is easy to understand and manipulate and is based on the report: *Guidelines for Estimating Volume, Biomass, and Smoke Production for Piled Slash*. (Hardy 1996)

Shortcomings

There are two notable shortcomings of the Consume model, both which increase the likeliness of error.

The larger issue is that moisture content is not considered in the 'activity-piled units' section. One cannot assume that piles are completely dry when burned because they are outside and exposed to elements like precipitation and wind. In consultation with the creator of Consume, Roger Ottmar, it was acknowledged that work on bulk density, emissions and consumption was still needed to make the equations "more robust".[23] To remedy this, moisture content was used to increase the overall density of the wood, which increased the mass of the wood which and also the emissions. Though it is possible that there is added

[23] Consultation with Roger Ottmar (rottmar@fs.fed.us) 30/10/2003

error associated with this procedure because of how the emission factors were developed for the model, there would likely be even greater error if all wood was considered dry when burned.

Another shortfall is the theory that the percentage of soil in a pile does not does not directly affect the emission factors. Higher percentage of soil in a pile should lead to increased emissions due to decreased combustion efficiency. However in Consume the effect of increasing soil content is to decrease emissions due to decreased fuel content. The formula is as follows:

(1.3) $$E_{PM} = BQ \times \frac{PpnMassConsumed}{100} \times \frac{EF_{PM}}{1000}\left(1 - \frac{\%soil}{100}\right)$$

Where $E_{PM}(t)$ is the emissions of PM (either TPM, PM_{10} or $PM_{2.5}$),

$BQ(t)$ is the base quantity (mass of fuel in pile),

$PpnMassConsumed$ is the percentage of fuel that fully combusts,

$EF_{PM}\left(\frac{kg}{t}\right)$ is the PM (either TPM, PM_{10} or $PM_{2.5}$) emission factor in kg PM emitted for every tonne of fuel consumed and

$\left(1 - \frac{\%soil}{100}\right)$ is the adjustment for soil content in the pile.

Consume still has a pile cleanliness section where the operator can decide if the pile is clean, dirty or very dirty (the dirtier the pile the higher the emission factor), though it has no apparent connection to the percentage of soil in the pile.

The Modified Consume 2.1 Emissions Calculator

This section is designed to illustrate the workings of the Consume model, including the extra information added to address local needs and to make the emissions compatible with CALPUFF.

In order to operate Consume in a metric setting (FERA operates Consume in U.S. Customary Units) and unequivocally control all of its parameters, the model was transposed onto a Microsoft Excel spreadsheet. Having Consume in spreadsheet format saved much time and allowed for further experimentation though control of otherwise fixed parameters such as wood density, emission factors, packing ratio and the proportion of mass consumed. It also allowed for the inputting of extra parameters to address local needs (temporal and spatial resolution) which were not included in the original Consume v2.1 model. Examples of these extra parameters are

a) Treatment date,
b) Latitude and longitude,
c) Base area (and total base area),
d) Wood moisture content,
e) Higher heating values,
f) Duration of each burn and
g) Fire temperature.

Adding input parameters enabled the development of extra variables such as

a) TPM, PM_{10} and $PM_{2.5}$ emission rates and
b) Energy release rates.

In the modified Consume model there are dependant variables, independent variables and storage variables. Dependant variables are formulas which rely on input values from the independent variables, while storage variables are used for tracking and housekeeping purposes and are not necessarily needed in either Consume or for spatial or temporal resolution. (An example of an independent variable is the length of a pile, while the dependent variable would be the pile's volume. A storage variable example is the case number.) The independent and storage variables were estimated using advice from experts in the field or best available science. All of these estimation methods introduce error into the emissions equation, however all possible attempts were made to reduce uncertainty. Throughout this appendix, dependent variables will have red font, independent variables will have black font and storage variables will have blue font.

The Entire Modified Consume Model

In each chapter where Consume was used the formatting was exactly the same for most of the dependent and independent variables. Only the storage variables and a few of the independent variables differ from section to section. The entire Consume model (including these small differences) is outlined below.

Variables Unique to Resource Management Debris Burning

i	ii	iii	iv			vi		
Case Number	Date Burned	Area	Licence	CP	Blk	Size	Latitude	Longitude
	dd/mm					(hectares)		
1	17/9/, 21/10	BABINE	A16830	576	2		55-16-30	126-44-30

Appendix Figure A – Variables unique to resource management debris burning

Variables Unique to Small Licensee, Agricultural and Land Development Debris Burning

i	ii	iii	iv	v		vi	vii	viii	ix	
Burn Category	Case Number	District	Reference Number	Burn Range Start	Burn Range End	Day, Year Burned	Year Burned	Size	Latitude	Longitude
								(hectares)		
7	1	1	R01-R01596	303	90	14-02	02		53.88432	126.35948

Appendix Figure B – Variables Unique to Small Licensee, Agricultural and Land Development Debris Burning

Variables Unique to Permitted Open Burning and Fall and Burn Programs

i	ii	
Date Burned	Latitude	Longitude
dd/mm		
9-Apr	54 21 25.15	125 56 14.88

Appendix Figure C – Variables Unique to Permitted Open Burning and Fall and Burn Programs

Variables found in All Sections of the MEI

a	b	c	d	e									f
Number of Piles	Primary Wood Type	Percentage	Oven Dry Density	Higher Heat Value (HHV)	Secondary Wood Type	Percentage	Oven Dry Density	Higher Heat Value (HHV)	Tertiary Wood Type	Percentage	Oven Dry Density	Higher Heat Value (HHV)	Average Dry Density
		(%)	ρ_{od}=(kg/m^3)	(MJ/kg)		(%)	ρ_{od}=(kg/m^3)	(MJ/kg)		(%)	ρ_{od}=(kg/m^3)	(MJ/kg)	ρ_{od}=(kg/m^3)
20	PINE	50	409	20.00	SPRUCE	50	360	19.78					384.5

Appendix Figure D – Consume Columns a-f

g	h	i	j	k	l			m	n	o	p	q	r	s	t	u
				Calculations Per Pile:												
Moisture Content (%)	Moisture Content (%)	Mass Water Per m^3	Wet Wood Density	Pile Shape	Length	Width	Height	Base Area	Total Base Area	Total Gross Volume	Adjusted for Pile	Packing Ratio	Net Volume	Mass Piled (Inc H_2O)	Percentage of soil	Pile Cleanliness
Dry Basis	Wet Basis	(kg)	ρ = (kg/m^3)		(m)	(m)	(m)	(m^2)	(m^2)	(m^3)	Shape	(%)	(m^3)	(kg)	in pile (%)	C/D/VD
25	20	96.125	480.625	paraboloid	15	15	5	225	4500	1125	441.8	20	88	42467	5	CLEAN

Appendix Figure E – Consume columns g-u

v			w	x		y	z							
TPT	PM10	PM2.5				Calculations for Total Piles								
Emission Factor	Emission Factor	Emission Factor	Total Mass Piled	Proption of mass		Total TPT Emissions	Totals TPT including		Total PM10 Emissions	Totals PM10 including		Total PM2.5 Emissions	Totals PM2.5 including	
(kg/t)	(kg/t)	(kg/t)	(kg)	consumed (%)		(kg)	% soil (kg)		(kg)	% soil (kg)		(kg)	% soil (kg)	
10.94	7.75	6.74	849,334	90		8363	7944		5924	5628		5152	4894	

Appendix Figure F – Consume columns v-z

aa	bb	cc	dd	ee		ff	gg	hh	ii			
									Rates			
Average HHV	Percent HHV Usable Heat	Heat Energy Released	Total Energy Released	Fire Temperature		Burn Start Time	Duration of Burn	Duration of Burn	Emission Rate TPT	Emission Rate PM10	Emission Rate PM2.5	Energy Release
(MJ/kg)	(% of HHV)	(MJ/kg)	(MJ)	(˚C)		(24 hour clock)	(Hours)	(Seconds)	(g/m^{2}s)	(g/m^{2}s)	(g/m^{2}s)	(MJ/sec)
19.89	62.07	12.35	9436703	315		09:00:00	48	172800	0.01022	0.00724	0.006294	54.61

Appendix Figure G – Consume columns aa-ii

General Emissions Formula

Outlined in Chapter 1, Section c, is the general formula for calculating emissions:

$$(1.1)\ E_{PM} = BQ \times \frac{EF_{PM}}{1000}$$

where $E_{PM}(t)$ are the emissions of PM (either TPM, PM_{10} or $PM_{2.5}$),

$BQ(t)$ is the base quantity (of fuel burned) and

$EF_{PM}\left(\frac{kg}{t}\right)$ is the emission factor of PM (either TPM, PM_{10} or $PM_{2.5}$).

As mentioned in chapters 2 and 3, and described in equation (1.3) the Consume v2.1 model uses a slightly more intricate formula:

$$(1.3)\ E_{PM} = BQ \times \frac{PpnMassConsumed}{100} \times \frac{EF_{PM}}{1000}\left(1 - \frac{\%soil}{100}\right)$$

where $\frac{PpnMassConsumed}{100}$ is the percentage of fuel that fully combusts and

$\left(1 - \frac{\%soil}{100}\right)$ is the adjustment for soil content in the pile.

The variable 'Base Quantity' (BQ) (tonnes) can be further broken down into its components

$$(1.5)\ BQ = \#Piles \times M_{W/P} \times \frac{1}{1000}$$

$$(1.6)\ M_{W/P} = V_{W/P} \times \rho$$

$$(1.7)\ V_{W/P} = V_{pile} \times PackingRatio$$

$$(1.8)\ V_{pile} = D_{pile} \times CorrectionforPileShape$$

$$(1.9)\ D_{pile} = L_{pile} \times W_{pile} \times H_{pile}$$

$$(1.10)\ \rho = \rho_{Avg.OD} + M_{H_2O/m^3}$$

$$(1.11)\ M_{H_2O/m^3} = \frac{MCD}{100} \times \rho_{Avg.OD}$$

where $M_{W/P}(kg)$ is the mass of wood per pile,

$V_{W/P}(m^3)$ is the volume of wood per pile,

$D_{pile}(m^3)$ are the combined dimensions of the pile,

$L_{pile}(m)$ is the length of the pile,

$W_{pile}(m)$ is the width of the pile,

$H_{pile}(m)$ is the height of the pile,

$\rho\left(\frac{kg}{m^3}\right)$ is the wet wood density of the pile,

$\rho_{Avg.OD}\left(\frac{kg}{m^3}\right)$ is the average oven dry wood density of the pile,

$M_{H_2O/m^3}\left(\frac{kg}{m^3}\right)$ is the mass of water per m^3 in the pile,

MCD is the moisture content of the wood on a dry basis and

$\frac{1}{1000}$ is a conversion factor from (kg) to (t).

Putting all of the above variables back into the equation, the variable BQ becomes:

$$(1.12)\ BQ = \frac{\#Piles \times L_{pile} \times W_{pile} \times H_{pile} \times ShapeCorrection \times PackingRatio \times \left(\rho_{Avg.OD} \times \left(1 + \frac{MCD}{100}\right)\right)}{1000}$$

All of these variables as well as the other independent, dependent and storage variables are outlined in greater detail in the next section of the appendix.

Variables Unique to Resource Management Debris Burning

Refer to Figure A

i) **Case Number:** This storage variable was used as a tracking tool for sorting.

ii) **Date Burned:** This dependent variable was needed to temporally resolve emissions.

iii) **Area:** In this section, area gives a general description of where burns occurred.

iv) **Licence, CP (cutting permit), Blk (block):** Legal descriptions of the location, enabling easy tracking and sorting of the different burns.

v) **Size:** The size of the block was mainly used as a storage variable, however for certain cases it was also used as an independent variable in the sense that where no data on the number of piles existed, it was assumed that 2- 10m x 10m x 5m piles were created per hectare of land harvested. This estimate was given by local expert foresters in the Resource Management Burning Subcommittee. Note that if the size was not reported by any licensee, it was left blank.

vi) **Latitude, Longitude:** Required for spatial resolution.

Variables Unique to Small Licensee, Agricultural and Land Development Debris Burning

Refer to Figure B

i) **Burn Category:** This storage variable was used to sort the different types of burns that occurred in the MOF's OFTS. For more information on the OFTS, refer to Appendix B, "The Open Fire Tracking System".

ii) **Case Number:** This storage variable was used as a tracking tool for sorting. Note that these case numbers have no connection to the case numbers used in the "Major Licensee Resource Management Debris Burning" Chapter.

iii) **District:** This variable was used to determine the wood species breakdown, as recommended by expert foresters. For more information on districts and wood species breakdowns refer to Appendix B.

iv) **Reference Number:** The burn reference number (BRN) was another tracking tool.

v) **Burn Range, Start and End**: These dates, taken from the OFTS, include the opening and closing dates for each operator's BRN. The days are given in the Julian Calendar, therefore day 92 is April 1st, and day 106 is April 15th.

vi) **Day, Year Burned:** This dependent variable is a function of the 'Burn Range Start' and 'Burn Range End'. It always falls exactly in between those two dates; therefore, day 99 is April 8th, and 01 is 2001.

vii) **Year Burned:** This variable was used for temporally sorting burns in chronological order

viii) **Size:** This variable was only used in for category 6 burns (grass burns), as they are the only kind where emission estimates depends on block size. For more information refer to the "Deviations for OFTS Category 6 Burns (Grass Burning)" Section later in the appendix.

ix) **Latitude, Longitude:** Required for spatial distribution of burns.

Variables Unique to Permitted Open Burning and Fall and Burn Programs

Refer to Figure C

i) **Date Burned:** This dependent variable was a needed to temporally resolve emissions.

ii) **Latitude, Longitude:** Required for spatial resolution.

Variables found in All Sections of the MEI

Refer to Figure D

a) **Number of Piles:** One of Consume's final steps is to multiply the emissions from one pile by the number of piles in a block to determine total emissions for the block. Note that all piles in a block are assumed to be the same size, consisting of the same wood species.

b) **Primary, Secondary Wood Type:** In the "Major Licensee Resource Management Debris Burning" Chapter, wood species were provided by the licensees. In cases where species were not provided it was estimated using the default OFTS district wood species estimated by expert foresters and outlined in Appendix B. In some cases tertiary an additional wood types were submitted. In the "Small Licensee, Agricultural and Land Development Debris Burning" Chapter, default OFTS district species were used while in the "Permitted Open Burning" and "Fall and Burn" Sections of the "Permitted Emissions" Chapter wood species data was supplied by the permitees.

c) **Percentage:** The percentage of each type of wood

d) **Oven Dry Density** $\rho_{OD}\left(\frac{kg}{m^3}\right)$**:** Oven dry density is the density of wood with a moisture content of zero. ρ_{OD} varies by wood type. [24]

e) **Higher Heating Value (HHV)** $HHV\left(\frac{MJ}{kg}\right)$**:** This variable also depended on the wood type. The US EPA defines HHV as "Quantity of heat liberated by the complete combustion of a unit volume or weight of a fuel assuming that the produced water vapour is completely condensed and the heat is recovered; also known as gross calorific value."[25] Note that while the HHV can never be fully realized, it is a necessary piece of information when calculating 'net usable heat', as seen later in the appendix.

f) **Average Dry Density** $\rho_{Avg.OD}\left(\frac{kg}{m^3}\right)$**:** This dependent variable is the weighted density average of all the wood in the pile.

Refer to Figure E

[24] Nielson, 1985, p14
[25] US EPA 2004

g) **Moisture Content, Dry Basis (MCD):** Moisture content, dry basis is expressed as the percentage of water in wood relative to the oven dry mass of the wood. For example, if a log has a mass of 12.5 kg, and the water in the log has a mass of 2.5 kg (the oven dry mass of the wood is 10kg), then the moisture content on a dry basis is $\frac{2.5}{10}\times 100 = 25\%$. MCDs were set to default values in each section or chapter.

Appendix Table A – Default MCD values used in the MEI

Chapter or Section	Default MCD (%)
Major Licensee Resource Management Debris Burning	25
Small Licensee, Agricultural and Land Development Debris Burning MOF Burn Category: 3, 4, 5 6 7-p, 7-s, 7-l	 30 20 25
Permitted Open Burning	20
Fall and Burn	dry trees 20% green trees 50%

h) **Moisture Content, Wet Basis (MCW):** Moisture content, wet basis is expressed as the percentage of water in wood relative to its total mass. For example, if a log has a mass of 12.5 kg and the water in the log has a mass of 2.5 kg (the oven dry mass of the log is 10kg), then the moisture content on a wet basis is $\frac{2.5}{12.5}\times 100 = 20\%$. Both wet and dry bases are commonly used, practical measurements.

i) **Mass Water Per m^3** $M_{H_2O/m^3}\left(\frac{kg}{m^3}\right)$**:** This variable uses the average dry density and the MCD to calculate the mass of water in the pile.

See Formula:(1.11)

j) **Wet Wood Density** $\rho\left(\frac{kg}{m^3}\right)$**:** The wet wood density is the actual density of the wood, used in the remainder of calculations requiring density. Note that Consume does not take moisture content into consideration when producing emission estimates. This was changed when the model was reformatted into Excel, as it was necessary to assume that there was moisture in the wood being burned.

See Formula: (1.10)

k) Pile Shape: The original Consume allows for a variety of pile shapes, including cubes, paraboloids, half-spheres, half-cylinders, cones, etc. Almost all piles were assumed to be paraboloids.

l) Length, Width, Height $L_{pile}(m), W_{pile}(m), H_{pile}(m)$**:** The dimensions of the pile. In the "Major Licensee Resource Management Debris Burning" Chapter, most piles were assumed to be 10m x 10m x 5m, as directed by local forestry experts. In some cases (for PIR's piles) the pile dimensions were set to15m x 15m x 5m because the piles number estimates were corrected for larger piles. In the "Small Licensee, Agricultural and Land Development Debris Burning" Chapter, pile dimensions varied by burn category (outlined in Appendix B). In the "Permitted Open Burning" Section of the "Permitted Sources" Chapter pile dimensions varied by permit requirements, while for the "Fall and Burn" Section pile dimensions were not used as total volume was estimated on a 'per tree' basis.

m) Base Area $BA_P(m^2)$**:** Base area of each individual pile was calculated by multiplying the length of the pile by the width of the pile.

n) Total Base Area $BA_T(m^2)$**:** The total base area is a required variable for spatial resolution. It incorporates the number of piles per case into a total base area and therefore gives a total area occupied by burns.

Formula: (1.13) $BA_T = \#Piles \times BA_P$

o) Total Gross Volume $D_{pile}(m^3)$**:** This variable is the product of the length, width and height of the pile.

See Formula (1.9)

p) Adjusted for Pile Shape $V_{A_{paraboliod}}(m^3)$**:** Recognizing that piles are not normally built into perfect cubes, this variable takes into account the shape of the pile, as outlined in the 'Pile Shape' column. For example, if the pile shape is a paraboloid the total gross volume would need to be adjusted to reflect its shape:

Formula:(1.14) $V_{A_{paraboliod}} = \dfrac{\pi \times L_{pile} \times W_{pile} \times H_{pile}}{8}$

q) Packing Ratio: Air comprises much of the gross volume of a pile and therefore it is necessary to know how much of the pile is actually wood. Packing ratio represents the fraction of the pile actually occupied by wood, and is usually a function of the piling equipment available combined with the type of woody debris in the piles (stumps and bigger logs have smaller packing ratios than branches and small limbs). A default of 20% was used in almost all cases.

r) **Net Volume** $V_{W/P}\left(m^3\right)$ **:** The actual volume of wood in a pile, determined by multiplying the 'Adjusted [volume] for Pile Shape' and the 'Packing Ratio' columns.

s) **Mass Piled (inc. H_2O)** $M_{W/P}\left(kg\right)$ **:** The mass piled column represents the mass of wood in one pile, including the mass of the water in the wood.

See Formula: (1.6)

t) **Percentage of Soil in Pile:** Consume assumes that soil in piles does not burn, and the final step in the emissions calculation is to reduce estimtes by the total percentage of soil in the pile. For example, if a pile should emit 100kg of PM_{10} but has a 4% soil content, Consume states the emissions are actually only 96kg PM_{10}. For almost all cases, Percentage Soil was set to 5%.

u) **Pile Cleanliness:** Pile Cleanliness is the independent variable that controls the TPM, PM_{10} and $PM_{2.5}$ emission factors. Emission factors were taken directly from the Consume model which were based on *Guidelines for Estimating Volume, Biomass, and Smoke Production for Piled Slash,* (Hardy1996).[26] For the "Major Licensee Resource Management Debris Burning" Chapter, piles were assumed to be clean. In the "Small Licensee, Agricultural and Land Development Debris Burning" Chapter, pile cleanliness varied by burn category (outlined in Appendix B). In the "Permitted Open Burning" Section of the "Permitted Sources" Chapter the cleanliness varied by what material was being burned (the burning of cull logs and log trimmings were clean but slabs intermixed with sawdust were considered dirty), while for the "Fall and Burn" Section piles were assumed to be clean. Note that pile cleanliness and the percentage of soil in a pile are not related.

Appendix Table B – Pile cleanliness and TPM, PM10 and PM2.5 emission Factors

Pile Cleanliness	TPM Emission Factor (kg/t)	PM_{10} Emission Factor (kg/t)	$PM_{2.5}$ Emission Factor (kg/t)
Clean	10.94	7.75	6.74
Dirty	13.48	10.02	8.49
Very Dirty	17.99	14.01	11.82

Refer to Figure F

[26] For more information on Consume's emission factors, refer to p146 of the Consume Users Guide, available online at http://www.fs.fed.us/pnw/fera/products/consume.html.

v) **TPM, PM_{10} and PM2.5 Emission Factor** $EF_{PM}\left(\frac{kg}{t}\right)$**:** Emission factors, described as kilograms of PM emitted per tonne of fuel burned.

w) **Base Quantity** $BQ(t)$**:** The base quantity is the product of the 'Number of Piles' and the 'Mass Piled (inc H_2O)' columns.

See Formula: (1.5)

x) **Proportion of Mass Consumed:** This independent variable was set to a default of 90%. It is based on Consume's assumption that only 90% of each completely combusts and therefore only 90% of emissions are emitted.

y) **Total TPM PM_{10} and $PM_{2.5}$ Emissions** $E_{PM_{NoSoil}}(t)$**:** This variable calculates emissions based closely to equation (1.1) except that the proportion of mass consumed is taken into consideration

Formula: (1.15) $E_{PM_{NoSoil}} = BQ \times \frac{PpnMassConsumed}{100} \times \frac{EF_{PM}}{1000}$

z) **Total TPM, PM_{10} and $PM_{2.5}$ Including [the reduction for] % soil** $E_{PM}(t)$**:** This variable takes the soil content of each pile into account. This is the final PM value.

Formula: (1.16) $E_{PM} = E_{PM_{NoSoil}} \times \left(1 - \frac{\%soil}{100}\right)$

Refer to Figure G

aa) **Average HHV** $HHV_{AVG}\left(\frac{MJ}{kg}\right)$**:** This dependent variable represents a weighted average of the different higher heating values in the pile, based on the wood species and their percentages.

bb) **Percent HHV [which translates into net] usable heat** $HHV_{\%Usable}$**:** Not all of the energy in wood can be transformed into usable heat, $UH\left(\frac{MJ}{kg}\right)$ because some energy is used vaporizing the moisture in the wood. Even with a moisture content of zero, net usable heat is only about 80% of the HHV (ie: if the HHV is 20 MJ/kg then the usable heat would be 16 MJ/kg).[27] Furthermore, the greater the moisture content, the less percentage of usable heat. Using Conversion Factors for the Forest Products Industry in Western Canada (CFFPIWC), (Neilson 1985) it was possible to develop a theoretical formula for moisture content (wet basis) vs. percentage of usable heat.

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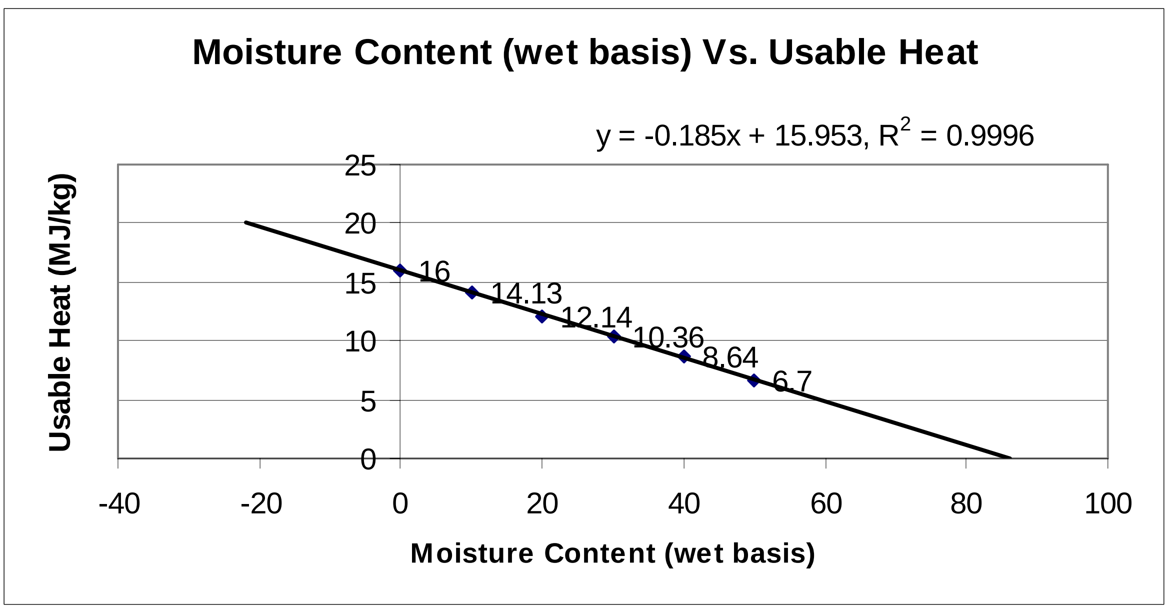
27 Neilson, 1985, p78

Appendix Table C – Theoretical net usable heat values derived from CFFPIWC

HHV = 20 (MJ/kg)				
Moisture Content		**Net Usable Heat**		
Oven Dry	Original Weight	CFFPIWC	Theoretical Formula Results	
(Dry Basis)	(Wet Basis)		UH	% of HHV
(%)	(%)	(MJ/kg)	(MJ/kg)	
0.0	0	16	15.953	79.765
11.1	10	14.13	14.103	70.515
25.0	20	12.24	12.253	61.265
42.9	30	10.36	10.403	52.015
66.7	40	8.64	8.553	42.765
100.0	50	6.7	6.703	33.515
150.0	60		4.853	24.265
233.3	70		3.003	15.015
400.0	80		1.153	5.765
900.0	90		-0.697	-3.485
9900.0	99		-2.362	-11.810



Appendix Figure H – Moisture content (wet basis) vs. usable heat (MJ/kg)

Formula: $(1.17)\, UH = -0.185 \times MCW + 15.953$ and

$$(1.18)\, HHV_{\%Usable} = \frac{UH}{HHV_{AVG}} * 100$$

cc) Heat Energy Released $UH\left(\frac{MJ}{kg}\right)$**:** Heat energy released and usable heat are the same for the purpose of the Consume. They represent the total energy (per kilogram of wet wood) that is converted into heat and released during the burn.

dd) Total Energy Released $e_T\,(MJ)$**:** This dependent variable is a product of the Heat Energy Released, the Total Mass Piled and the Proportion of Mass Consumed, and represents the total energy released from burning all piles in the block.

Formula: (1.19) $e_T = BQ \times \frac{PpnMassConsumed}{100} \times (UH \times 1000)$

ee) Fire Temperature $T(^\circ C)$**:** Fire temperature was set to a default of 315 degrees Celsius. (588 Kelvin or 600 degrees Fahrenheit).

ff) Burn Start Time: 09:00:00 was selected as the default time for each and every pile.

gg) Duration of Burn Hours, Seconds $time_{burn}\,(\sec)$**:** In general, most burns were set to be 48 hours in length, or 172800 seconds, though some burns did occur over 72 hours. As will be seen, changing the burn length changes the emission rates and is something that may wish to be further explored, resources pending.

hh) Emission Rate TPM, PM_{10} and $PM_{2.5}$ $E_{PM}\,Rate\left(\frac{g}{m^2 \cdot \sec}\right)$**:** Expressed as the emissions emitted (in grams) per square metre of burn area in the block per second for the entire length of the burn.

Formula: (1.20) $E_{PM}\,Rate = \frac{E_{PM} \times 1000000}{BA_T \times time_{burn}}$

ii) Energy Release Rate $eRate\left(\frac{MJ}{\sec}\right)$**:** The rate for the entire burn at which usable heat is being released by the fire. Like the PM emission rates, this value was assumed to be constant throughout the burn period.

Formula: (1.21) $eRate = \frac{e_T}{time_{burn}}$

Deviations For OFTS Category 6 Burns (Grass Burning)

Because category 6 burns (grass burns) are not piled and are measured by hectare (as opposed to by number of piles), estimating emissions follows a slightly different format. For these burns, a net fuel loading was determined based on the number of hectares burned. A value of five tonnes was estimated per hectare.[28] MCD was set to a default of 20%, which gave a total of 1000kg of water per hectare. These deviations did not alter the methodology or theory behind the emissions equation. It was assumed that only grass (no duff) burned and that moisture content had the same effect as it did in wood (increased density, decreased net usable heat).

a	b	c	d	e	f	g	h	i
Primary Wood Type	Percentage	Default Loading	Higher Heat Value (HHV)	Average Dry Loading	Moisture Content (%)	Moisture Content (%)	Mass Water Per ha	Wet Grass Loading
	(%)	$load_{od}$=(t/ha)	(MJ/kg)	$load_{od}$=(t/ha)	Dry Basis	Wet Basis	(tonnes)	load=(t/ha)
GRASS	100	5	15	5	20	16.66666667	1	6

Appendix Figure I – Consume columns a-i for OFTS category 6 burns

j	k	l TPM	PM10	PM2.5	m	n	
Percentage of soil	Pile Cleanliness	Emission Factor	Emission Factor	Emission Factor	Base Quantity	Proption of mass	
in pile (%)	C/D/VD	(kg/t)	(kg/t)	(kg/t)	(t)	consumed (%)	
0	CLEAN	13.48	10.02	8.49	8	95	

Appendix Figure J – Consume columns j-n for OFTS category 6 burns

a) **Primary Wood Type:** in order to remain consistent with the remainder of Consume, the primary wood type column was kept and set to a default of 'GRASS'.

b) **Percentage:** Category 6 burns were assumed to be 100 percent grass.

c) **Default Loading (oven dry)** $L_D(t)$**:** It was necessary for Consume's emission calculations to have a mass variable. Five tonnes of grass per hectare was selected as the default independent variable,

[28] Taylor, 1996, p18

based on the report *Biomass Consumption and Smoke Emissions from Contemporary and Prehistoric Wildland Fires in British Columbia*. (Taylor 1996)

d) **Higher Heating Value (HHV):** Similar to wood, grass also has a higher heating value. Though different grass species have different HHV's 15 MJ/kg was chosen as the default value, based on the report *Determining 'Burnability' of Grassy Crop Materials*. (Bransby unknown)

e) **Average Dry Loading** $L_{D.Avg}\left(\frac{t}{ha}\right)$**:** The purpose of the 'Average Dry Loading' column is to enable the addition of other fuel into the category 6 burns emission estimates. Soil is an example of material which may be burned when grass is burned. This option may be further explored at a later time. Currently, average dry loading is equal to the default oven dry loading.

f) **MCD:** As mentioned in Appendix Table B, this variable was set to a default 20%

g) **MCW:** Calculated using the same formula as wood's MCW.

h) **Mass Water, Per ha** $M_{H_2O/ha}\left(\frac{t}{ha}\right)$**:** This variable is the product of the average dry loading and the MCD.

Formula: (1.22) $M_{H_2O/ha} = L_{D.Avg} \times \frac{MCD}{100}$

i) **Wet Grass Loading** $L_W\left(\frac{t}{ha}\right)$**:** Wet grass loading is the sum of the dry grass and the mass of water per hectare.

Formula: (1.23) $L_W = L_{D.Avg} + M_{H_2O/ha}$

j) **Percentage of Soil in Pile:** Not a variable used in the category 6 burns. (Refer to line 'e')

k) **Pile Cleanliness:** Also not a variable used in category 6 burns, however, if there is a time when burning soil is included in emission estimates, 'Pile Cleanliness' could be used to reflect soil content.

l) **TPM, PM_{10} and $PM_{2.5}$ Emission Factor** $EF_{PM}\left(\frac{kg}{t}\right)$**:** Default TPM, PM_{10} and $PM_{2.5}$ emission factors were set to 13.48, 10.02 and 8.49 g/kg respectively.

m) Base Quantity $BQ_G(t)$**:** Gives the total mass of grass through incorporating the number of hectares involved in the burn.

Formula: (1.24) $BQ_G = Size \times L_W$

Where $Size(ha)$ is the area of grass burned.

n) Proportion of Mass Consumed: This variable is set to a default 95% for category 6 grass burns.

The remainder of the OFTS category 6 burn equation is the same as for all other burns.

Other Models

Other methods to estimate emissions from piled burns do exist. The two prominent ones were explored but not used. Introductions to these models are given here.

The first model is called "Air and Emissions Information of British Columbia". This is an interactive map and has open burning activity data in an easy to view format, available online at http://imf.geocortex.net/mapping/air/index.html. (This same website was used to gather permitted source emission data and is part of the Year 2000 Provincial Emissions Inventory.) Unfortunately, data is not available for the year 2002, one of the years included in the MEI. Also, emission estimates for the year 2001 are significantly different than estimates obtained through the OFTS. Furthermore, not enough information is provided to temporally resolve burns. While this program has much potential for future use, it could not be used to estimate open burn emissions for the MEI.

The other usable emissions model is the US Forest Service Fire Emission Production Simulator (FEPS). This model appears to be a very comprehensive approach to emission estimation, including not only fuel consumption and emission values, but also heat energy release values. Also, FEPS has temporal profiles for all emission variables, making it possible to view how emissions change as the burn progresses through all of its three phases (preheating, flaming, smouldering). Unfortunately, FEPS was only introduced in 2004 and emission estimates had been made prior to its release. Also, FEPS's formulas are very non-linear and are much more difficult to transpose into Excel than Consume's. This may be one avenue worth exploring at a later date. More information is available online at http://www.fs.fed.us/pnw/fera/feps/, where it can be downloaded.

Appendix B: The Open Fire Tracking System

With the emissions formula from Consume, MOF's OFTS was used in the MEI to estimate emissions in the "Major Licensee Resource Management Debris Burning" Chapter as well as in the "Small Licensee, Agricultural and Land Development Debris Burning" Chapter. The following elaborates on the OFTS and discusses how certain input variables taken from the OFTS are applied to Consume in order to estimate emissions.

With the exception of back yard burns and grass burns under 0.2 hectares in size, any burn operator wishing to open burn must obtain a BRN from the MOF. This management tool tracks all open burning throughout the province. Generally speaking, if a BRN is obtained between mid-March and mid-October (non-"winter conditions") it is valid for two weeks. If a BRN is obtained between mid-October and mid-March (during "winter conditions") it is valid until the following March 31st. BRNs can be extended at any time for an additional 2 weeks, should an operator require it.

The MOF divides open burning into 8 categories, listed in the table below.

Appendix Table D – MOF burn categories and definitions

Category	Definition
1	Small open fire for waste material (not exceeding 2 metres in height and 3 metres in diameter).
2	Grass or stubble fire less than 0.2 ha
3	Piles or windrows more than 50m from combustible material
4	Root-raked windrows less than 200 m long, 2 m wide, 1 m high
5	Piles or windrows less than 50 m from combustible material
6	Grass fires greater than 0.2 hectares
7	Resource management landing/roadside debris disposal
8	Broadcast burns (commonly referred to as prescribed burns when, in fact, all burn types are prescribed)

Prior to estimating emissions, all reference numbers activated between January 1st 2001 and December 31st 2002 were divided into their respective categories. Burn categories 3-5 are typically agricultural based while category 7 burns are resource management based. No category 8 broadcast burns occurred within the BVLD during the inventory period.

Resource management burns are conducted by large and small licensees, as well as land developers.[29] To better estimate emissions, category 7 burns were further subdivided.

Appendix Table E – Subdivisions of MOF burn category 7

7 – private (7-p)	Resource management landing/roadside debris disposal
7 – small licensee (7-s)	Resource management landing/roadside debris disposal
7 – large licensee (7-l)	Resource management landing/roadside debris disposal

Data submitted from operators to the OFTS includes the location of the lot (or cut block) as well as the number of piles to be burned. Note that for the larger licensees this number tends to be an estimate, while for smaller licensees or agriculturally based burns this number is thought to be more exact. For this reason tracking burns of categories 3-6 is likely more accurate, while OFTS category 7 burns have a higher degree of uncertainty. That being said, category 7 burns conducted by BC Timber Sales and Woodlot licensees are likely tracked accurately as well, as pile estimates are usually smaller.

Burn dates are not included in the OFTS, however one can assume that open burns are restricted to the 2 week window of the active BRN. For both winter and non-winter conditions, burn dates were assumed to be the exact middle of the 2 week window. For cases in the winter of 2002/2003, when the middle date was located during 2003, it was assumed that at least half of the piles were burned in 2002. It should be noted that emissions were not included in the MEI for BRNs activated in the winter of 2000 where the middle date was in 2001.This may be inserted at a later time. Also, it was assumed that not more than 500 piles were burned by one licensee in one day. If one BRN included more than 500 piles, these burns were assumed to occur over the course of two days.

Consume v2.1 was used to estimate TPM, PM_{10} and $PM_{2.5}$ emissions for all burns in the OFTS. As each burn category represents a different type of burn, different independent variables from 3 major components of Consume's emissions formula (as discussed in Appendix A) were used throughout the OFTS for the different burn categories.

[29] Through correspondence MOF staff in Victoria.

1) **Pile Size**

Pile sizes for the different categories were estimated through discussions with forestry officials, expert foresters as well as observation.

Appendix Table F – MOF burn categories and default pile sizes

Category	**Pile Size**
3	5m x 5m x 5m
4	200m x 2m x 1m
5	5m x 5m x 5m
6	Area burned is submitted by operators.
7 – private	8m x 8m x 5m
7 – small licensee	10m x 10m x 5m
7 – large licensee	10m x 10m x5m
8	- no burns

2) **Emission Factors**

Different emission factors were used for the different category burns, as it was assumed that agricultural burns were dozer built and were dirtier than crane built resource management piles. Windrows were assumed to be the dirtiest, and had the highest emission factors. This assumption can be changed if need be, as it does not represent all piles of all categories. The emission factors used are from Consume and correspond with pile cleanliness as reported in Table B.

Appendix Table G – MOF burn categories and default TPM, PM10 and PM2.5 emission factors

Category	**Emission Factors (kg/t)**		
	TPM	**PM_{10}**	**$PM_{2.5}$**
3	13.48	10.02	8.49
4	17.99	14.01	11.82
5	13.48	10.02	8.49
6	13.48	10.02	8.49
7 – private	13.48	10.02	8.49
7 – small licensee	10.94	7.75	6.74
7 – large licensee	10.94	7.75	6.74
8	No burns	No burns	No burns

3) Wood Species

The BVLD airshed is comprised mainly of 2 (formerly four) MOF forest districts (FD), the Nadia and Skeena-Sitkine. The OFTS however, tracks burns not through these districts but by the older, more specific FDs, namely the Lakes, Morice, Bulkley-Cassiar and Kispiox. (Other FD's in the BVLD airshed include the Vanderhoof FD, Fort St. James FD and the Kalum FD. Burns in these FD's were not included in the MEI but may be inserted at a later date.) Each forest district has different properties, including different wood species. For the purpose of estimating emissions, the different wood species of each FD were estimated by 2 expert foresters for agricultural and logging purposes in both low and high elevation areas.[30]

Appendix Table H – OFTS districts and default wood species breakdowns for low and high elevation agriculture and logging

	District		Spruce	Pine	Balsam fir	Aspen, Cottonwood	Hemlock
Low Elevation	4	Kispiox -agriculture	40	10		40	10
	3	Bulkley Cassiar - agriculture	50	10	-	40	-
	2	Morice - agriculture	40	30	-	30	-
	1	Lakes - agriculture	40	30	-	30	-
	4	Kispiox - logging	40	30	10		20
	3	Bulkley Cassiar - logging	50	30	20	-	-
	2	Morice - logging	50	50	-	-	-
	1	Lakes - logging	40	60	-	-	-
Mid-High Elevation	4	Kispiox - agriculture	30	10	30	20	10
	3	Bulkley Cassiar - agriculture	40	10	30	20	-
	2	Morice - agriculture	40	30	20	10	-
	1	Lakes - agriculture	40	30	20	10	-
	4	Kispiox - logging	30	30	30		10
	3	Bulkley Cassiar - logging	50	30	20	-	-
	2	Morice - logging	40	30	30	-	-
	1	Lakes - logging	40	40	20	-	-

These tree species were used to estimate emissions for all MOF burn categories in the "Small Licensee, Agricultural and Land Development Debris Burning" Chapter as well as in the "Major Licensee Resource Management Debris Burning" Chapter where tree species was not supplied by the licensee.

[30] Robert Shiach MOF, Paul Schwarz, PIR.

Benefits of the OFTS

The OFTS is an easy and manageable tool to use. It tracks most open burns in the province and identifies basic features of each burn, such as location, number of piles and purpose.

Shortcomings

In terms of estimating emissions, there are some significant shortcomings of the OFTS. The most significant is that no actual date of burn is given. It was assumed that the exact middle date of the active reference number was the date of burn, however in some cases burn reference numbers were extended and it was unclear whether or not burns took place at all. For these cases educated guesses were made to temporally resolve the burns. Another shortcoming of the OFTS is that it does not accurately track the activity of major licensees as suggested by the large discrepancy in emission estimates from the data supplied by the licensees and that obtained through the OFTS. One potential reason for this is that BRNs are obtained prior to commencing resource management burning activities and only pile estimates are known at that time. For the purpose of the MEI, the OFTS therefore provided the means to accurately estimate emissions for burn categories 3-6, category 7-person and small licensee burns, though not category 7- large licensee burns.

Appendix C: Emissions by Permit and Estimation Type

All emissions are reported in tonnes per year.

Tier 1 Beehive Burners and Mills

Appendix Table I – a through e (Tier 1 beehive burner and respective mill emissions)

Table I-a – Tier 1 beehive burner and respective mill emissions based on PFPs

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 01543	Canfor Houston	2118.8	1011.5	630.3		2118.8	1011.5	630.3
PA 01691	Pacific Inland Resources	1368.5	708.6	466.2		1368.5	708.6	466.2
PA 05339	Houston Forest Products Company	1302.6	649.3	398.1		1302.6	649.3	398.1
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		4789.9	2369.3	1494.6		4789.9	2369.3	1494.6

Table I-b – Tier 1 beehive burner and respective mill emissions based on AEIBC (Actual)

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 01543	Canfor Houston	841.5	510.5	325.4		841.5	510.5	325.4
PA 01691	Pacific Inland Resources	534.1	261.5	153.5		534.1	261.5	153.5
PA 05339	Houston Forest Products Company	917.3	451.5	284.4		917.3	451.5	284.4
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		2292.9	1223.1	763.8		2292.9	1223.1	763.8

Table I-c – Tier 1 beehive burner and respective mill emissions based on AEIBC (Maximum)

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 01543	Canfor Houston	2483.3	1389.5	953.77		2483.3	1389.5	953.77
PA 01691	Pacific Inland Resources	1168.2	599.6	387.2		1168.2	599.6	387.2
PA 05339	Houston Forest Products Company	1170.3	599.0	384.27		1170.3	599.0	384.27
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		4821.8	2588.1	1725.2		4821.8	2588.1	1725.2

Table I-d – Tier 1 beehive burner and respective mill emissions based on SENES consulting reporting methodology for beehive burner emissions and permit fees for all other sources

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 01543	Canfor Houston	1456.3	830.7	524.3		1456.3	830.7	524.3
PA 01691	Pacific Inland Resources	857.9	426.8	264.1		857.9	426.8	264.1
PA 05339	Houston Forest Products Company	900.8	427.5	239.1		900.8	427.5	239.1
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		3215.0	1685.0	1027.5		3215.0	1685.0	1027.5

Table I-e – Tier 1 beehive burner and respective mill emissions based on SENES consulting reporting methodology for beehive burner emissions corrected for reported throughput (from mills) to burner and emission sack tests for hog boiler or volcano energy recovery system where applicable

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 01543	Canfor Houston	1311.3	701.2	415.1		1309.1	700.0	414.2
PA 01691	Pacific Inland Resources	642.5	308.8	177.0		514.2	238.5	125.0
PA 05339	Houston Forest Products Company	766.8	354.3	185.0		734.6	336.6	171.9
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		2720.6	1364.3	777.1		2557.8	1275.1	711.2

Note, the parent company of Canfor Houston is Canadian Forest Products Ltd, and the parent company of both Pacific Inland Resources and Houston Forest Products Company is West Fraser Mills Ltd.

Tier 2 Beehive Burners and Mills

Appendix Table J – a through d (Tier 2 beehive burner and respective mill emissions)

Table J-a – Tier 2 beehive burner and respective mill emissions based on PFPs

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 03019	Decker Lake Forest Products Ltd.	583.5	320.0	222.1		583.5	320.0	222.1
PA 04122	Babine Forest Products Ltd.	694.1	373.9	233.6		694.1	373.9	233.6
PA 07748	Skeena Cellulose Inc.	222.9	119.6	84.2		0.0	0.0	0.0
PA 16903	Cheslatta Forest Products Ltd.	41.1	22.6	16.4		750.0	412.4	300.0
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		1541.6	836.1	556.4		2027.6	1106.3	755.7

Table J-b – Tier 2 beehive burner and respective mill emissions based on AEIBC (Actual)

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 03019	Decker Lake Forest Products Ltd.	301.2	165.0	112.1		301.2	165.0	112.1
PA 04122	Babine Forest Products Ltd.	318.3	169.1	95.8		318.3	169.1	95.8
PA 07748	Skeena Cellulose Inc.	504.7	273.6	193.6		0.0	0.0	0.0
PA 16903	Cheslatta Forest Products Ltd.	19.4	10.6	7.9		354.4	194.1	143.4
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		1143.6	618.3	409.3		973.8	528.2	351.3

Table J-c – Tier 2 beehive burner and respective mill emissions based on AEIBC (Maximum)

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 03019	Decker Lake Forest Products Ltd.	583.6	320.1	222.2		583.6	320.1	222.2
PA 04122	Babine Forest Products Ltd.	683.1	367.7	231.1		683.1	367.7	231.1
PA 07748	Skeena Cellulose Inc.	2523.7	1368.1	967.9		0.0	0.0	0.0
PA 16903	Cheslatta Forest Products Ltd.	41.1	22.6	16.4		750.0	412.4	300.0
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		3831.6	2078.6	14437.6		2016.7	1100.3	753.3

Table J-d – Tier 2 beehive burner and respective mill emissions based on SENES consulting reporting methodology for beehive burner emissions and permit fees for all other sources

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 03019	Decker Lake Forest Products Ltd.	435.5	237.4	159.3		435.5	237.4	159.3
PA 04122	Babine Forest Products Ltd.	437.8	232.5	132.5		437.8	232.5	132.5
PA 07748	Skeena Cellulose Inc.	171.3	90.9	62.4		0.0	0.0	0.0
PA 16903	Cheslatta Forest Products Ltd.	19.4	10.6	7.9		354.4	194.1	143.4
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		1064.1	571.4	361.7		1227.7	664.0	435.0

Mines

Appendix Table K – a through c (Mine emissions)

Table K-a – Mine emissions based on PFPs

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 02399	Thompson Creek Mining Ltd.	540.6	540.6	190.8		540.6	540.6	190.8
PA 14800	Huckleberry Mines Ltd.	17.3	8.8	2.6		17.3	8.8	2.6
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		557.8	549.4	193.4		557.8	549.4	193.4

Table K-b – Mine emissions based on AEIBC (Actual)

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 02399	Thompson Creek Mining Ltd.	409.9	409.9	144.7		409.9	409.9	144.7
PA 14800	Huckleberry Mines Ltd.	16.9	8.63	2.54		16.9	8.63	2.54
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		426.8	418.5	147.2		426.8	418.5	147.2

Table K-c – Mine emissions based on AEIBC (Maximum)

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 02399	Thompson Creek Mining Ltd.	484.0	484.0	170.87		484.0	484.0	170.87
PA 14800	Huckleberry Mines Ltd.	17.3	8.8	2.59		17.3	8.8	2.59
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		501.3	492.8	173.5		501.3	492.8	173.5

Small Sawmills

There are four permitted small sawmills with emission sources other than open burning (cyclones, chip conveyor systems, kilns, boilers, etc.). Of the four sources, one was not in operation for the entire emission inventory period (PA 12099) and one closed mid March of 2001 (PA 07864). Furthermore, it has recently been discovered that another permit PA 11401 ceased operations in June of 2001. Emissions for these permits have been adjusted to reflect changes in operations.

Appendix Table L – a through c (Annual sawmill emissions)

Table L-a – Annual sawmill emissions based on PFPs

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 04171	Kitwanga Lumber Co. Ltd.	7.77	3.08	1.61		7.77	3.08	1.61
PA 07864	Skeena Cellulose Inc.	3.68	2.25	1.77		0.00	0.00	0.00
PA 11401	Burns Lake Specialty Wood Ltd.	76.01	30.37	15.20		0.00	0.00	0.00
PA 12099	Kispiox Forest Products Ltd.	0.00	0.00	0.00		0.00	0.00	0.00
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		87.46	35.69	18.57		7.77	3.08	1.61

Table L-b – Annual sawmill emissions based on AEIBC (Actual)

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 04171	Kitwanga Lumber Co. Ltd.	5.81	2.32	1.16		5.81	2.32	1.16
PA 07864	Skeena Cellulose Inc.	1.37	0.70	0.21		0.00	0.00	0.00
PA 11401	Burns Lake Specialty Wood Ltd.	28.48	13.10	5.62		0.00	0.00	0.00
PA 12099	Kispiox Forest Products Ltd.	0.00	0.00	0.00		0.00	0.00	0.00
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		35.66	16.12	6.99		5.81	2.32	1.16

Table L-c – Annual sawmill emissions based on AEIBC (Maximum)

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 04171	Kitwanga Lumber Co. Ltd.	7.77	3.11	1.55		7.77	3.11	1.55
PA 07864	Skeena Cellulose Inc.	1.84	0.94	0.28		0.00	0.00	0.00
PA 11401	Burns Lake Specialty Wood Ltd.	36.94	17.00	7.29		0.00	0.00	0.00
PA 12099	Kispiox Forest Products Ltd.	0.00	0.00	0.00		0.00	0.00	0.00
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		46.55	21.05	9.12		7.77	3.11	1.55

Permitted Open Burning at Sawmills

Appendix Table M – a through e (Annual permitted open burning at sawmill emissions)

Table M-a – Annual permitted open burning at sawmill emissions based on PFPs

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 12888	Boo Flat Lumber Ltd.	2.82	2.22	1.27		2.82	2.22	1.27
PA 13415	Merkley Enterprises	1.28	1.01	0.58		1.28	1.01	0.58
PA 14322	Ootsa Lake Sawmill Ltd.	3.84	3.03	1.73		3.84	3.03	1.73
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		7.94	6.27	3.57		7.94	6.27	3.57

Table M-b – Annual permitted open burning at sawmill emissions based on AEIBC (Actual)

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 12888	Boo Flat Lumber Ltd.	1.07	0.72	0.67		1.07	0.72	0.67
PA 13415	Merkley Enterprises	0.49	0.33	0.30		0.49	0.33	0.30
PA 14322	Ootsa Lake Sawmill Ltd.	1.46	0.98	0.91		1.46	0.98	0.91
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		3.02	20.3	1.88		3.02	20.3	1.88

Table M-c – Annual permitted open burning at sawmill emissions based on AEIBC (Maximum)

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 12888	Boo Flat Lumber Ltd.	2.82	1.88	1.75		2.82	1.88	1.75
PA 13415	Merkley Enterprises	1.28	0.85	0.80		1.28	0.85	0.80
PA 14322	Ootsa Lake Sawmill Ltd.	3.84	2.56	2.39		3.84	2.56	2.39
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		7.94	5.29	4.94		7.94	5.29	4.94

Table M-d – Annual permitted open burning at sawmill emissions based on the Consume v2.1 emission model

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 12888	Boo Flat Lumber Ltd.	1.16	0.84	0.72		1.16	0.84	0.72
PA 13415	Merkley Enterprises	0.42	0.30	0.26		0.42	0.30	0.26
PA 14322	Ootsa Lake Sawmill Ltd.	1.41	1.00	0.87		1.41	1.00	0.87
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		2.99	2.14	1.85		2.99	2.14	1.85

Table M-e – Annual permitted open burning at sawmill emissions based on the Consume v2.1 emission model & contact with permitees

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 12888	Boo Flat Lumber Ltd.	0.00	0.00	0.00		0.00	0.00	0.00
PA 13415	Merkley Enterprises	0.42	0.30	0.26		0.00	0.00	0.00
PA 14322	Ootsa Lake Sawmill Ltd.	1.41	1.00	0.87		1.41	1.00	0.87
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		1.82	1.29	1.12		1.41	1.00	0.87

Fall and Burn Programs

Emission estimates using Consume were based on consultation with the permitees. Factors taken into consideration for the Canfor permits (including Northwood Inc.) were the number of trees burned with an estimated volume of $0.4m^3$ per tree. For the West Fraser permit it was assumed (through consultation with the permitee) that all of the permitted volume was used.

Appendix Table N – a through d (Annual fall and burn emissions)

Table N-a – Annual fall and burn emissions based on PFPs

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 15262	Canadian Forest Products Ltd.	12.80	10.11	5.76		12.80	10.11	5.76
PA 15521	Northwood Inc.	6.40	5.06	2.88		6.40	5.06	2.88
PA 15780	West Fraser Mills Ltd.	6.40	5.06	2.88		6.40	5.06	2.88
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		25.60	20.22	11.52		25.60	20.22	11.52

Table N-b – Annual fall and burn emissions based on AEIBC (Actual)

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 15262	Canadian Forest Products Ltd.	21.40	14.30	13.30		21.40	14.30	13.30
PA 15521	Northwood Inc.	4.30	2.90	2.70		4.30	2.90	2.70
PA 15780	West Fraser Mills Ltd.	2.40	1.60	1.50		2.40	1.60	1.50
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		28.10	18.80	17.50		28.10	18.80	17.50

Table N-c – Annual fall and burn emissions based on AEIBC (Maximum)

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 15262	Canadian Forest Products Ltd.	32.00	21.33	19.94		32.00	21.33	19.94
PA 15521	Northwood Inc.	6.40	4.27	3.99		6.40	4.27	3.99
PA 15780	West Fraser Mills Ltd.	6.40	4.27	3.99		6.40	4.27	3.99
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		44.80	29.87	27.92		44.80	29.87	27.92

Table N-d – Annual fall and burn emissions based on the Consume v2.1 emission model & contact with permitees

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
PA 15262	Canadian Forest Products Ltd.	3.34	2.37	2.06		4.60	3.26	2.83
PA 15521	Northwood Inc.	0.58	0.41	0.36		0.00	0.00	0.00
PA 15780	West Fraser Mills Ltd.	2.81	1.99	1.73		2.81	1.99	1.73
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		6.74	4.77	4.15		7.41	5.25	4.56

Miscellaneous Permits

Appendix Table O – a through d (Annual miscellaneous emissions)

Table O-a – Annual miscellaneous emissions based on PFPs

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
RA 03732	L B Paving Ltd.	37.5	0.0	0.0		37.5	0.0	0.0
PA 06099	Northern Engineering Wood Products Ltd.	323.38	164.95	84.75		323.38	164.95	84.75
PA 06686	Pacific Northern Gas Company Ltd.	8.70	8.68	8.68		8.70	8.68	8.68
PA 06687	Pacific Northern Gas Company Ltd.	8.83	8.80	8.80		8.83	8.80	8.80
PA 07189	Chemical Lime Company of Canada Inc.	0.38	0.32	0.10		0.38	0.32	0.10
RA 07865	L B Paving Ltd.	27.29	0.00	0.00		27.29	0.00	0.00
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		406.1	182.7	102.3		406.1	182.7	102.3

Table O-b – Annual miscellaneous emissions based on PFPs, considering emission testing on 2 stacks at Newpro

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
RA 03732	L B Paving Ltd.	37.5	0.0	0.0		37.5	0.0	0.0
PA 06099	Northern Engineering Wood Products Ltd.	271.41	127.88	58.93		271.41	127.88	58.93
PA 06686	Pacific Northern Gas Company Ltd.	8.70	8.68	8.68		8.70	8.68	8.68
PA 06687	Pacific Northern Gas Company Ltd.	8.83	8.80	8.80		8.83	8.80	8.80
PA 07189	Chemical Lime Company of Canada Inc.	0.38	0.32	0.10		0.38	0.32	0.10
RA 07865	L B Paving Ltd.	27.29	0.00	0.00		27.29	0.00	0.00
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		354.1	145.7	76.5		354.1	145.7	76.5

Table O-c – Annual miscellaneous emissions based on AEIBC (Actual)

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
RA 03732	L B Paving Ltd.	0.63	0.00	0.00		0.63	0.00	0.00
PA 06099	Northern Engineering Wood Products Ltd.	227.49	117.6	56.0		227.49	117.6	56.0
PA 06686	Pacific Northern Gas Company Ltd.	8.68	8.68	8.68		8.68	8.68	8.68
PA 06687	Pacific Northern Gas Company Ltd.	8.83	8.83	8.83		8.83	8.83	8.83
PA 07189	Chemical Lime Company of Canada Inc.	0.38	0.32	0.12		0.38	0.32	0.12
RA 07865	L B Paving Ltd.	1.13	0.00	0.00		1.13	0.00	0.00
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		247.1	135.4	73.6		247.1	135.4	73.6

Table O-d – Annual miscellaneous emissions based on AEIBC (Maximum)

		2001				2002		
Permit	Name	TPM	PM_{10}	$PM_{2.5}$		TPM	PM_{10}	$PM_{2.5}$
RA 03732	L B Paving Ltd.	0.00	0.00	0.00		0.00	0.00	0.00
PA 06099	Northern Engineering Wood Products Ltd.	322.88	164.88	78.78		322.88	164.88	78.78
PA 06686	Pacific Northern Gas Company Ltd.	8.68	8.68	8.68		8.68	8.68	8.68
PA 06687	Pacific Northern Gas Company Ltd.	8.83	8.83	8.83		8.83	8.83	8.83
PA 07189	Chemical Lime Company of Canada Inc.	0.38	0.32	0.12		0.38	0.32	0.12
RA 07865	L B Paving Ltd.	0.00	0.00	0.00		0.00	0.00	0.00
		Total TPM	Total PM_{10}	Total $PM_{2.5}$		Total TPM	Total PM_{10}	Total $PM_{2.5}$
		340.8	182.7	96.4		340.8	182.7	96.4

Appendix D: Permitted Point Source Normalized Emission Ratios

As mentioned in Chapter 4, PFP emissions are estimated based on the equation

$$(1.4)\ \sum_{i=1}^{n} E_{TPM_i} = \left(\frac{60}{1,000,000,000} \times R_{PD_i} \times C_{PD_i} \right) \times H_{D_i} \times D_{Y_i}$$

where i is an individual section of a permit,

n is the number of sections in a permit,

$E_{TPM}\,(t)$ is the annual emissions of TPM,

$R_{PD}\left(\frac{m^3}{\min}\right)$ is the rate of permitted discharge,

$C_{PD}\left(\frac{mg}{m^3}\right)$ is the characteristics of permitted discharge,

$H_D\,(hours)$ is the daily number of permitted discharge hours,

$D_Y\,(days)$ is the annual number of permitted discharge days of TPM and

$\frac{60}{1,000,000,000}$ converts emissions of $\frac{mg}{\min}$ into $\frac{t}{a}$.

PM_{10} and $PM_{2.5}$ emission estimates are determined based on a ratio to TPM emissions and depend on the source. Presented in this appendix are normalized emission ratios for most the different sources found in the "Permitted Sources" Chapter.

Appendix Table P – a through i – Normalized emission ratios for different sources found in the "Permitted Sources" Chapter of the MEI

Beehive Burner		
	TPM	1.0
Emissions Ratio		
	PM_{10}	0.5499
	$PM_{2.5}$	0.4000

Lumber Dry Kilns		
	TPM	1.0
Emissions Ratio		
	PM_{10}	0.5800
	$PM_{2.5}$	0.1900

Hog Fuel Fired Boilers		
	TPM	1.0
Emissions Ratio		
	PM_{10}	0.9000
	$PM_{2.5}$	0.7597

Cyclones (most)		
	TPM	1.0
Emissions Ratio		
	PM_{10}	0.4000
	$PM_{2.5}$	0.2000

Blow pipes, Railcar loaders & Vent fans		
	TPM	1.0
Emissions Ratio		
	PM_{10}	0.5800
	$PM_{2.5}$	0.1900

Cyclones (other) & Baghouses		
	TPM	1.0
Emissions Ratio		
	PM_{10}	0.5300
	$PM_{2.5}$	0.2600

Volcano Energy Recovery System		
	TPM	1.0
Emissions Ratio		
	PM_{10}	0.4000
	$PM_{2.5}$	0.2000

Molybdenum dryers, Crushers and bucking rooms, conveyor systems & Energy recovery cyclones.		
	TPM	1.0
Emissions Ratio		
	PM_{10}	0.5100
	$PM_{2.5}$	0.1500

Natural gas powered boilers and compressors		
	TPM	1.0
Emissions Ratio		
	PM_{10}	1.0000
	$PM_{2.5}$	1.0000

Appendix E: Beehive Burner Emissions Calculations

Annual beehive burner emission estimates are based on the same formula as all other sources in the MEI.

Recall (1.1) $E_{PM} = BQ \times \frac{EF_{PM}}{1000}$.

where $E_{PM}\left(\frac{t}{a}\right)$ are the annual emissions of PM (either TPM, PM_{10} or $PM_{2.5}$),

$BQ\left(\frac{t}{a}\right)$ is the base quantity (of wood residue burned annually) and

$EF_{PM}\left(\frac{kg}{t}\right)$ is the emission factor of PM (either TPM, PM_{10} or $PM_{2.5}$).

The variable 'Base Quantity' (BQ) (t) can be further broken down into its components, recalling previous formulas

(1.25) $BQ = \frac{V_{W/a} \times \rho}{1000}$

(1.10) $\rho = \rho_{OD} + M_{H_2O/m^3}$

(1.11) $M_{H_2O/m^3} = \frac{MCD}{100} \times \rho_{OD}$

where $V_{W/a}\left(\frac{m^3}{a}\right)$ is the permitted volume of wood residue fed to the beehive burner per year,

$\rho\left(\frac{kg}{m^3}\right)$ is the wet wood density,

$\rho_{OD}\left(\frac{kg}{m^3}\right)$ is the oven dry wood density,

$M_{H_2O/m^3}\left(\frac{kg}{m^3}\right)$ is the mass of water per m^3 and

MCD is the moisture content of the wood on a dry basis.

Both the BQ and EF_{PM} variables have been hotly contested in various reports, most notably the SENES report mentioned previously and the Jacques-Whitford Environmental Ltd. report *Revised Air Quality Assessment of Beehive Burner Emissions Bulkley Valley*. (Jacques-Whitford 2000) This appendix briefly outlines the different values used for the above variables in the PFP, SENES and Whitford estimation methodologies.

Estimating Emissions Using the Permit Fee Parameter Methodology

The PFP methodology determines BQ through formula (1.25) and multiplies this mass by an emission factor for TPM, set at 10 kg/t. PFP assumes an oven dry density of 400 kg/m^3 and a MCD of 100%. For example, using parameters from permit PA 01691 (PIR), beehive burner emissions are estimated to be:

$V_{W/a}\left(\frac{m^3}{a}\right)$ =121,000 m^3

$\rho\left(\frac{kg}{m^3}\right)$ =800 kg/m^3

$\rho_{OD}\left(\frac{kg}{m^3}\right)$ =400 kg/m^3

$M_{H_2O/m^3}\left(\frac{kg}{m^3}\right)$ =400 kg/m^3

MCD =100%

$EF_{TPT}\left(\frac{kg}{t}\right)$ =10

$$(1.26)\ E_{TPT} = \frac{121,000\times\left(400+\frac{100}{100}\cdot 400\right)}{1000}\times\frac{10}{1000} \rightarrow E_{TPT} = 968.0\left(\frac{t}{a}\right)$$

Estimating Emissions Using the SENES Methodology

The SENES methodology for estimating emissions uses the same equation though SENES estimates emissions of PM_{10}, not TPM as in the PFP estimates. An oven dry density of 450 kg/m^3 is assumed as well as a PM_{10} emission factor of 2.3 kg/t. Using the same permit, PA 01691 (PIR) emissions are estimated as

$V_{W/a}\left(\frac{m^3}{a}\right)$ =121,000 m^3

$\rho\left(\frac{kg}{m^3}\right)$ =900 kg/m^3

$\rho_{OD}\left(\frac{kg}{m^3}\right)$ =450 kg/m^3

$M_{H_2O/m^3}\left(\frac{kg}{m^3}\right)$ =450 kg/m^3

MCD =100%

$EF_{PM_{10}}\left(\frac{kg}{t}\right)$ =2.3

$$(1.27)\ E_{PM_{10}} = \frac{121,000\times\left(450+\frac{100}{100}\cdot 450\right)}{1000}\times\frac{2.3}{1000} \rightarrow E_{PM_{10}} = 250.5\left(\frac{t}{a}\right)$$

Estimating Emissions using the Jacques Whitford Methodology

Like SENES, Jacques Whitford's methodology estimates annual emissions of PM_{10}. It employs the same wood density and MCD as the PFP methodology, however uses a PM_{10} emission factor of 0.5 kg/t, much lower than the SENES methodology. Using this methodology, emissions for PA 01691 (PIR) are estimated to be:

$V_{W/a}\left(\frac{m^3}{a}\right)$ =121,000 m^3

$\rho\left(\frac{kg}{m^3}\right)$ =800 kg/m^3

$\rho_{OD}\left(\frac{kg}{m^3}\right)$ =400 kg/m^3

$M_{H_2O/m^3}\left(\frac{kg}{m^3}\right)$ =400 kg/m^3

MCD =100%

$EF_{PM_{10}}\left(\frac{kg}{t}\right)$ =0.5

$$(1.28)\ E_{PM_{10}} = \frac{121,000\times\left(400+\frac{100}{100}\cdot 400\right)}{1000}\times\frac{0.5}{1000} \rightarrow E_{PM_{10}} = 48.4\left(\frac{t}{a}\right)$$

Because the PFP equation (1.26) estimates TPM emissions while the SENES and Whitford equations (1.27) and (1.28) estimate emissions of PM_{10}, a direct comparison of SENES and Whitford emissions with PFP estimates cannot be made. To compare PFP emissions with SENES or Whitford estimates, the PFP estimates must be converted from TPM to PM_{10}. This can be done using the normalized emission ratios of Appendix D. As outlined in Table P-a, the normalized PM_{10} (and $PM_{2.5}$) emission ratios for beehive burners are:

Appendix Table Q – Beehive burner emission ratios normalized to TPM and PM10

Beehive Burner			
	Normalized to TPM	or	Normalized to PM_{10}
TPM	1.0		1.8182
Emissions Ratio			
PM_{10}	0.5499		1
$PM_{2.5}$	0.4000		0.7273

In other words, where the emission ratios are normalized to TPM, PM_{10} emissions can be estimated based on the formula $E_{PM_{10}} = 0.5499\times E_{TPT}$ and $PM_{2.5}$ emissions can be estimated based on

$E_{PM_{2.5}} = 0.4000 \times E_{TPT}$. Similarly, where the emission ratios are normalized to PM_{10}, TPM emissions can be estimated using $E_{TPT} = 1.8182 \times E_{PM_{10}}$ and $PM_{2.5}$ emissions can be estimated based on $E_{PM_{2.5}} = 0.7273 \times E_{PM_{10}}$. Using these formulas it is possible to calculate TPM, PM_{10} and $PM_{2.5}$ emissions for all three methodologies and arrive at contrastable numbers.

Appendix Table R – Annual PM emissions (t) using the PFP, SENES and Whitford methodologies for the PA 1691 beehive burner

PA 1691	PFP	SENES	Whitford
TPM	968.0	457.4	88.0
PM_{10}	532.3	250.5	48.4
$PM_{2.5}$	387.2	185.1	35.2

TPM, PM_{10} and $PM_{2.5}$ emission factors can also be calculated using similar formulas with the same normalized ratios in Table Q.

Appendix Table S – Beehive burner emission factors (kg/t) using the PFP, SENES and Whitford methodologies

	PFP	SENES	Whitford
TPM	10.0	4.2	0.91
PM_{10}	5.5	2.3	0.50
$PM_{2.5}$	4.0	1.7	0.36

It should be noted that the PM_{10} emission factor of 0.5 kg/t used in the Whitford estimation methodology is based on US EPA data that is dated (over 30 years old) and applies only to ideal operating conditions.[31] The EPA's beehive burner (sometimes called tepee or wigwam burners) emission data is dated because in most provinces and states in North America its use has been outlawed. 0.5 kg/t is extremely low; lower than emission factors used for advanced technology woodstoves, catalytic woodstoves and even pellet stoves. When translated to discharge characteristics, an emission factor of 0.5 kg/t has lower emission rates than high efficiency hog fuel incinerators or volcano energy recovery systems[32]. In fact, this is the lowest wood burning PM_{10} emission factor used in the entire MEI. This is significant because such a low emission factor indicates that beehive burners have the highest combustion efficiency of all wood burning appliances or activities, a claim which can be disputed based on simple observation. It is recommended

[31] US EPA, 1992 b, Table 2.7-1
[32] SENES, 2000, Table 3-5

that this PM_{10} emission factor (as well as the TPM and $PM_{2.5}$ emission factors corresponding with this emission factor from the Whitford methodology) not be used for estimating beehive burner emissions as it is too ideal to represent a realistic average for beehive burner combustion efficiency.

The PFP TPM emission factor of 10 kg/t is very high, and may not be representative of a functioning beehive burner. Using it on a 'worst case' basis however, may be acceptable as the high nature of PFP emissions could be suitable for maximum impact assessment purposes.

The emission factors based on the SENES methodology are recommended for airshed management purposes. The PM_{10} emission factor of 2.3 kg/t is based on the publication Wood and Bark Residue Disposal in Wigwam Burners (Corder et al. 1970) and represents the most likely beehive burner emission factor under average operating conditions. Section 3.1.2 of the SENES report discusses the development of this emission factor in great detail. Also suggested is an upper bound PM_{10} emission factor of 3.5 kg/t (upper bound emission factors for TPM and $PM_{2.5}$ were estimated to be 6.4 and 2.5 kg/t respectively using the normalized emission ratios in Table Q), however annual estimates based on this emission factor (as well as the estimated TPM and $PM_{2.5}$ emission factors) have not been provided in the MEI because of the already accumulated quantity of estimates. It should be noted, however, that after conferring with WLAP regional staff in Smithers the upper bound TPM, PM_{10} and $PM_{2.5}$ emission factors were applied to estimate average beehive burner emissions for the DLFP (PA 03019) and SCI Carnaby (PA 07748) beehive burners because the operating temperatures of those burners were consistently lower than the remaining burners during the inventory period, and lower operating temperatures have been linked to decreased combustion efficiency and higher emissions[33]. These estimates, along with the estimates for all beehive burner emissions are presented in Table 8-b, "Beehive burner emissions (t) based on the SENES Consulting reporting methodology for beehive burner emissions corrected for throughput to burner where available".

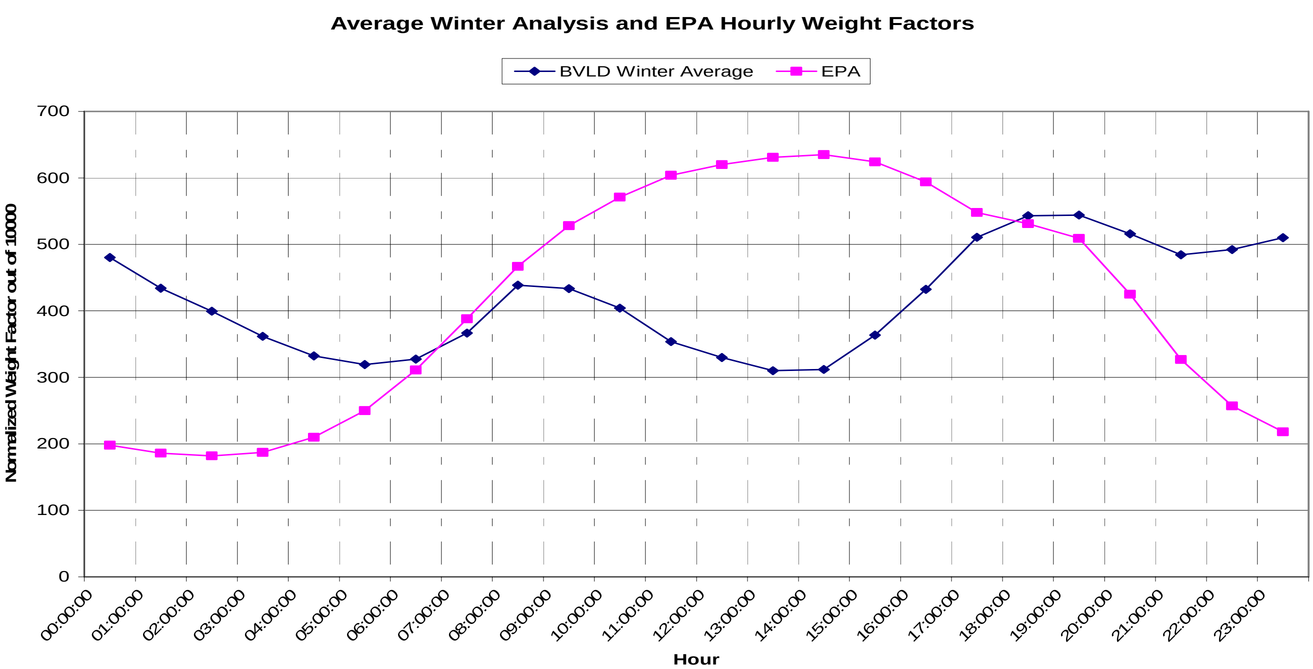
It should also be noted that while beehive burners have higher emission rates during start up and shut down periods, only one emission factor for each of TPM, PM_{10} and $PM_{2.5}$ was used when estimating emissions. It is recommended that this be changed to reconcile emissions during these start up and shut down periods as well as for documented periods of high opacity due to decreased combustion efficiency.

[33] Corder, 1970, p24

Appendix F: Derivation of the Hourly and Monthly Emissions Profiles for Residential Wood Appliances

The Hourly Emissions Profile

To rectify discrepancies between the US EPA's hourly normalized emissions profile and observed wood appliance emissions tendencies in the BVLD, a customized temporal profile was created based on ambient PM_{10} hourly data from Burns Lake, Houston, Telkwa and Smithers averaged over the winter months of December, January and February in 2000/01, 2001/02 and 2002/03. It was assumed that woodstoves have the greatest ability to influence ambient air quality during these months due to the general absence of many other sources. (Typically, emissions from resource management debris burning, road dust and back yard burning are limited during these months.) This allowed for a profile developed over the winter to be valid during all seasons. Both profiles are displayed below, the customized profile in blue and the US EPA profile in pink. Data from the BVLD shows peaks during three points of the day, one between the hours of 08:00 and 09:00, another between the hours of 18:00 and 20:00 and a third peak between 23:00 and 00:00. These peaks correspond to typical times when wood appliances are damped down to ensure longer heating from the smouldering of fires: once in the morning and twice in the evening.



Appendix Figure K – Customized and US EPA wood appliance normalized hourly emissions profiles

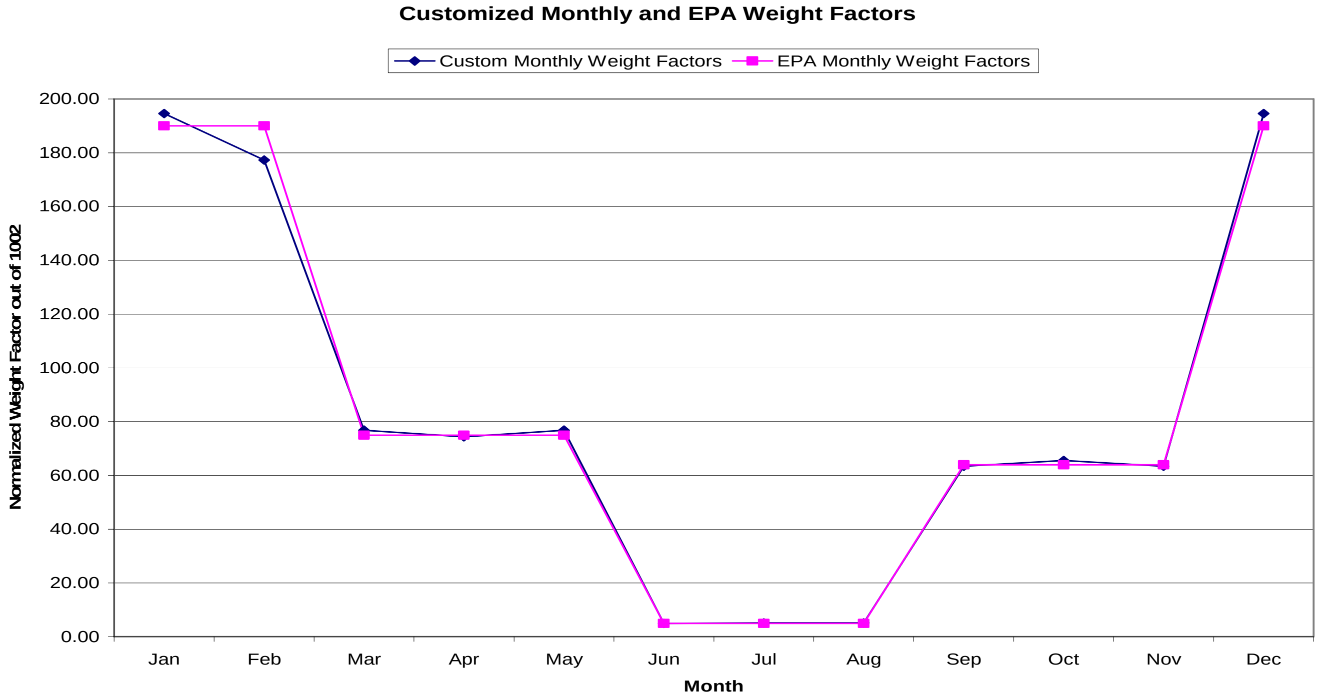
It is likely that meteorology also plays a role in influencing ambient air quality data. During the winter months, collapse of the unstable mixing layer occurs early in the afternoon and is followed by the development of a nocturnal boundary layer which is highly stable and inhibits vertical mixing. This lack of vertical movement creates stagnant conditions and the build up of pollutants. It is possible to conceive that, were there more vertical movement at night time, the peaks observed in Appendix Figure T would be reduced because pollutants would be more dispersed. However, if meteorology was the only influence on ambient data, a steady increase of PM readings would be expected overnight due to continual build up of pollutants in the air, with no dispersion until sunrise and the collapse of the nocturnal boundary layer. Therefore it can be assumed that the normalized profile displayed in Appendix Figure T is the result of a combination of increasing residential wood emissions (from decreased combustion efficiency due to damping of fires) and meteorology.

The Daily Emissions Profile

The US EPA's daily profile which gives equal weight to each day of the week was used. If it can be shown that weekends have different emission structures than weekdays this may need to be changed at a later time.

The Seasonal (Monthly) Emissions Profile

The seasonal profile used in the MEI for wood appliances was similar to that of the EPA, however some minor changes were made. Seasonal weights taken from the EPA gives the winter months of December, January and February the greatest weight followed by the spring months of March, April and May, the autumn months of September, October and November and finally the summer months of June, July and August. However, the EPA profile places equal weight on the months January and February even though January has 31 days and February has 28. Equal weight on the months of January and February means unequal weights on the *days* in the months. This issue was overcome by putting equal weight on the days in both of these months which, when summed, means that the February's weight is slightly less than January's. Both profiles are displayed below, the customized profile in blue and the US EPA profile in pink.



Appendix Figure L – Customized and US EPA wood appliance normalized monthly emissions profiles

Combining the hourly weights with the daily and seasonal weights along with annual emissions for all appliances gives hourly emission rates for every hour of every day for an entire year in the BVLD.

For Example:

In the BVLD, 332.3 tonnes of PM_{10} are emitted each year from wood burning appliances. How many tonnes are emitted January 1st between 00:00 and 01:00?
332.3 tonnes = 332,300 kg/year.
Based on the January's normalized monthly weight factor (194.58/1002) which is 19.419% of the annual total, PM_{10} emissions in January are 64529.87 kg.
As every day is weighted the same, January 1st daily totals are 1/31st of the monthly total = 64529.87 kg/31 days in Jan = 2081.61 kg on the 1st.
Based on the hour 00:00, (480.262/10000) which is 4.803% of the daily total, 99.97 kg of PM_{10} are emitted between the hours of 00:00 – 01:00 on January 1st.