Integration of 2013 Odour Data for the Human Exposure Monitoring Program (HEMP)

Prepared For

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The content and opinions expressed by the author in this report do not necessarily reflect the views of the Wood Buffalo Environmental Association (WBEA) or of HEMP.

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Executive Summary

The Wood Buffalo Environmental Association (WBEA) is a not-for-profit society registered under the Societies Act of Alberta. WBEA monitors human exposure to selected air quality constituents through the Human Exposure Monitoring Program or HEMP. In 2009 odours had become a prominent issue in some communities within the Wood Buffalo region. As a result, HEMP's direction was refocused from personal exposure studies in communities to one of odour detection and chemical characterization. HEMP's current community of focus is Fort McKay, some sixty kilometers north of Fort McMurray. The need to effectively communicate the meaning behind the data collected under the odour projects of HEMP resulted in the HEMP Committee's members requesting an initial integrated data review using 2012 data (Dann, 2013). This report provides a similar data review using the 2013 data sets. The objective of this data integration is to provide HEMP further information on what the combined data from all of the collection methods are indicating and to provide a means of sharing information on the state of odours in the region with public individuals and stakeholders.

Odour assessment is a complex undertaking as the ability of humans to distinguish different odour intensities is highly subjective with changes in concentration of the order of over 25% needed for an individual to recognize different odour intensities. There is also a wide variation in sensitivity towards odours between individuals and a factor of 100 between the thresholds of two subjects for the same substance is not uncommon. The sensitivity to odours is specific rather than general and the sensitivity of a person to one odour or group of odours does not predict their sensitivity towards other odours.

For the community sites in 2013 there was only 1 hour with TRS greater than 10 ppb (Alberta Ambient Air Quality Oblective) which occurred at Anzac. A comparison of 2012 and 2013 TRS results shows that there was a reduction in maximum TRS concentration and in hours greater than 3 ppb at all sites with the largest change (90% reduction) at the Bertha Ganter site in Fort McKay. With the exception of the Anzac site, 2013 had the lowest frequency of elevated TRS at community sites over the past 15 years. Despite this, there was an increase in complaints to the Alberta Hotline between 2012 and 2013 and there were 108 odour observations reported to the Community Odour Monitoring Project (COMP) between June and December 2013. Approximately half of the COMP observations identified the odour as asphalt/tar or hydrocarbon/solvent.

At all community sites there was no consistent association between any of the measured air quality parameters and reported odours although higher concentration values were most commonly reached for non-methane hydrocarbons (NMHC). The majority of odour complaints were associated with only a few wind directions at the community sites and are undoubtedly associated with specific sources. Meteorology appears to be an important element in odour complaints with some sites more susceptible to complaints with low wind speeds and stable dispersion conditions and other sites recording complaints with moderate wind speed persisting from a source direction.

The COMP project provides more consistent observations of odours and its renewal for another year should complement the existing valuable data set. Obtaining a similar record of community complaints from Fort McKay and Anzac would be useful.

The performance of the eNose system remains a puzzle and there were step changes in response and a lack of directionality in results regardless of the processing methods employed that resulted in the data being of very limited value to the data integration effort. The PFGC system is the only instrument deployed that is capable of producing hourly estimates of specific volatile organics (VOC) and reduced sulphur compounds (RSC) that would be useful in identifying specific sources during complaint periods so it is potentially of great value to any odour characterization efforts. However, it also had variable output during the year and at times did not respond to sulphur species, aromatics and heavier molecular weight VOC.

Detection levels for the VOC/RSC canister sampling are too high to identify any of the most odorous target species and either the measurements should be terminated or improvements in detection levels should be sought. The THC measurements are serving no useful purpose for odour identification but many of the complaints refer to hydrocarbon odours so additional effort is required to identify and possibly measure odorous VOC species. Measurement data suggest that conventional TRS instruments may not respond quantitatively to other RSC such as carbonyl sulphide and carbon disulphide.

There is a disconnect between odour complaints and occurrence of elevated levels of currently measured ambient species suggesting that the specific compounds responsible for complaints are not being measured and/or detected. It may be more beneficial to carry out source emission characterization for a list of candidate odorous compounds than to implement new ambient measurement programs. The strong directionality of odour complaints at all community sites suggests that there are specific sources responsible for the odour complaints. Data on source and control equipment operations during complaint periods should be obtained to see if there are any linkages to odour complaints.

1 Background

The Wood Buffalo Environmental Association (WBEA) is a not-for-profit society registered under the Societies Act of Alberta. WBEA is the second regional airshed management zone to be developed in the province and has the most extensive airshed monitoring network in Alberta and the largest non-urban network in Canada. The Athabasca Oil Sands Region (AOSR) is within the municipality, and includes both traditional bitumen mining operations and in situ oil production. The region also encompasses the communities of Fort McMurray, Fort Chipewyan, Fort McKay, Anzac, Janvier and Conklin. WBEA is committed to reporting accurate and timely high quality data from their Air, Terrestrial and Human Exposure Monitoring Programs to ensure regional stakeholders have the information they need to make informed environmental decisions. WBEA monitors human exposure to selected air quality constituents through the Human Exposure Monitoring Program or HEMP (WBEA, 2013).

In 2009 odours had become a prominent issue in some communities within the Wood Buffalo region. As a result, HEMP's direction was refocused from personal exposure studies in communities to one of odour detection and chemical characterization. HEMP's current community of focus is Fort McKay, some sixty kilometers north of Fort McMurray. WBEA has operated an air quality monitoring station, AMS#1, (re-named Bertha Ganter-Fort McKay in 2012), in Fort McKay since 1998. Two specialized odour detection, evaluation and quantification instruments operate alongside other WBEA analyzers at this air monitoring station. In the Wood Buffalo region, volatile organic compounds (VOCs) and sulphur containing compounds, such as reduced sulphur compounds (RSCs) are well known to cause odours, either individually or in combination (WBEA, 2013).

The need to effectively communicate the meaning behind the data collected under the odour projects of HEMP resulted in the HEMP Committee's members requesting an initial integrated data review using 2012 data (Dann, 2013). This is the second review and encompasses the 2013 data sets. The vision is that as new data sets are collected annually from HEMP projects and other odour monitoring efforts, subsequent integrated data reviews will be conducted to build on previous year's data sets, recommendations and correlations to provide more insight and to maintain a unified complete monitoring data set of odours and related environmental variables in the Wood Buffalo region.

2 Odour and Odour Characterization

2.1 Perception of Odours

Of the five senses, the sense of smell is the most complex and unique in structure and organization. While human olfaction supplies 80% of flavor sensations during eating, the olfactory system plays a major role as a defense mechanism by creating a natural aversion response to malodours and irritants.

Human response to odourant perception follows certain characteristic patterns common among sensory systems. For example, olfactory acuity in the population conforms to a normal distribution. Most people have a "normal" sense of smell whereas two percent of the population is hypersensitive and two percent insensitive.

Whether an odour has an objectionable or offensive effect will depend on the frequency, intensity, duration, offensiveness and location of the odour event. These factors are collectively known as the FIDOL factors (MOE NZ, 2003):

Frequency: How often an individual is exposed to odour

Intensity: The strength of the odour

Duration: The length of a particular odour event

Offensiveness/character: The character relates to the 'hedonic tone' of the odour, which may be pleasant, neutral or unpleasant

Location: The type of land use and nature of human activities in the vicinity of an odour source

Different combinations of these factors can result in adverse effects. Odours may occur frequently in short bursts, or for longer, less-frequent periods, and may be defined as having 'chronic' or 'acute' effects. Depending on the severity of the odour event, one single occurrence may be sufficient to deem that a significant adverse effect has occurred. However, in other situations the duration may be sufficiently low and the impact on individuals sufficiently minor that the frequency of events would need to be higher before an adverse effect would be deemed to have occurred. (MOE NZ, 2003)

2.2 Parameters associated with Odours

2.2.1 Odour Threshold

The detectability of an odour is related to its concentration. The concentration at which an odour is first perceived is often referred to as the odour threshold or detection threshold. It is important to note that this value varies from individual to individual, sometimes by as much as two orders of magnitude, due to variations in individual sensitivities. Moreover, other factors such as exposure duration can drastically affect the odour threshold because of olfactory fatigue, and acclimatization (B.C. 2002).

Odour thresholds are related to detectability and refer to the theoretical minimum concentration of odorous substance necessary for detection in a specified percentage of the population. This percentage is often defined as the mean, 50%, i.e. the lowest odour concentration that can be detected by 50% of the population. Threshold values are not fixed physiological facts or physical constants, but rather, a statistical point representing the best estimate from a tested population. Two types of thresholds are evaluated: the detection threshold, which is the lowest concentration at which an odour is detected, with no recognition of the odour quality; and the recognition threshold, which is the minimum concentration that is recognized as having a characteristic odour quality. Typically, the concentration at which an odour is first recognized as having a certain characteristic quality (recognition threshold) is 1.5

to 10 times higher than the detection threshold, depending on the individual and the odorous compound (B.C. 2002).

2.2.2 Character of Odour (Hedonic Tone)

Once the odour is at a sufficiently high concentration to allow recognition, the quality of the odour may be described. The odour quality is a purely subjective descriptor of an odour's aesthetic impression, such as sweet, sour, musty, rancid, etc. The intensity of a given odour is defined as its perceived strength, but is not necessarily related to its concentration. For example, a particularly pungent odour at a very low concentration may be perceived to be more intense than a less pungent substance at a higher concentration. The odour acceptability, which is also known as the Hedonic tone, is an indication of the pleasantness or unpleasantness of the odour. The acceptability of a particular odour varies with the individual, and may be affected by experience, frequency of occurrence, duration, and odour intensity and character. It should also be noted that environmental conditions, including temperature and relative humidity have also been found to alter the sensory perception of odours.

Another factor is the portion of the population who are sensitized to a particular odour as a result of repeated exposure. This is distinct from olfactory fatigue or adaptation to odour after prolonged exposure. It should be noted that these terms describe a temporary desensitization after smelling an odour. For example, after exposure to a strong odour an individual may be unable to detect a weaker one. The response of humans to mixtures of odorous compounds is difficult to predict, since the odour threshold of the mixture is rarely an additive combination of the individual odours. All odours have the ability to mask the odours of other compounds, and odorous constituents may react with each other, changing the odour character or intensity.

Another phenomenon, which may lead to confusion in odour sensing, is the ability of an odour to change character with concentration. For example, carbonyl sulphide has a “burnt” character at concentrations below 1 part per million (ppm), but takes on a “rotten egg” smell at higher concentrations. It is obvious that many of the discrepancies in odour complaints are due in part to this property of odour, in combination with individual variability and geography. The ability of humans to distinguish different odour intensities is highly subjective. Studies indicate that changes in concentration of the order of 25 to 33% are needed for an individual to recognize different odour intensities. There is a wide variation in sensitivity towards odours between individuals and that a factor of 100 between the thresholds of two subjects for the same substance is not uncommon. The sensitivity to odours is specific rather than general and the sensitivity of a person to one odour or group of odours does not predict their sensitivity towards other odours. Perceived odour quality varies with the individual and also with the strength of an odour. An individual's background will influence their attitude towards odours. A person with a rural background may find an agricultural odour acceptable whereas a person with an urban background may find the same odour offensive. Other psychological factors may influence an individual's perception of an odour. A visual stimulation, for example, may influence an individual's response to an odour stimulus (B.C. 2002).

2.2.3 Odour Units and Reported Thresholds

The parameter "odour unit" is frequently encountered in the field of odour measurement: in simplest terms, it is the amount of dilution required to bring a specific species (or species group) of chemical in a given air sample to its detectable threshold. The greater the amount of dilution required, the more odorous the sample and the lower the odour threshold. The analysis is performed by a selected human panel and the result is presented as ppb (for pure single substance samples) or Odour Units (o.u.) /m^3. The measurement of odour concentration is standardized in a European Committee for Standardization method (CEN, 2003). Many publications carry tables of odour thresholds for single substances but there is often conflict between these and often the threshold is reported as a range rather than a specific number. Comparing a chemical quantification to the odour threshold of a simple one to two species odour can be somewhat effective, but as the chemical mix of the odour becomes more complex, the odour threshold of specific components is of little use (SEPA, 2010).

As a reference, 2-3 o.u./m^3 generally corresponds to the level at which 50% of the population can start to recognize an odour in an odourless environment. In general, odour presenting concentrations above 5 o.u./m^3 are considered discernable (can be identified) above the ambient background. For example, a perfumed person could represent 20-50 o.u./m^3, freshly cut grass would be around 250 o.u./m^3 and old garbage could reach 500 o.u./m^3. (Odotech, 2014).

Estimated odour thresholds (ppb) and their reported range are provided in Table 1 for those species currently measured at one or more WBEA sites (continuous or integrated measurement) and other species of interest. A number of references are used and it should be noted that there is a wide variation in reported odour thresholds depending on the reference. Much of the reported data comes from studies carried out decades ago but a more recent set of data from Japan (Nagata, 2003) using a triangular bag method is also included in the Table.

Hydrogen sulphide is a good example of variable reported odour thresholds with values ranging from 0.5 to 12 ppb. Amoore (1985) analyzed a large number of reports from the scientific literature and found that reported thresholds for H_2S detection were log-normally distributed, with a geometric mean of 8 ppb. Detection thresholds for individuals were reported to be log-normally distributed in the general population, with a geometric standard deviation of 4.0, i.e. 68% of the general population would be expected to have a detection threshold for hydrogen sulphide between 2 and 32 ppb. He also predicted that at 8 ppb, 50% of the general population would be able to detect the odor of hydrogen sulphide under controlled conditions, but only 5% would find it annoying at this level. At 35 ppb, 50% would find the odor annoying. As noted in Table 2 the Alberta 1h ambient air quality objective (AAQO) for H_2S is set at 10 ppb based on odour.

Table 1: Examples of Odour Thresholds for Selected Compounds measured at WBEA sites (consolidated and adapted from Woodfield and Hall 1994, the U.K. Royal Society of Chemistry Chemical Data Sheets 1989 -1992, Ruth, 1986 and Nagata, Y., 2003).

Compound	Descriptor where available	Reported threshold Range (ppb)	Odour threshold (ppb)	Odour Threshold (ppb) (Nagata, 2003)
Acetone	chemical/sweet	450 – 13,000	4,580	42
Allyl sulphide			15	0.22
Ammonia	sharp, pungent	144 – 16,700		1,500
Benzene	solvent	400 – 29,000	8,650	2,700
Benzyl mercaptan	garlic, leeks		2.6	
1,3-Butadiene	mild, gasoline	190 – 450	455	230
Butyl mercaptan	stinks	0.5 – 1.0		0.0028
Carbon Disulphide	disagreeable, sweet	11 – 700		210
Carbonyl sulphide			10	55
m-Cresol	coal-tar			0.1
o-Cresol	coal-tar			0.28
p-Cresol	coal-tar			0.054
Dimethyl sulphide	decayed cabbage	0.8 – 15		3
Dimethyl disulphide		0.3 – 90		2.2
2,5-dimethyl thiophene		None Found		
Ethyl mercaptan		0.1 – 36		0.0087
2-ethyl Thiophene		None Found		
Hydrogen sulphide	rotten eggs	0.5 - 12	0.5	0.41
Isobutyl mercaptan			0.8	0.0068
Isopropyl mercaptan	skunk like		0.3	0.006
Methyl mercaptan	sulphur	0.02 – 42		0.07
2-methyl Thiophene	sulphur	None Found		
3-methyl Thiophene		None Found		
Naphthalene	mothballs		38	
Nitrogen dioxide	acrid, pungent	10 – 1,000		
Pentane	gasoline			1,400
Propyl mercaptan		0.06 – 24		0.013
sec-Butyl mercaptan		None Found		0.03
Sulphur dioxide	suffocating	340 – 8000		870
Styrene	penetrating, rubbery, plastic		38	35
tert-Butyl mercaptan			0.3	0.029
Thiophene	aromatic, gasoline	0.4 - 4	0.8	0.56
Toluene	floral, pungent, moth balls	125 – 210	160	330

2.3 Other Air Quality Criteria and Potential Toxicity of Odourous Species

Humans instinctively react to odour whether the odour is pleasant or offensive. The most common reaction is a disturbance in mood. For example, agreeable odours can induce feelings of relaxation and pleasure while offensive odours can induce feelings of anger, or even fatigue. Since odours can cause quantifiable increases in measurable stress responses such as blood pressure and blood sugar levels, the effects of odour on mood disturbances are not entirely psychological (Martin, 1996).

In some cases, reactions to offensive odours can actually result in physical symptoms. Such ailments are said to be annoyance-mediated. That is, the physical symptoms of illness are a result of a psychological reaction to odour and not any toxin-mediated irritation. For instance, individuals exposed to irritating odours may report headaches, nausea, and irritation of the eyes, nose, and throat and other self-reported physical symptoms. Therefore, humans can respond both mentally and physically to unpleasant odours. The two types of reactions, however, may not be mutually exclusive. In fact, one study examining odours associated with a hazardous waste site described the relationship between worry (a mood disturbance) and physical symptoms such as headaches, and eye and throat irritations as one where physical and psychological effects of the irritating odour acted synergistically to produce overall reactions (Shusterman et al, 1991).

Many odorous substances do have toxic properties at high concentrations and jurisdictions have established air quality criteria for the substance to prevent adverse health effects. Table 2 contains Alberta ambient air quality objectives (AAQO) for all relevant species as of February 2013. Species for which the AAQO is based on odour are listed first in the Table. For some species, health effects do potentially occur at levels below their odour threshold whereas for most species the odour threshold is below the known adverse effect level.

Table 2: Alberta Ambient Air Quality Objectives (AAQO) for measured WBEA species.

Contaminant	AAQO (µg/m³)	AAQO (ppb)	Averaging Time	Basis	Date	Limiting Effect
Ammonia	1,400	2,000	1 Hour			***Odour***
Carbon disulphide	30	10	1 Hour		2005	***Odour***
Hydrogen sulphide	4	3	24 Hour		1975	***Odour***
	14	10	1 Hour			***Odour***
Acetaldehyde	90	50	1 Hour	Adopted from Texas	1999	Health
Acetone	5,900	2,400	1 Hour	Adopted from Texas	2005	Health
Benzene	3	0.9	Annual		2012	Carcinogenic effects
	30	9	1 Hour			Haematological effects
Carbon monoxide	6,000	5,000	8 Hour		1975	Health
	15,000	13,000	1 Hour			Oxygen carrying capacity of blood
Ethyl benzene	2000	460	1 Hour	Adopted from Texas	2005	Health
Ethylene	30	26	Annual		2004	Conifers and perennials
	45	40	3 day			Crop yield
	1,200	1,050	1 Hour			Crop yield
Ethylene oxide	15	8	1 Hour	Adopted from Ontario	1999	Health
Formaldehyde	65	53	1 Hour	Adopted from Texas	2007	Health
n-Hexane	7,000	1,990	24 Hour	Adopted from California	2008	Health
	21,000	5,960	1 Hour	Derived from 24-hr California objective		Health
Hydrogen chloride	75	50	1 Hour	Adopted from Texas	1999	Health
Isopropanol	7,850	3,190	1 Hour	Adopted from Texas	2005	Health
Methanol	2,600	2,000	1 Hour	Adopted from Texas	1999	Health
Nitrogen dioxide	45	24	Annual		2009	Respiratory effects
	300	159	1 Hour			Vegetation
Ozone	160	82	1 Hour		2007	Health
Phenol	100	26	1 Hour	Adopted from Ontario	1999	Health
Styrene	215	52	1 Hour	Adopted from Texas	1999	Health
Sulphur dioxide	20	8	Annual		2008	Adopted from European Union - ecosystems
	30	11	30 day			Vegetation
	125	48	24 Hour			Adopted from European Union – human health
	450	172	1 Hour			Pulmonary function
Toluene	400	106	24 Hour	Adopted from Michigan and Washington	2005	Health
	1,880	499	1 Hour	Adopted from Texas		Health
Vinyl chloride	130	51	1 Hour	Adopted from Texas	1999	Health
Xylenes	700	161	24 Hour	Adopted from Ontario	2005	Health
	2,300	530	1 Hour	Adopted from California		Health

3 Emission Sources in the WBEA Area

3.1 Total Reduced Sulphur Species

In the National Pollutant Release Inventory (NPRI) total reduced sulphur (TRS) refers to a gaseous mixture of compounds containing one or more sulphur atom in its reduced state. For the purposes of reporting to the National Pollutant Release Inventory (NPRI), the class of substances is restricted to the substances listed in Table 3. Three of the TRS compounds (H_2S, CS_2 and COS) are also listed individually and if any of these substances meets the 10 tonne reporting threshold alone, then it must also be reported individually. When determining the reporting threshold and reporting to the NPRI, TRS must be expressed in terms of hydrogen sulphide (H_2S). TRS quantities can be determined using several methods, including summing H_2S equivalencies, emissions monitoring or source testing. To use the equivalence factor method, the equivalency of the individual TRS compounds in tonnes of H_2S must be determined and added together to determine if TRS is required to be reported. The H_2S equivalence factors are included in Table 3 (NPRI, 2014).

Table 3: Total Reduced Sulphur Species in the NPRI.

Substance Name	Formula	Hydrogen Sulphide Equivalence Factor
Hydrogen sulphide	H_2S	1.000
Carbon disulphide	CS_2	0.895
Carbonyl sulphide	COS	0.567
Dimethyl sulphide	C_2H_6S	0.548
Methyl mercaptan	CH_4S	0.708
Dimethyl disulphide	$C_2H_6S_2$	0.724

Estimated emissions of TRS (tonnes) for 2012 for sources in the WBEA region are shown in Table 4. Overall 61% of TRS emissions were from fugitive sources. A breakdown of TRS emissions for Syncrude and Suncor into the species H_2S, COS and CS_2 is shown in Table 5. Based on the NPRI data, for Suncor, emissions of H_2S account for 7% of TRS emissions and for Syncrude, H_2S accounts for 42% of TRS emissions.

Table 4: Emissions of TRS (tonnes) from Sources in the WBEA Airshed - 2012 (NPRI Estimates).

Company Name	Facility Name	Latitude	Longitude	Stack Emissions	Fugitive Emissions	Storage / Handling	Total
Syncrude Canada Ltd.	Mildred Lake Plant Site	57.04	-111.62	106	12		118
Suncor Energy Oil Sands Limited Partnership	Suncor Energy Inc. Oil Sands	57.00	-111.47	47	239	2	288
Canadian Natural Resources Limited	Horizon Oil Sands Processing Plant and Mine	57.34	-111.76	14	2	2	18
Syncrude Canada Ltd.	Aurora North Mine Site	57.30	-111.50		11		11

TOTAL	167	264	4	435

Table 5: Emissions of H_2S, Carbonyl Sulphide, Carbon Disulphide and TRS from two Largest Emission Sources in the WBEA Area (tonnes of H_2S) 2012 (NPRI Estimates).

Company Name	Facility Name	Compound	Stack Emissions	Fugitive Emissions	Other	Total
Suncor Energy Oil Sands Limited Partnership	Suncor Energy Inc. Oil Sands	COS	29	20		49
		CS_2	5	67		72
		H_2S	15	5	2	21
		TRS	**47**	**239**	**3**	**289**
Syncrude Canada Ltd.	Mildred Lake Plant Site	COS	45			45
		CS_2	9	1		10
		H_2S	42	8		50
		TRS	**106**	**12**		**118**

3.2 Sulphur Dioxide and VOC Emissions

Estimated emissions of SO_2 and VOC (tonnes) for 2012 for sources in the WBEA region are shown in Tables 6 and 7. SO_2 emissions were essentially all from stacks whereas 83% of VOC emissions were from fugitive sources. Major source locations for TRS, SO_2 and VOC are provided in Figure 1 and Figure 2.

Table 6: Emissions of SO_2 (tonnes) from major sources in the WBEA Airshed (> 200 tonnes) – 2012 (NPRI Estimates).

Company Name	Facility Name	Lat.	Long.	Stack Emissions
Syncrude Canada Ltd.	Mildred Lake Plant Site	57.04	-111.62	72,971
Suncor Energy Oil Sands Limited Partnership	Suncor Energy Inc. Oil Sands	57.00	-111.47	18,538
Nexen Inc.	Long Lake Project	56.41	-110.94	3,076
Canadian Natural Resources Limited	Horizon Oil Sands Processing Plant and Mine	57.34	-111.76	2,423
Devon Canada Corporation	Jackfish 1 SAGD Plant	55.53	-110.87	481
Suncor Energy Oil Sands Limited Partnership	Firebag	57.22	-110.90	348
ConocoPhillips Canada Resources Corp.	Surmont SAGD Commercial Battery	56.19	-110.95	263
Japan Canada Oil Sands Ltd.	Hangingstone SAGD Demonstration Facility	55.58	-110.89	222
TOTAL				98,322

Table 7: Emissions of VOC (tonnes) from major sources in the WBEA Airshed (> 500 tonnes) – 2012 (NPRI Estimates).

Company Name	Facility Name	Lat.	Long.	Stack Emissions	Fugitive Emissions	Storage / Handling	Spills	Other	Total
Suncor Energy Oil Sands Limited Partnership	Suncor Energy Inc. Oil Sands	57.00	-111.47	3,840	10,313	1,934			16,087
Canadian Natural Resources Limited	Horizon Oil Sands Processing Plant and Mine	57.34	-111.76	95	11,740	40			11,875
Syncrude Canada Ltd.	Mildred Lake Plant Site	57.04	-111.62	629	6,857	9		276	7,495
Syncrude Canada Ltd.	Aurora North Mine Site	57.30	-111.50	17	4,667			8	4,692
Shell Canada Energy	Shell Albian Sands Muskeg River Mine and Jackpine Mine	57.35	-111.52	78	2,180		1		2,259
Enbridge Pipelines	Athabasca Terminal	56.98	-111.48	3		538			541
TOTAL				4,662	35,757	2,521	1	284	43,225

Figure 1: Location of Major TRS, SO_2 and VOC Emission Sources in the WBEA Airshed.

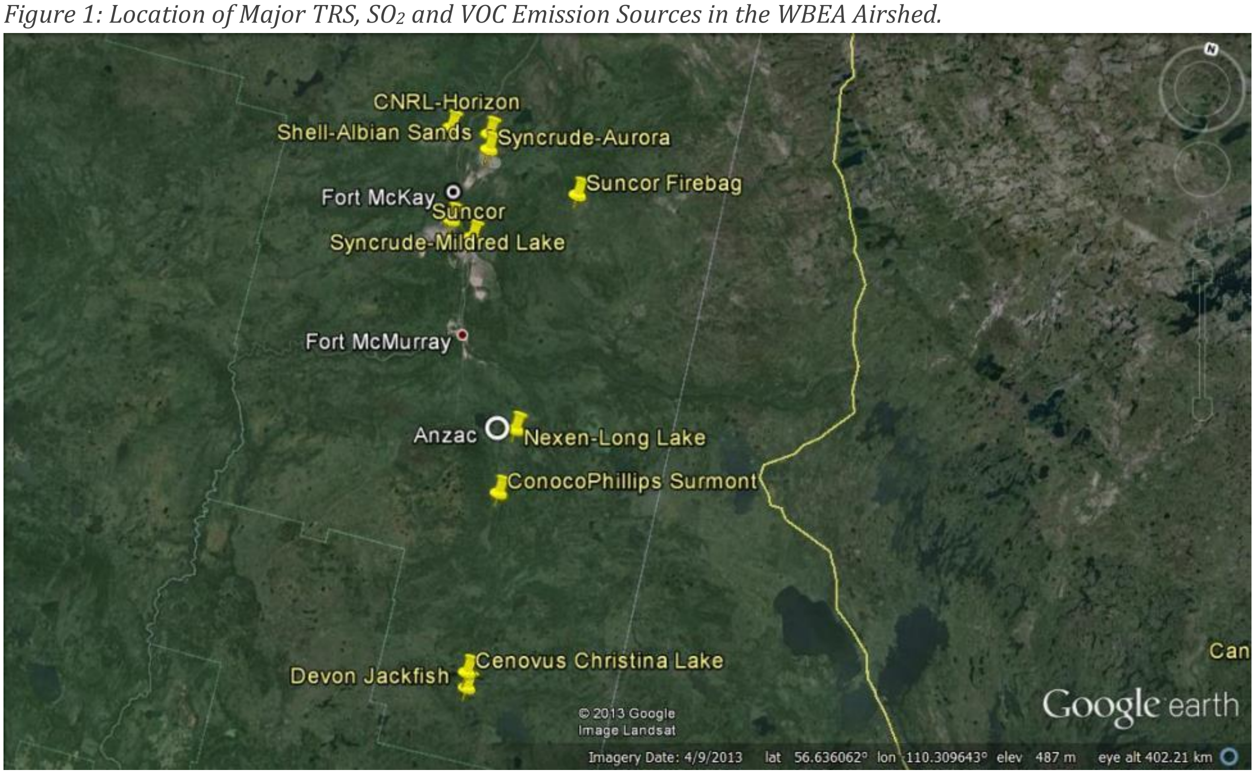


Figure 2: Location of Major TRS, SO_2 and VOC Emission Sources near Fort McKay.

3.3 Comparison of 2012 and 2011 NPRI Emission Estimates

A comparison of total emissions of TRS, SO_2 and VOC for 2011 vs. 2012 for the major sources is provided in Table7. In general, estimated emissions increased from most facilities in 2012 as compared to 2011. Final NPRI emission data for 2013 are not yet available.

Table 7: Comparison of Total Emissions of TRS, SO_2 and VOC (tonnes) from Selected Sources and All Sources in the WBEA Airshed for 2011 and 2012 (NPRI Estimates).

Company Name	Facility Name	TRS		SO_2		VOC	
		2011	2012	2011	2012	2011	2012
Syncrude Canada Ltd.	Mildred Lake Plant Site	117	118	64,727	72,971	7,704	7,495
Suncor Energy Oil Sands Limited Partnership	Suncor Energy Inc. Oil Sands	87	288	20,258	18,538	12,649	16,087
Canadian Natural Resources Limited	Horizon Oil Sands Processing Plant and Mine	22	18	1,988	2,423	3,432	11,875
Syncrude Canada Ltd. - Aurora	Aurora North Mine Site	11	11	-	-	4,702	4,692
Shell Canada Energy	Shell Albian Sands Muskeg River Mine and Jackpine Mine	-	-	-	-	2,050	2,259
Nexen Inc.	Long Lake Project	-	-	1,744	3,076	-	-
All Sources		237	435	90,124	98,322	30,537	43,225

4 Discussion of Available Data for 2013

4.1 Monitoring Sites and Locations and Measured Parameters

A listing of WBEA sites and measured air quality and meteorological parameters (as used in this report) is found in Table 8 and site locations are shown in Figure 3. The Wapasu (AMS#17) site is the newest site and began reporting data on November 19, 2013.

Parameters routinely measured in the WBEA network on a continuous basis and used in this report include sulphur dioxide (SO_2), hydrogen sulphide (H_2S) or total reduced sulphur (TRS), nitric oxide (NO), nitrogen dioxide (NO_2) and total hydrocarbons (THC). Methane (CH_4) and total non-methane hydrocarbons (NMHC) are measured at the 4 community sites (AMS#1, AMS#6, AMS#7 and AMS#14). A number of other specialized measurements are made at AMS#1 including a pneumatic focusing dual detector GC (PFGC) for volatile organic compounds (VOC) and volatile reduced sulphur compounds (RSC) and an Odotech electronic nose (eNose) system. An additional PFGC instrument was installed in September at a new special study site (AMS#104) which is co-located with the AMS#2 Mildred Lake site. The AMS#104 site also measures TRS, methane, NMHC, THC and meteorological parameters. The location of the site relative to AMS#2 is shown in Figure 4. Ammonia (NH_3) is measured continuously at two community sites – AMS#1 and AMS#6. Table 8 also shows the sites where integrated 24-hour samples are collected for VOC and RSC using evacuated canisters. Data for all parameters for 2013 were obtained either from the CASA data website or direct from WBEA staff. Environment Canada (EC) also measures VOC in canisters at AMS#13 and at a non-WBEA site in Fort McKay. All data have been processed as described below and stored in a unified data system.

Table 8: WBEA Monitoring Sites, Continuous Parameters reported in 2013 and canister sample locations (only those sites and parameters used in this report).

WBEA ID	PURPOSE	STATION NAME	TRS	H_2S	SO_2	NO/NO_2	THC	Methane NMHC	Other*	Canister VOC/RSC
1	COMMUNITY	FORT MCKAY BERTHA GANTER	X		X	X	X	X	X	X
2	INDUSTRIAL	MILDRED LAKE		X	X		X			
3	METEOROLOGY	LOWER CAMP MET TOWER								
4	INDUSTRIAL	BUFFALO VIEWPOINT		X	X		X			
5	INDUSTRIAL	MANNIX		X	X		X			
6	COMMUNITY	FORT MCMURRAY PATRICIA MCINNES	X		X	X	X	X	X	X
7	COMMUNITY	FORT MCMURRAY ATHABASCA VALLEY	X		X	X	X	X		X
9	INDUSTRIAL	BARGE LANDING	X				X			X
11	INDUSTRIAL	LOWER CAMP		X	X		X			
12	INDUSTRIAL	MILLENNIUM	X		X	X	X			X
13	INDUSTRIAL N	FORT MCKAY SOUTH	X		X	X	X			X, EC
14	COMMUNITY	ANZAC	X		X	X	X	X		X
15	INDUSTRIAL	CNRL HORIZON	X		X	X	X			X
16	INDUSTRIAL	SHELL MUSKEG RIVER			X	X	X			
17	INDUSTRIAL	WAPASU		X	X	X	X			
104	SPECIAL STUDY	AMS#104	X					X	X	

* other measurements include OdoCheck, PFGC and ammonia at AMS#1, ammonia at AMS#6 and PFGC at AMS#104.

Figure 3: WBEA Continuous Monitoring Network (excluding Fort Chipewyan).

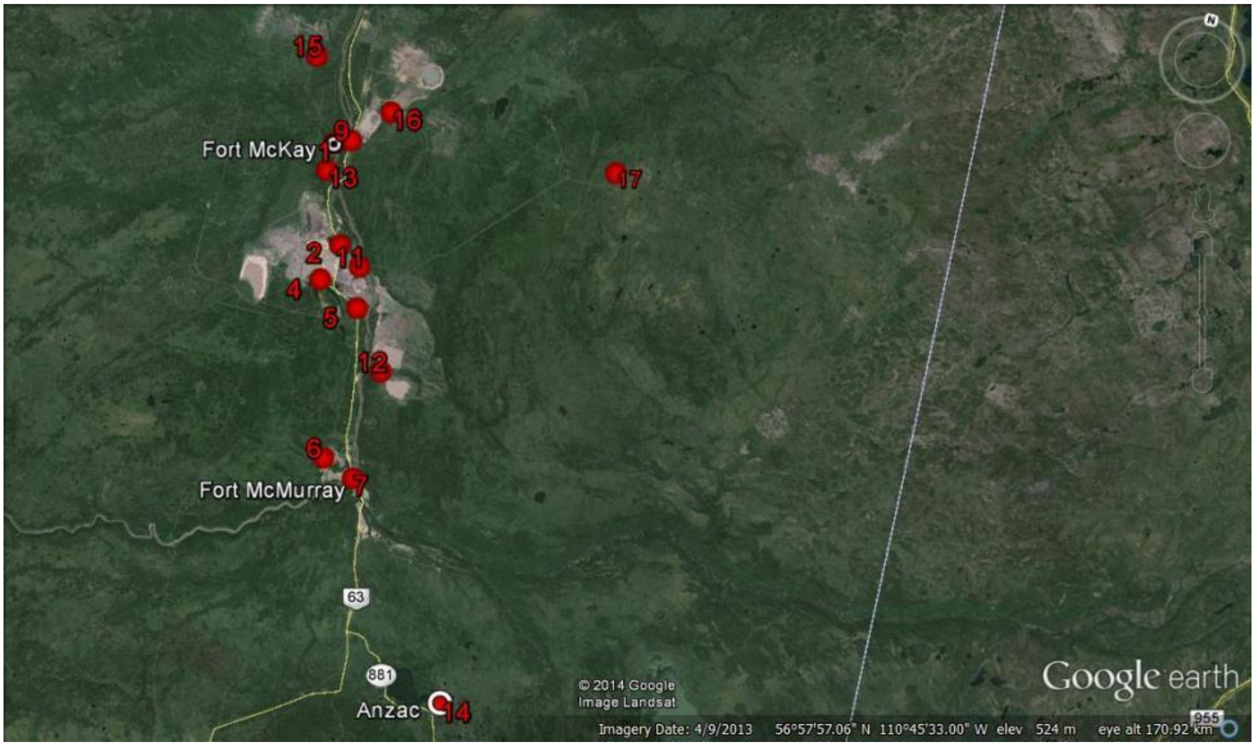


Figure 4: AMS#104 Special Study Site (AMS#2 on the right).

4.2 Routine Continuous Measurements: TRS, H_2S, SO_2, NO, NO_2, THC, NMHC, Methane and Ammonia

4.2.1 Measurement Methods

As shown in Table 8 the air pollutants continuously measured by WBEA in the air network and used in this report include H_2S, TRS, SO_2, NO, NO_2, total hydrocarbons (THC), methane (CH_4), non-methane hydrocarbons (NMHC) and ammonia. Sulphur dioxide is measured continuously using pulsed fluorescence gas analyzers, operated on the 0 to 1000 ppb range. The detection limits observed under field conditions vary from 0.5 to 1 ppb. The oxides of nitrogen analyzers are based on the principle that nitric oxide (NO) and ozone (O_3) react to produce a characteristic luminescence with intensity linearly proportional to the NO concentration. NO_2 is measured by first converting it to NO using a heated molybdenum converter (325 °C). Detection limits are typically less than 1 ppb. The ammonia analyzers operate on the same principle as the oxide of nitrogen analyzers but an additional heated stainless steel converter (725 °C) is used to convert both NO_2 and NH_3 to NO. The ammonia concentration is determined by difference and typical detection levels are 1 ppb.

Total hydrocarbons are measured using a flame ionization detector (FID) operated on a 0 - 25 ppm range, with a detection limit of 0.1 ppm. Methane and NMHC are co-measured using a back-flush chromatography system that provides a direct measurement of non-methane hydrocarbons. The minimum detection limits are 0.05 ppm for CH_4, and 0.05 ppm for NMHC as propane.

Hydrogen sulphide and TRS are measured with pulsed fluorescence technology that detects SO_2 formed by the catalytic conversion of hydrogen sulphide or other sulphur compounds. Analyzer ranges are set at 0-100 ppb. H_2S is the regulated substance but TRS is a better measure of odour. The H_2S measurement is non-specific; hence there is still potential for positive interference from other reduced sulphur compounds (Percy, 2013). The response of TRS analyzers to other sulphur compounds is not necessarily proportional to their response to H_2S.

4.2.2 Results for 2013

All 2013 data for TRS, H_2S, SO_2, NO, NO_2, THC, methane, NMHC and ammonia were obtained directly from WBEA in the form of station files. The WBEA data files typically contain a higher level of precision than files from the CASA data warehouse. For sites with only THC data, the methane data from AMS#1 was used to adjust the THC data to estimate hourly NMHC values at each site (referred to in the report as derived NMHC or dNMHC). This was done because it was felt THC data alone would not be a useful metric.

Summary statistics for 2013 for TRS/H_2S, SO_2, NO, NMHC/dNMHC and ammonia are provided in Tables 9, 10, 11, 12 and 13 respectively.

For the community sites there was only 1 hour with TRS greater than 10 ppb (Alberta AAQO) which occurred at Anzac. For the industrial sites there were 13 hours with H_2S greater than 10 ppb at Mannix and 5 hours at Mildred Lake. The highest maximum and mean SO_2 concentrations were measured at

Mannix. Of the community sites, Bertha Ganter recorded the highest hourly maximum SO_2 concentration and the highest annual mean. The peak hourly value recorded at the site did not exceed the Alberta 1h AAQO for SO_2, however.

Nitric oxide is emitted from all types of light duty and heavy duty motor vehicles, industrial combustion sources and industrial mining equipment. Since NO is rapidly converted to NO_2 in the atmosphere, high NO concentrations can be a useful indicator of fresh and nearby emissions. Of the community sites, the highest mean and 90th percentile NO concentrations were measured at the Athabasca Valley and Bertha Ganter sites. Of the industrial sites, the highest concentrations were measured at the Millennium and Shell Muskeg River sites.

The highest NMHC concentrations were measured at Bertha Ganter but mean NMHC levels were very low at all sites as measured by the continuous method. Further discussion related to the inter-comparison of NMHC data from various measurement methods is provided in Section 4.5. The derived NMHC resulted in much higher means and 90th percentile values possibly because the Fort McKay methane levels are lower than at the industrial sites. Comparing the methane data from AMS104 to Bertha Ganter for coincident time periods (September to December) shows that mean methane levels were 0.2 ppb higher at AMS104 and 90th percentile methane values were 0.4 ppb higher.

For the ammonia measurements, only seven hours were above detection at Bertha Ganter and zero hours at Patricia McInnes.

Table 9: Summary Statistics for 1-h TRS/H_2S (ppb) – 2013.

Location	**N**	**Percentiles**			**Max.**	**Mean**	**Std.**
		90th	**95th**	**98th**			**Dev.**
TRS							
BERTHA GANTER	8284	0.7	1.0	1.3	5.3	0.4	0.3
PATRICIA MCINNES	8311	0.4	0.5	0.8	3.1	0.2	0.2
ATHABASCA VALLEY	8280	0.7	0.8	1.0	4.1	0.4	0.3
ANZAC	8210	0.6	0.7	1.0	11.8	0.4	0.3
BARGE LANDING	8309	0.7	0.9	1.2	5.8	0.3	0.3
MILLENNIUM	8333	0.5	0.6	0.9	4.4	0.2	0.2
FORT MCKAY SOUTH	8294	0.5	0.7	1.0	6.2	0.2	0.3
CNRL HORIZON	8328	0.7	0.9	1.1	4.3	0.4	0.3
AMS#104	3182	1.1	1.9	3.5	14.7	0.5	1.0
H_2S							
MILDRED LAKE	8308	1.1	1.5	2.4	13.5	0.5	0.7
BUFFALO VIEWPOINT	8261	0.6	0.9	1.4	5.8	0.3	0.4
MANNIX	8289	1.2	1.8	3.0	31.3	0.5	1.0
LOWER CAMP	8262	1.1	1.5	2.2	8.0	0.5	0.6
WAPASU	924	0.3	0.4	0.7	1.6	0.2	0.2

Table 10: Summary Statistics for 1-h SO_2 (ppb) – 2013.

Location	N	Percentiles 90th	95th	98th	Max.	Mean	Std. Dev.
BERTHA GANTER	8292	2.4	5.2	11.3	135.3	1.3	4.3
PATRICIA MCINNES	8321	2.3	4.7	8.5	48.2	1.0	2.7
ATHABASCA VALLEY	8270	1.3	2.9	6.7	37.9	0.7	2.1
ANZAC	8240	1.6	3.0	5.6	77.6	0.7	1.9
MILDRED LAKE	8304	3.4	7.6	15.6	110.4	1.7	4.7
BUFFALO VIEWPOINT	8258	1.3	3.2	8.7	139.2	0.9	4.2
MANNIX	8252	4.8	10.4	20.2	225.8	2.3	6.8
LOWER CAMP	8326	2.4	4.9	11.0	134.2	1.3	3.8
MILLENNIUM	8323	1.2	2.9	7.7	121	0.9	3.5
FORT MCKAY SOUTH	8194	2.2	5.1	11.6	108.6	1.3	3.7
CNRL HORIZON	8057	2.1	4.9	9.9	50.1	1.0	2.9
SHELL MUSKEG RIVER	8180	2.5	6.4	13.3	94.5	1.2	3.9
WAPASU	969	4.0	8.1	13.5	82.1	1.8	5.1

Table 11: Summary Statistics for 1-h NO (ppb) – 2013.

Location	N	Percentiles 90th	95th	98th	Max.	Mean	Std. Dev.
BERTHA GANTER	8277	10.7	22.9	40.9	130.4	3.8	9.9
PATRICIA MCINNES	8269	7.2	13.7	26.8	84.7	3.0	6.7
ATHABASCA VALLEY	8284	15.6	28.0	45.1	276.6	5.9	12.2
ANZAC	8241	2.0	4.3	8.6	88.5	0.9	3.2
MILLENNIUM	8305	40.0	62.8	92.3	331.6	12.9	25.4
FORT MCKAY SOUTH	8265	10.9	23.9	50.0	192.8	4.5	13.1
CNRL HORIZON	8283	9.1	21.9	39.8	206.6	3.8	11.8
SHELL MUSKEG RIVER	8153	23.0	40.3	69.9	271.1	9.2	18.2
WAPASU	961	3.0	4.7	8.8	25.4	1.7	2.2

Table 12: Summary Statistics for 1-h NMHC and Estimated NMHC (ppm) – 2013.

Location	N	Percentiles 90th	95th	98th	Max.	Mean	Std. Dev.
NMHC							
BERTHA GANTER	8220	0.163	0.234	0.338	1.530	0.039	0.094
PATRICIA MCINNES	8252	0.000	0.100	0.200	0.700	0.014	0.054
ATHABASCA VALLEY	8249	0.034	0.055	0.099	0.947	0.011	0.033
ANZAC	8155	0.100	0.100	0.100	0.400	0.012	0.033
AMS#104	3042	0.002	0.009	0.050	3.784	0.005	0.071
Estimated NMHC							
MILDRED LAKE	8095	0.8	1.1	1.5	10.2	0.4	0.4
BUFFALO VIEWPOINT	8080	0.5	0.7	1.1	4.9	0.3	0.3
MANNIX	8077	0.6	0.9	1.2	7.1	0.3	0.3
BARGE LANDING	8007	0.6	0.7	0.9	3.4	0.4	0.2
LOWER CAMP	8109	0.7	0.9	1.1	6.2	0.4	0.3
MILLENNIUM	8116	0.9	1.3	1.8	4.4	0.5	0.4
FORT MCKAY SOUTH	8013	0.5	0.7	0.8	2.6	0.3	0.2
CNRL HORIZON	8079	0.6	0.8	1.3	8.8	0.3	0.3
SHELL MUSKEG RIVER	7623	0.9	1.2	1.5	4.0	0.5	0.4
WAPASU	952	0.3	0.4	0.4	0.5	0.1	0.1

Table 13: Summary Statistics for 1-h Ammonia (ppb) – 2013.

Location	N	Percentiles 90th	95th	98th	Max.	Mean	Std. Dev.
NMHC							
BERTHA GANTER	7700	0.00	0.00	0.00	22.70	0.01	0.45
PATRICIA MCINNES	7852	0.00	0.00	0.00	0.00	0.00	0.00

4.2.3 Comparison of TRS results between 2012 and 2013 for Community Sites

A comparison of 2012 and 2013 TRS results (hours greater than 3 and 10 ppb and maximum) is provided in Table 14 for the community sites. There was a reduction in maximum TRS concentration and in hours greater than 3 ppb at all sites with the largest change (90% reduction) at the Bertha Ganter site and the smallest change (30% reduction) at the Anzac site.

Table 14: Comparison of 1-h TRS results for community sites for 2012 and 2013.

SITE	Max. (ppb)		Hours > 3 ppb		Hours > 10 ppb	
	2012	2013	2012	2013	2012	2013
BERTHA GANTER	87	5	126	13	2	0
PATRICIA MCINNES	9	3	27	4	0	0
ATHABASCA VALLEY	9	4	28	9	0	0
ANZAC	14	12	36	25	2	1

4.2.4 Fifteen year trends in TRS and H_2S values at WBEA sites

All TRS and H_2S data for 1999 to 2013 were downloaded from the CASA website in order to examine 15 year trends in concentrations particularly at the community monitoring sites. Figure 5 shows the trend in the 99th percentile of daily maximum 1-hour TRS concentrations (ppb) at the sites while Figures 6 and 7 show the trend in number of hours greater than or equal to 3 ppb and 10 ppb respectively. Figure 8 shows the number of hours with H_2S greater than or equal to 10 ppb at the industrial sites for 1999 to 2013. The year 2009 was a peak year in almost all the site records whereas the year 2013 is one of the lowest years in the records. The Anzac site is an exception with the highest values recorded in 2007 with little change in the later years. In 2013 Anzac recorded the highest 99th percentile and most hours greater than 3 ppb of the community sites.

Figure 5: 99th Percentile of daily maximum 1-h TRS concentrations (ppb) for 1999 to 2013 for community sites.

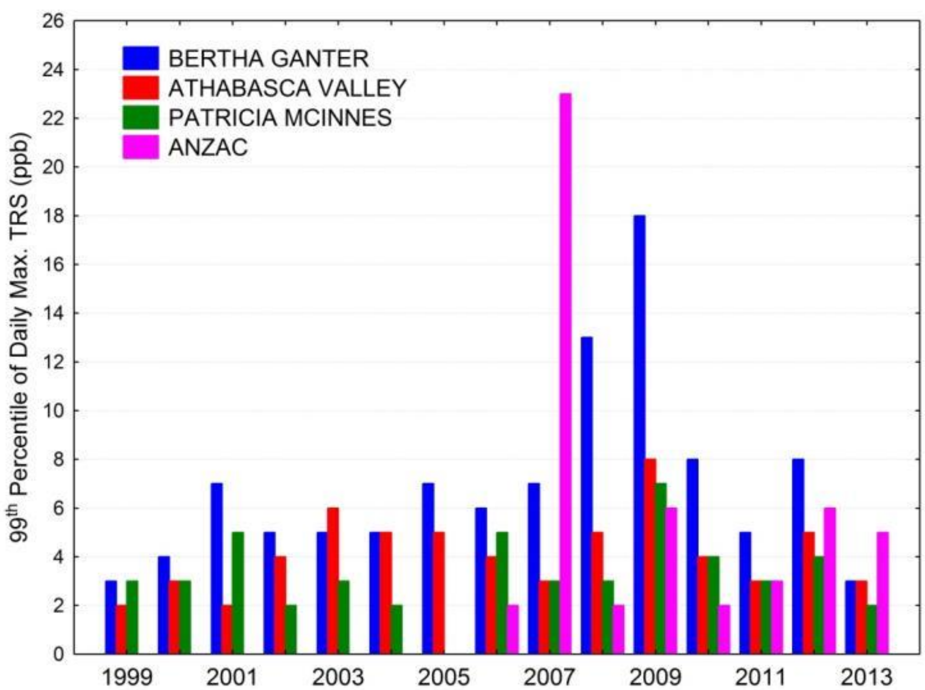


Figure 6: Count of hours with TRS concentrations greater than or equal to 3 ppb for 1999 to 2013 for community sites.

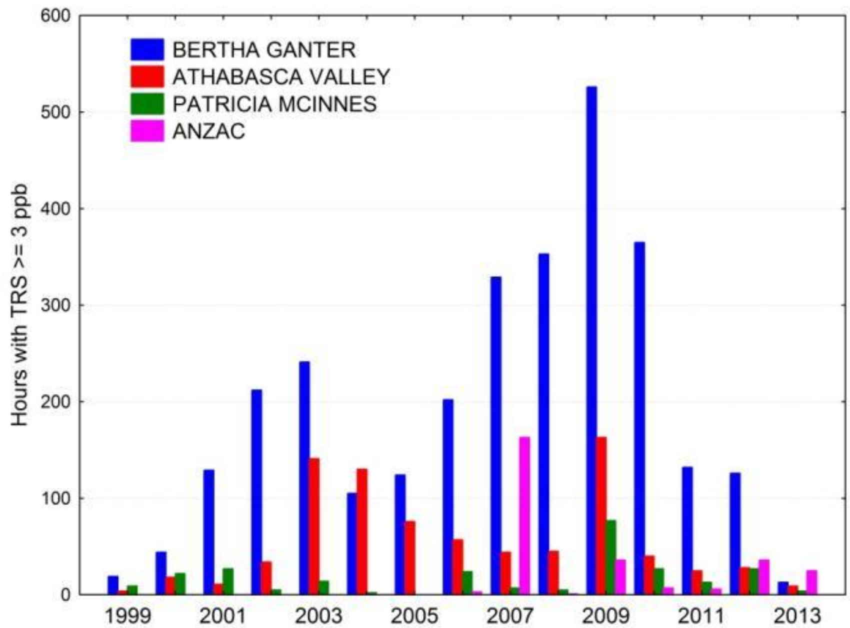


Figure 7: Count of hours with TRS concentrations greater than or equal to 10 ppb for 1999 to 2013 for community sites.

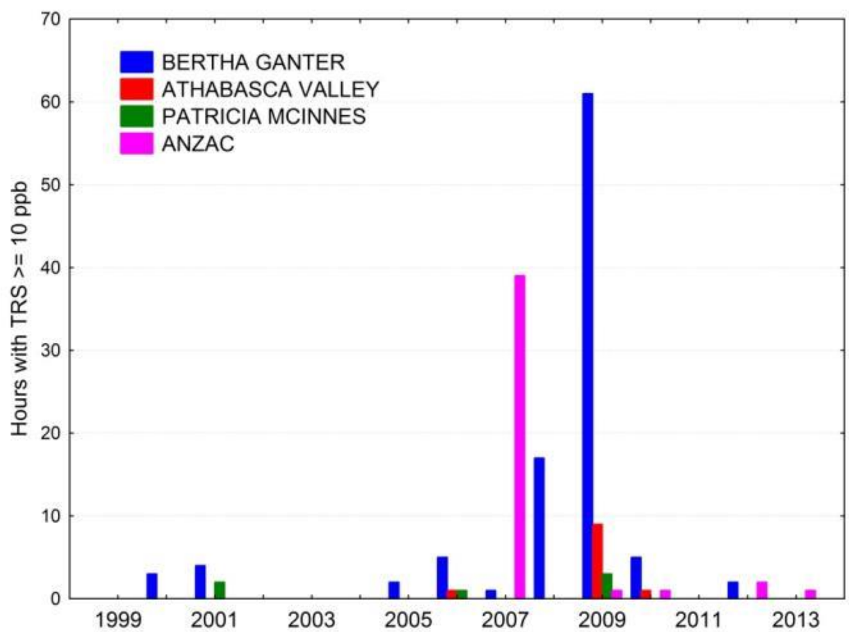
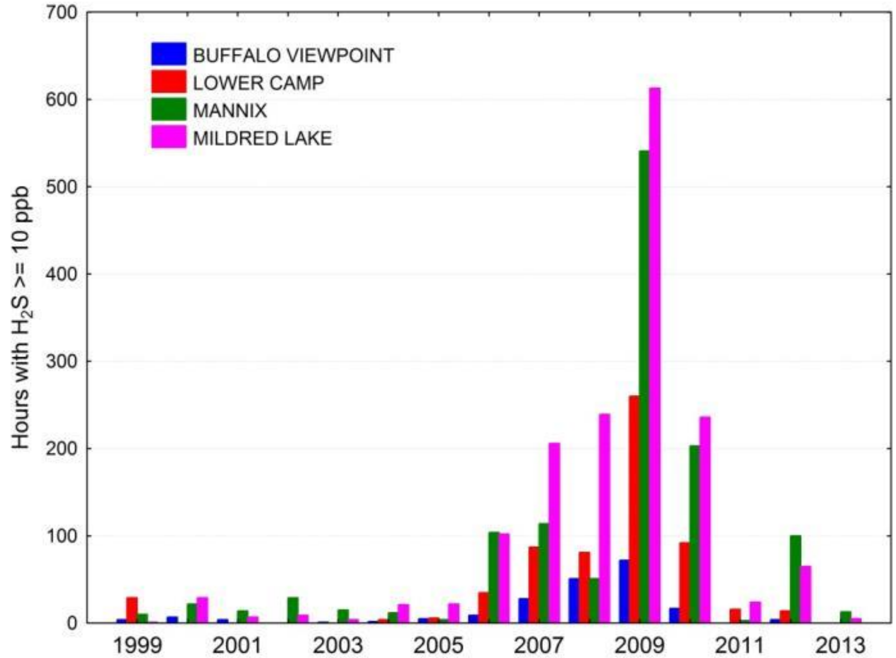


Figure 8: Count of hours with H_2S concentrations greater than or equal to 10 ppb for 1999 to 2013 for industrial sites.



4.3 Meteorological Measurements

4.3.1 Background

As an air pollutant is transported from a source to a community, the pollutant mixes with, and is dispersed into the surrounding air so that it generally arrives at a much lower concentration than it was on leaving the source. The concentration of an air pollutant at a given place, often referred to as a receptor location, is a function of a number of variables, including the amount of the pollutant released at the source (the upwind emission rate), the height of the source, the distance from the community to the source, topography and local weather conditions. The most important weather influences are wind speed, wind direction, precipitation (both rain and snow), sunlight and the amount of turbulence in the atmosphere.

Atmospheric turbulence mixes pollutants into the surrounding air. For example, during a hot summer day, the air near the surface can be much warmer than the air above. Sometimes large volumes of this warm air will rise to great heights and resulting in vigorous vertical mixing. Alternately at night when the earth cools, vertical motion is suppressed resulting in a stable or non-turbulent atmosphere. Sometimes the condition of the atmosphere is very stable and there is very little mixing. This occurs when the air near the surface of the earth is cooler than the air above (a temperature inversion). This cooler air is heavier and will not easily mix with the warmer air above. Any pollutants released near the surface will get trapped and build up in the cooler layer of air near the surface. Such temperature inversions often form during calm clear nights with light winds. They can even persist throughout the day during the winter. In the Oil Sands region, prolonged wintertime periods of very cold, Arctic air with light wind can lead to some of the highest pollutant levels at receptors on the ground.

Increases in wind speed enhance turbulence and wind also contributes to how quickly pollutants are carried away from their original source. Generally, strong winds disperse pollutants, whereas light winds can allow pollutants to build up over an area. However, sometimes strong winds during more stable conditions can transport pollutants from a distant source, such as the smoke from forest fires, to arrive at a receptor in higher concentrations. High wind speeds can also generate dust from roadways, surface mining operations and tailings piles. The direction of the wind determines where emissions are transported. Variations in wind direction, which are typical hour by hour and day by day lead to complex downwind pollutant patterns. Precipitation can remove pollutants from the air and can also reduce emissions through reductions in the amount of dust raised by mining operations and by vehicles. Topography can create conditions that allow the trapping of pollutants and also funneling of winds in preferred directions, such as along river valleys. At night when conditions are typically calmer, cold air tends to drain downhill, settling into low-lying basins and valleys. Unable to rise, the cool air settles and accumulates in these valleys, trapping air pollutants.

Many pollutants undergo chemical reactions when they encounter water vapour and other pollutants in the air. The products of these chemical reactions are called secondary pollutants, as opposed to primary pollutants that are emitted directly into the atmosphere. Ground-level ozone is an example of a secondary pollutant that forms when nitrogen dioxide (NO_2) and volatile organic compounds (VOCs) mix in the presence of sunlight. Chemical reactions are enhanced by sunlight and moisture, including fog and clouds.

4.3.2 Meteorological Parameters used in this Report

The meteorological parameters barometric pressure, relative humidity, temperature and wind speed/direction were used in the project and 2013 data for all sites were obtained from WBEA. Wind direction, wind speed and temperature at 20, 45, 100 and 167 m for Lower Camp Tower (AMS#3) and wind direction, wind speed and temperature at 20, 45, 75 and 90 m for the Mannix tower (AMS#5) were also obtained from WBEA. For episode/complaint analysis the following were used: wind speed and direction at 100 m from Lower Camp tower and wind speed and direction at 45 m from the Mannix tower. For hours experiencing TRS/H_2S equal to or greater than 1.5 ppb and for complaint hours, a calculation of the average wind direction, standard deviation of wind direction and wind speed for the previous 6 hours was made using the Yamartino method. An estimation of inversion strength was also made using the temperature difference between 90 m and 20 m at Mannix and between 167 m and 20 m at Lower Camp Tower. Inversion strength is a useful predictor of the amount of atmospheric turbulence.

4.3.3 Wind Roses

Wind roses for the community sites are shown in Figure 9 and wind roses for all heights at the Lower Camp tower and the Mannix met tower are shown in Figures 10 and 11. Wind roses for all other sites are found in Figure 12. Wind direction patterns reflect site location relative to the local river valleys as well as the size and orientation of the clearing around each site. Most of the WBEA sites are in river valleys where winds near the surface are subject to channeling especially for the stations at lower elevations. The tower measurements are less affected by local flows.

Figure 9: Wind Roses for Fort McKay Bertha Ganter, Fort McMurray Patricia McInnes, Fort McMurray Athabasca Valley and Anzac – 2013.

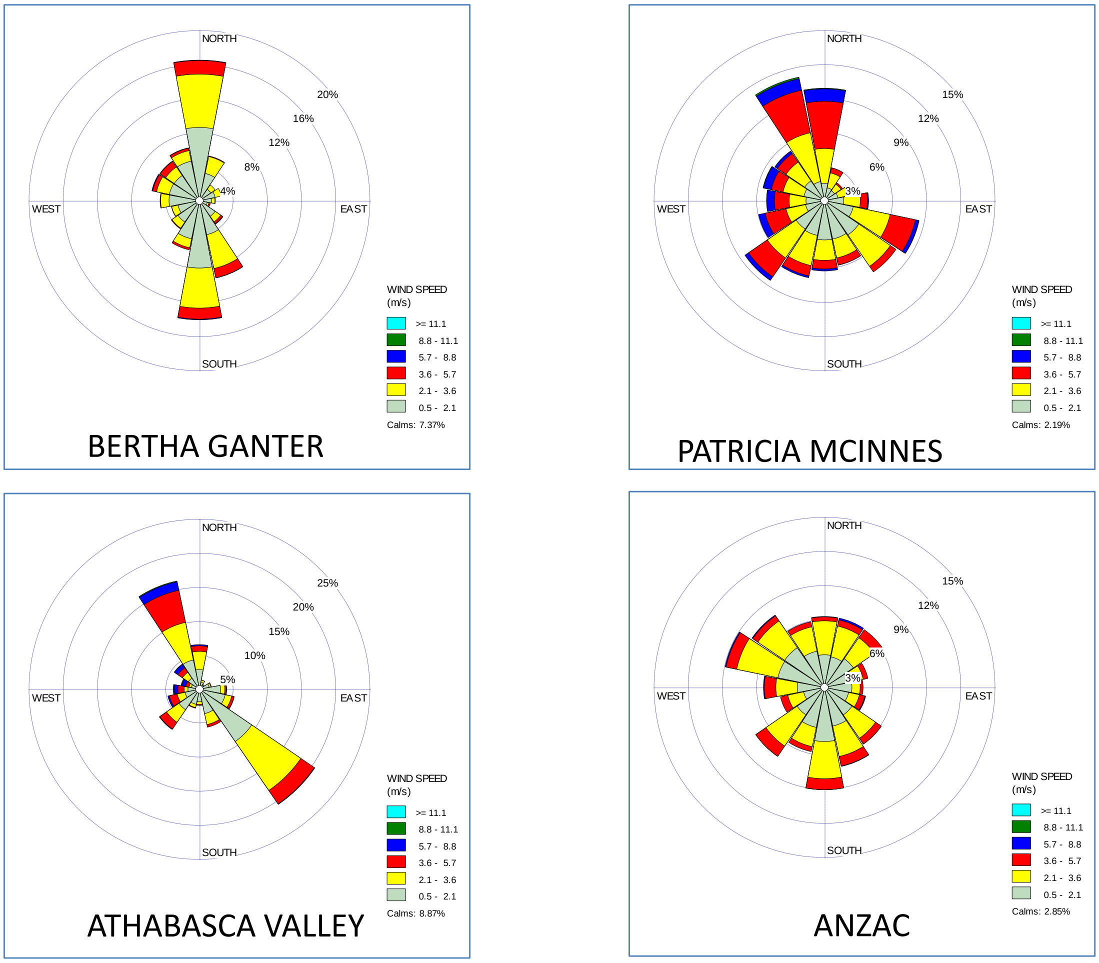


Figure 10: Wind Roses by Height for Lower Camp Met Tower (2013).

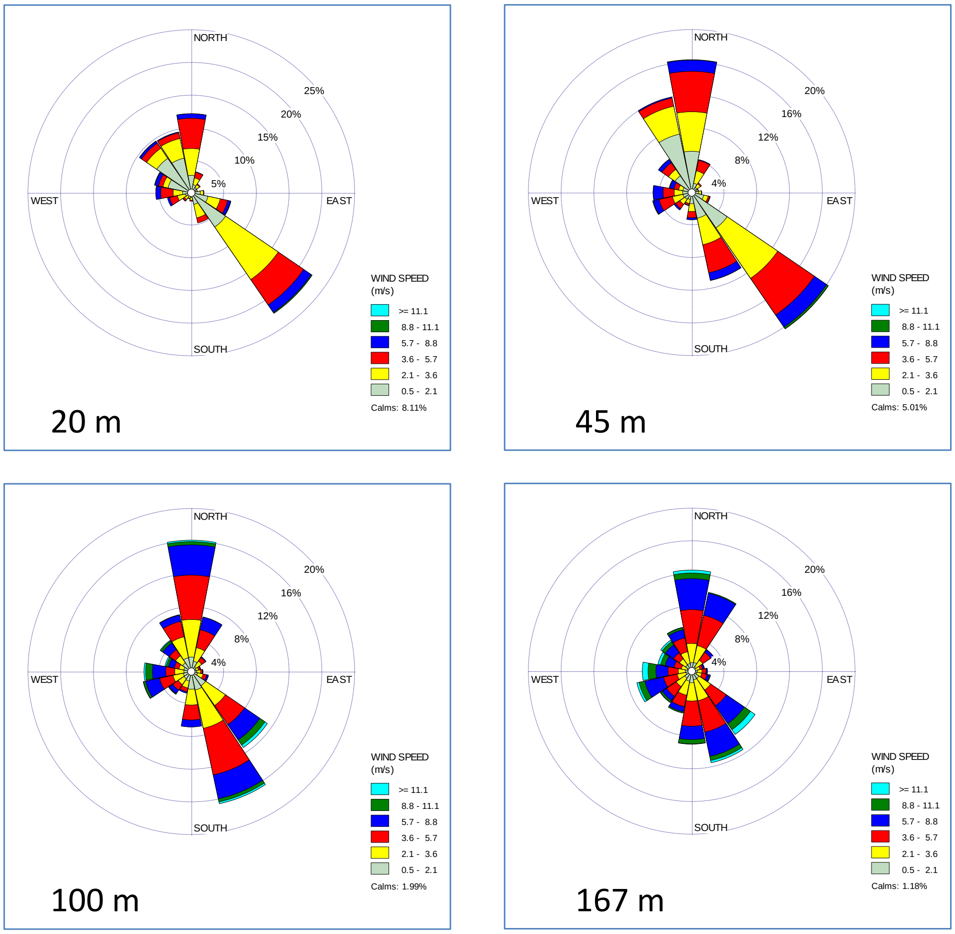


Figure 11: Wind Roses by Height for Mannix Met Tower (2013).

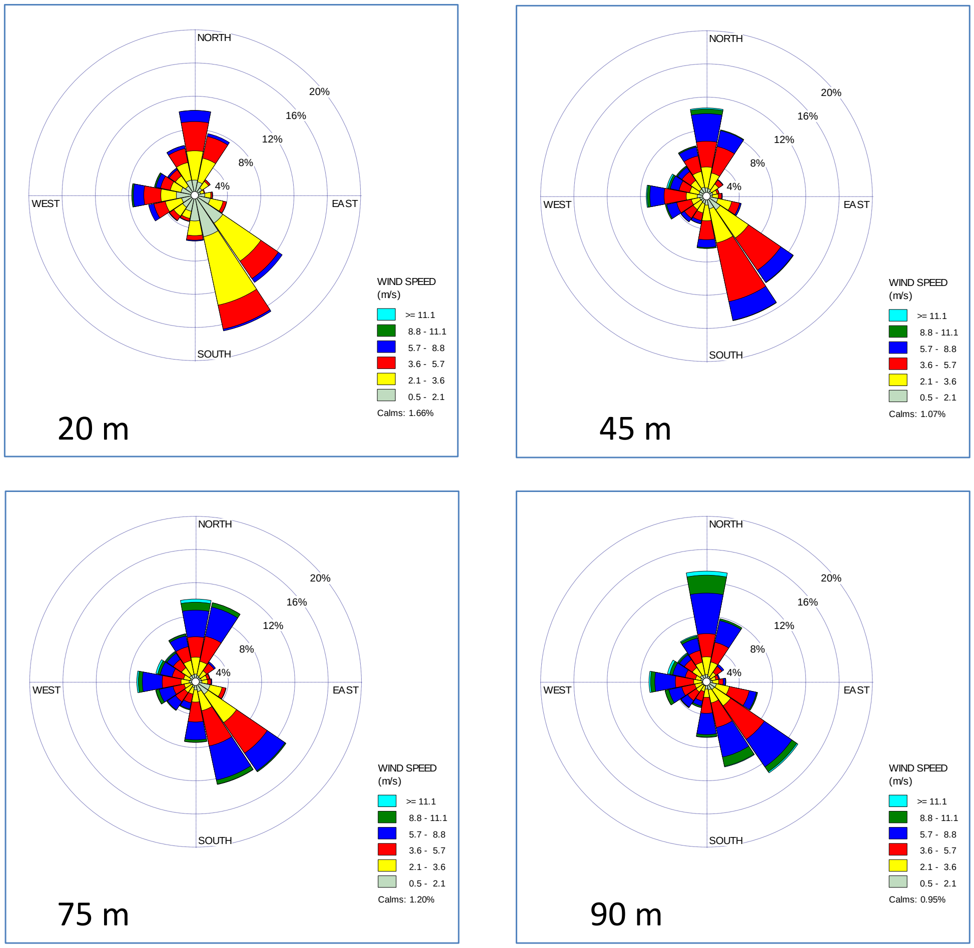
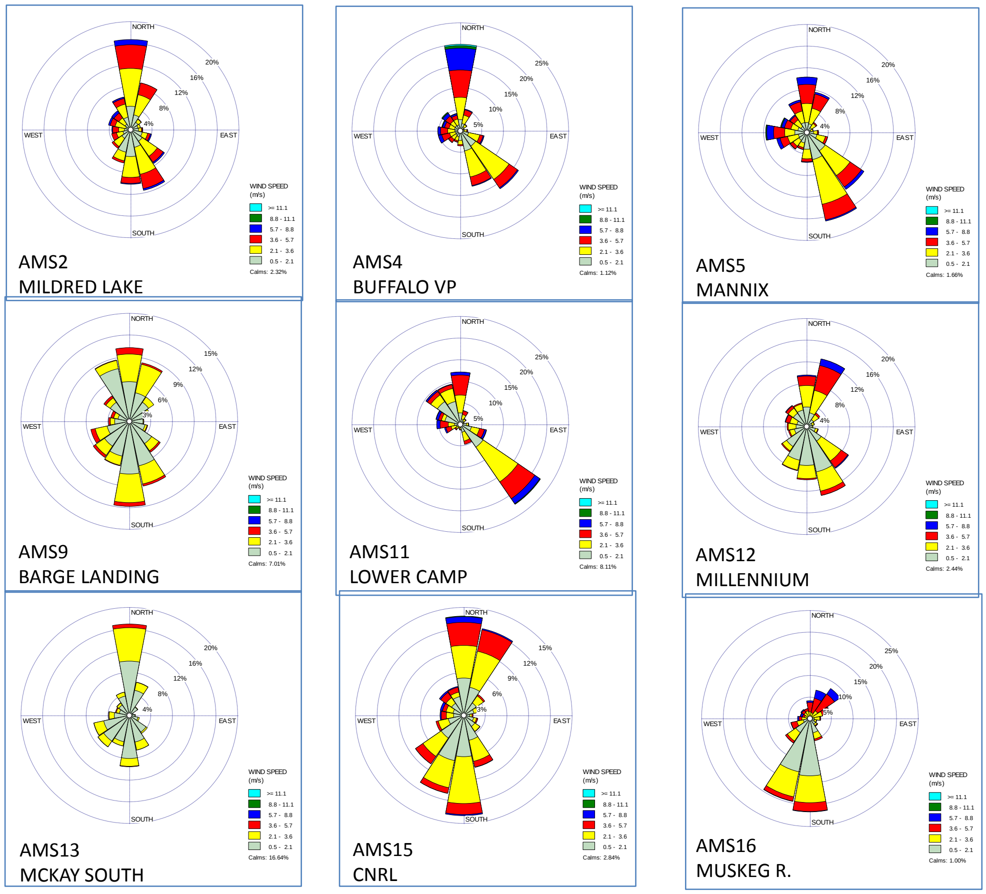


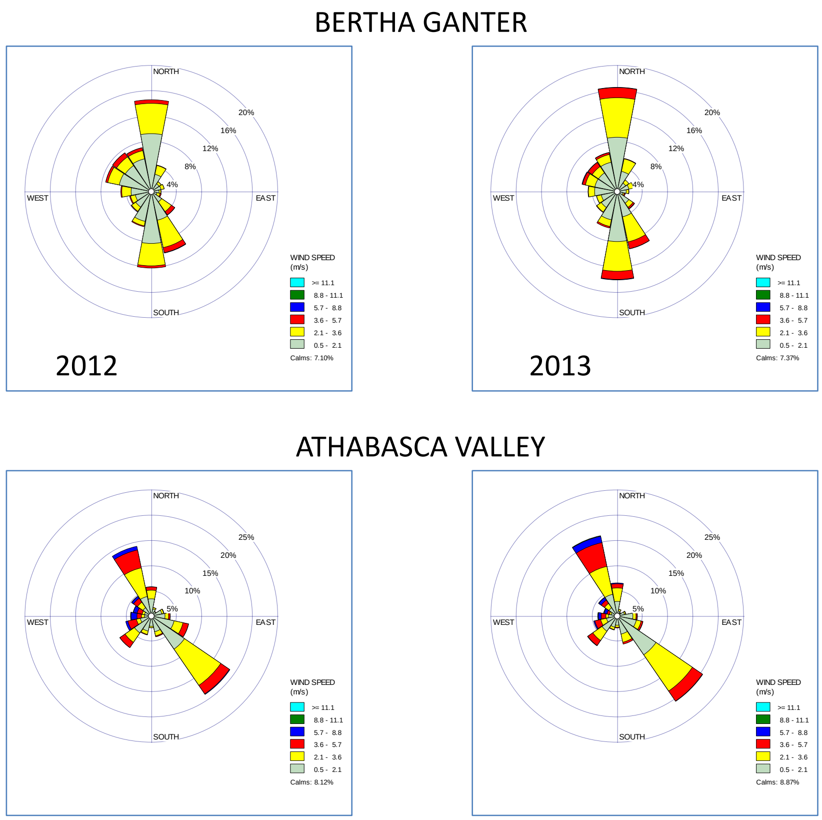
Figure 12: Wind Roses for Other WBEA Sites (AMS2, AMS4, AMS5, AMS9, AMS11, AMS12, AMS13, AMS15 and AMS16.



4.3.4 Wind Roses for 2013 vs. 2012

Comparison of wind direction and wind speed in 2012 and 2013 for the Bertha Ganter and Athabasca Valley sites are provided in Figure 13. There were no major differences in predominant wind direction between the two years for these sites.

Figure 13: Comparison of Wind Roses for Bertha Ganter and Athabasca Valley Sites for 2012 and 2013.



4.3.5 Inversion Strength at Tower Sites

As noted previously an estimation of inversion strength was also made using the temperature difference between 90 m and 20 m at Mannix and between 167 m and 20 m at Lower Camp Tower. Figures 14 and 15 show the temperature difference as a function of hour of the day and categorized by season: Winter (D,J,F), Spring (M,A,M), Summer (J,J,A) and Fall (S,O,N). A positive delta indicates a stable atmosphere and a temperature inversion.

Figure 14: Inversion Strength by Hour of Day and Season based on Temperature Difference between 167 and 20 m at Lower Camp Tower (2013).

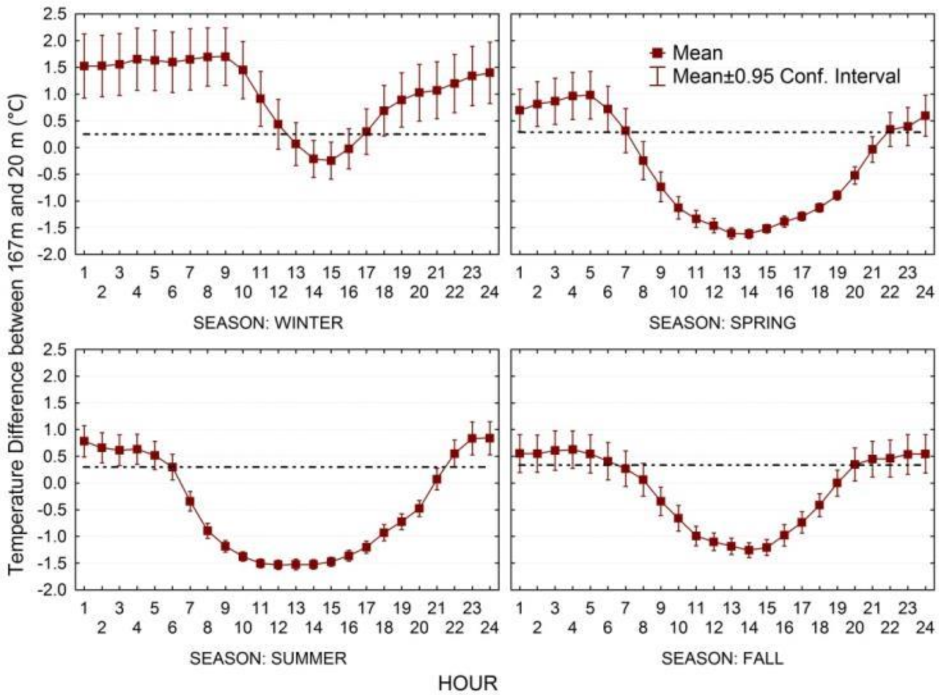
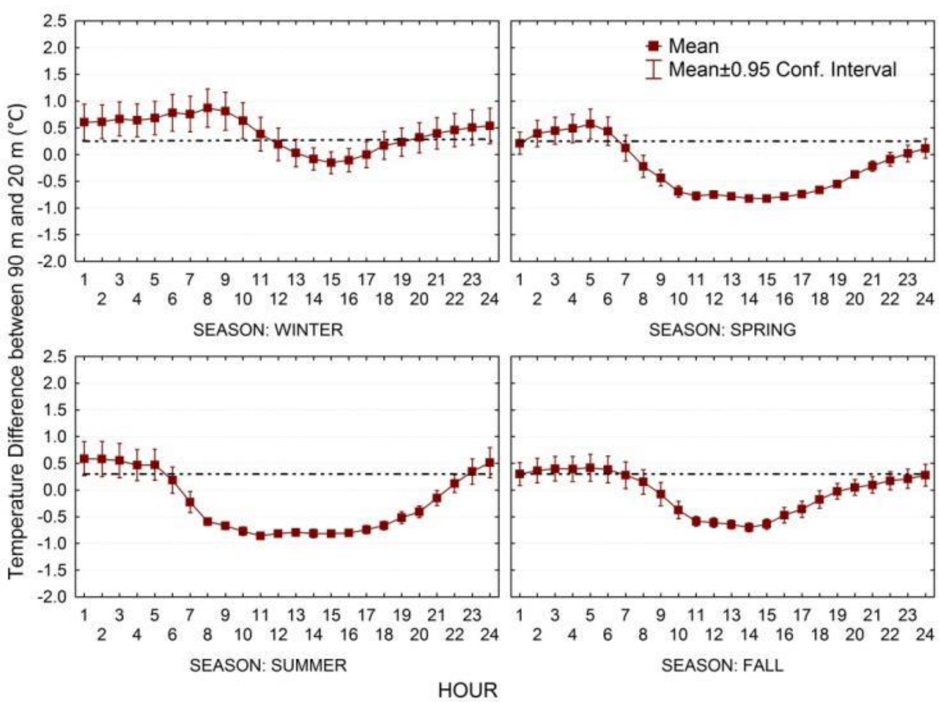


Figure 15: Inversion Strength by Hour of Day and Season based on Temperature Difference between 90 and 20 m at Mannix Tower (2013).



4.4 OdoCheck System (eNose)

4.4.1 Background

The OdoCheck system from Odotech is composed of an electronic nose (eNose) which consists of a continuous sampling device that collects air samples and directs it thru 16 non-specific sensors located inside a flow chamber that react to the different odorous compounds present in the air. The instrument is located at the Bertha Ganter site (AMS#1) and is connected to the same glass manifold that supplies ambient air to the other analyzers at the site. The eNose responses are collected every 4 minutes and stored in a local computer onsite. Data are accessed and extracted remotely by Odotech. The instrument nominally reports in odour units (o.u./m^3) but as stated by the manufacturer: "*Odour measurements in ambient air provide information on odour variability in the vicinity of the system rather than fixed odour concentration comparable to the above perception scale. In this project, because of the location of the eNose in ambient air, the number of potential odour sources and calibration methodology, the odour concentration values should be interpreted carefully as these are related to indicators of variability rather than absolute concentrations." (Odotech, 2014).*

Each sensor of the eNose is calibrated according to a specific range based on the odour samples used. Measures outside the calibrated range may occur and lead to inconclusive results in terms of odour concentrations (Odotech, 2014). Pollutants, interactions, temperatures and humidity are all factors that may contribute to sensors responses. Null concentrations are indicative of captor responses outside their calibrated range and tend to indicate odour concentrations lower than the odour concentrations on which the calibration is based on.

4.4.2 Operation and Results for 2013

Monthly data files were received from WBEA and processed into one annual data file including all four-minute readings. There were some periods of missing data as shown in Table 15 and the original instrument was replaced on August 14, 2013 with a new unit. Responses from the new eNose installed in August 2013 provided on average (baseline response) lower odour concentrations than the previous equipment (Odotech, 2014). Overall data recovery for 2013 was 96.3%.

For 2013, 88% of the data recorded were within the calibration range. Data outside the calibration range were recorded mostly in January, November and December 2013 (Odotech, 2014).

Table 15: eNose System Operation in 2013.

Start Date	End Date	Issue
February 4	February 14	Communication issue.
March 12	March 15	Communication issue.
April 27	April 27	Routine maintenance.
July 15	July 16	Routine maintenance and tests to investigate oscillation pattern. Relocation of eNose in station.
August 14	August 14	Replacement of eNose.
October		the power supply to the eNose was modified by WBEA to better filter any electrical noise coming from the grid
December 12	December 12	Routine maintenance.

As noted "*the odour concentrations should not be interpreted as being absolute but should rather be used to assess the variations*". Accordingly, for this project the data were reprocessed to calculate hourly averages, the integer value of the difference between the maximum four-minute reading and the mean of all readings for each hour (DELTA) and the ratio of the standard deviation of the four-minute averages to their mean (coefficient of variation or CV). These latter two calculated values provide a measure of variability instead of an absolute reading and were also used in subsequent episode analysis along with the original eNose hourly and maximum readings. Plots of the data before (maximum reported four-minute readings each hour) and after processing (DELTA and CV by hour) are shown in Figures 16, 17 and 18 (separate scales). There are notable step changes in response for all values after the change of the instrument on August 14. There were other step changes in response from March 27 to April 10 and from May 27 to August 14.

Figure 16: Maximum reported four-minute readings from eNose at Bertha Ganter by hour in odour units.

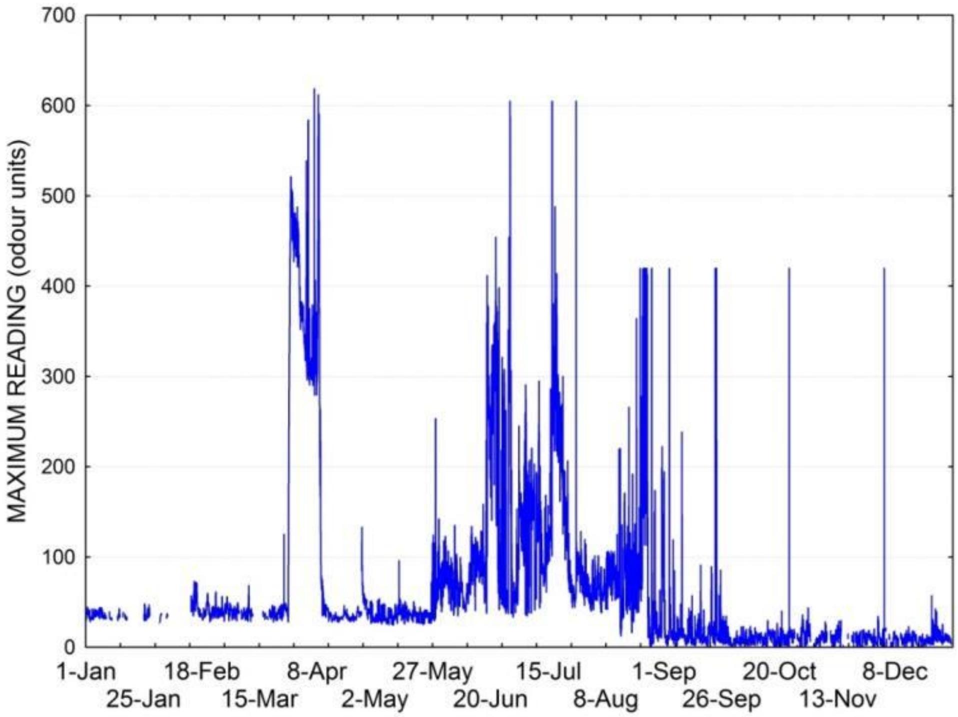


Figure 17: Difference between maximum and mean (DELTA) reported readings from eNose at Bertha Ganter by hour in odour units.

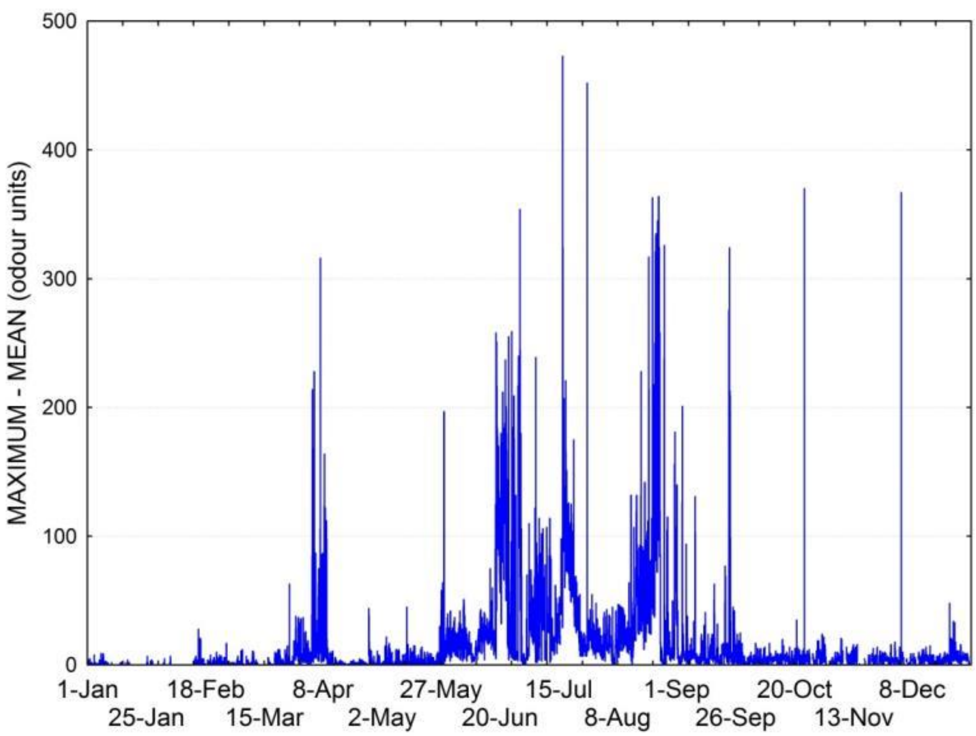
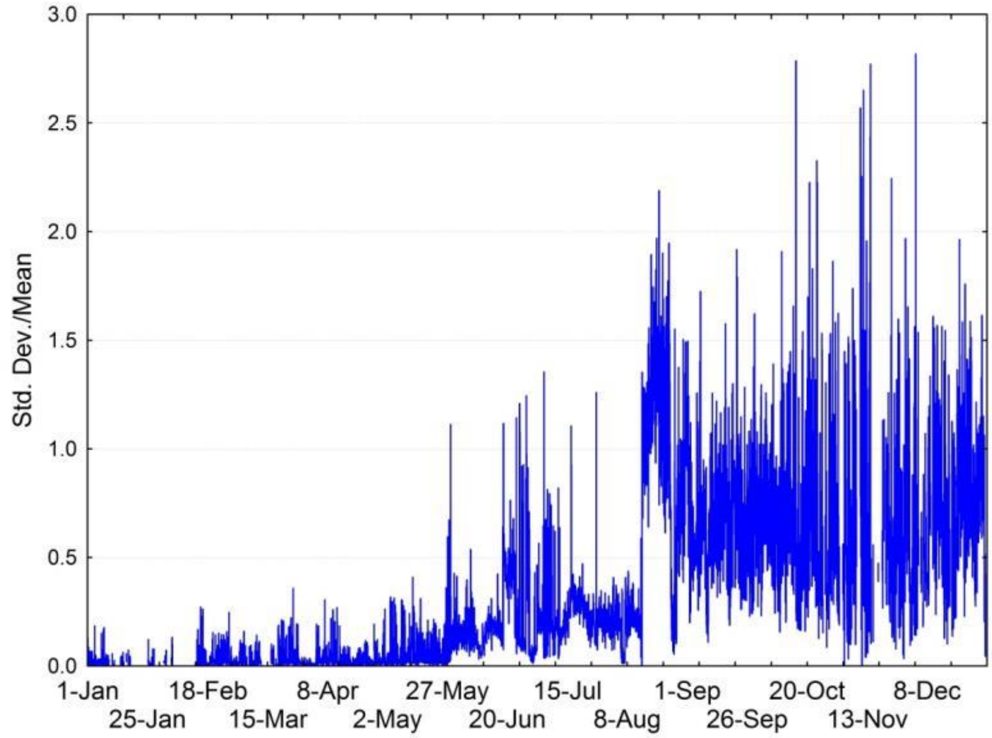


Figure 18: Ratio of standard deviation to mean of 5 minute reported readings (CV) from eNose at Bertha Ganter by hour.



4.4.3 Remaining Questions on eNose

The following questions were posed to Odotech and at time of writing are awaiting an answer:

1. Are the periods of zero's i.e. Jan. 9 17:36 to Jan. 10 23:32 – invalid? "Null concentrations are indicative of captor responses outside their calibrated range and tend to indicate odour concentrations lower than the odour concentrations on which the calibration is based on"
2. What is the upper bound of calibrated range? What extremes of temperature and/or humidity might affect response?
3. There are large differences in the 'look' of data for different periods i.e. avg. and max response, baseline etc. Definite change in response after original unit replaced in August.
4. "the odour concentration values should be interpreted carefully as these are related to indicators of variability rather than absolute concentrations" –"It is the magnitude of the sensors responses that is translated into an interpreted odour concentration"– not sure what this is trying to say – could be better worded.
5. "even if the type of sensors is the same as before, their responses to similar stimuli can be slightly different" – how do the multitude of eNose sensors in Fort McKay compare in terms of absolute outputs and simultaneous response to odours?
6. It seems no calibration was actually carried out in 2013 (results were deemed invalid for Sep 2013 bags).

4.5 Pneumatic Focusing Gas Chromatograph (PFGC)

VOC Technologies (VOCTEC) operates a Pneumatic Focusing Gas Chromatograph (PFGC) at the Fort McKay Bertha Ganter site which includes dual detection with both a flame ionization detector (FID) for volatile organic compounds and a sulphur chemiluminescence detector (SCD) for sulphur-containing compounds. Details of the principles, operating procedures and calibration of this instrument are found in O'Brien, 2013 and O'Brien, 2014. The SCD was added in 2012 and has the capability to measure the concentrations of reduced sulphur compounds (RSCs) at levels below 50 parts-per-trillion (ppt). Typical VOC detection levels are estimated to be 0.1 ppb. A second PFGC instrument was installed at the AMS#104 site on September 1, 2013. Integrated data files for both sites were received from VOC Technologies and were processed into annual data files with readings by hour retained for VOC and RSC. Some periods of data were missing for the instrument at the Bertha Ganter site as shown in Table 16. The instrument typically collects a 5 minute sample every 70 minutes resulting in 19 to 20 observations per 24-hour period. These grab samples were assigned to the hour in which they were collected.

Table 16: PFGC and SCD System operation at Bertha Ganter for 2013.

Start Date	End Date	Issue
PFGC		
April 1	June 11	The PFGC suffered extensive damage, whose origin is under investigation. This damage required the GC to be returned to Oregon for repairs. The GC was replaced with a new PFGC/SCD in June.
August 26	August 27	The PFGC/SCD unit was replaced with a second instrument.
October 17	October 22	GC gases ran out.
December 13	December 15	FID went off scale.
December 20	December 30	GC gases ran out.
SCD		
January 1	June 1	Overhaul of SCD.
August 26	August 27	The PFGC/SCD unit was replaced with a second instrument.

Summary statistics for all identified VOC species from Bertha Ganter and AMS#104 are provided in Tables 17 and 18 (values below detection were set to zero). The sum of selected classes of species are also broken into naphtha, aromatic, sum of identified species (SUM_ID) and high molecular weight (HEAVY). The instrument at Bertha Ganter produced 4,304 hours of data from January to December and the instrument at AMS#104 produced 2,095 hours of data from September to December.

Hourly results for naphtha, aromatic and heavy molecular weight compounds at Bertha Ganter for 2013 are shown in Figure 19 for January to December, 2013 while Figure 20 shows results for naphtha and aromatics at AMS#104 for September to December, 2013. At the Bertha Ganter site the heavy MW weight species were not detected after the new PFGC was installed on June 11. Benzene was not detected after the change of instrument in August and toluene was not measured above detection for any hour beginning on October 1. At the AMS#104 site aromatics were not measured above zero until November 1. Naphtha species were detected consistently at both sites.

Figure 21 and 22 compares the sum of all identified species at the two sites for September to December 2013 with the total NMHC results from the continuous analyzers. The two measurements would not be expected to agree in absolute values because of differences in calibration, in time resolution (5 minutes for PFGC versus 1 hour for NMHC) and because of differences in species included in the totals. Some agreement in peaks would be expected, however. The patterns for the two sites are quite different with NMHC consistently higher than sum of species at Bertha Ganter (as would be expected) and consistently lower at AMS#104. One data point is excluded from the AMS#104 plot: on Nov. 6, 2013 at 02:00 the PFGC sum of species was 8,500 ppbC and the NMHC reading was 3,780 ppbC.

Table 17: Identified VOC Compounds, Frequency of Detection and Summary Statistics (ppbC) for all measurements at Bertha Ganter (total reported hours of data were 4,304).

Compound	Class	Frequency of Detection	95^{th} Percentile	Maximum	Mean	Std. Dev.	Median
Butanes		32%	2.6	20.5	0.4	1.3	0.0
Acetone		37%	4.9	72.3	0.8	2.6	0.0
Isoprene		45%	12.1	151.1	2.4	5.6	0.0
2&3-Methylbutane	N	85%	11.0	206.3	3.2	7.9	1.3
Pentane	N	87%	9.5	355.3	3.0	10.6	1.1
Benzene	A	52%	1.8	32.3	0.6	0.9	0.2
2-Methylpentane	N	79%	9.2	270.8	2.8	7.8	1.2
3-Methylpentane	N	78%	3.8	83.5	1.2	3.3	0.5
Hexane	N	87%	5.9	84.6	1.8	3.1	1.0
Toluene	A	59%	3.9	70.0	1.0	2.5	0.2
diMethylpentane		40%	2.0	21.2	0.4	1.1	0.0
2&3-Methylhexane		45%	5.9	56.7	1.2	3.1	0.0
Heptane		43%	3.1	36.0	0.6	1.8	0.0
Ethylbenzene	H	27%	0.9	21.8	0.2	0.7	0.0
m&p-Xylene	H	31%	1.7	58.0	0.4	1.9	0.0
o-Xylene	H	31%	2.0	48.5	0.4	1.8	0.0
Octane	H	20%	0.4	56.5	0.1	1.0	0.0
NAPHTHA	N	97%	38.5	978.3	12.2	29.4	5.9
AROMATIC	A	70%	5.3	70.0	1.6	2.8	0.9
SUM_ID		99%	55.0	999.0	19.5	32.3	12.1
HEAVY	H	36%	4.8	116.5	1.1	4.1	0.0

Table 18: Identified VOC Compounds, Frequency of Detection and Summary Statistics (ppbC) for all measurements at AMS#104 (total reported hours of data were 2,095).

Compound	Class	Frequency of Detection	95th Percentile	Maximum	Mean	Std. Dev.	Median
Butanes		38%	4.2	249.0	1.2	8.2	0.0
Acetone		41%	10.3	2220.2	3.3	49.2	0.0
Isoprene		18%	17.2	114.7	2.5	9.7	0.0
2&3-Methylbutane	N	54%	12.3	4758.7	5.1	104.2	0.2
Pentane	N	56%	16.2	756.2	4.4	23.6	0.5
Benzene	A	26%	1.6	22.6	0.3	1.0	0.0
2-Methylpentane	N	53%	10.1	363.0	3.1	15.6	0.1
3-Methylpentane	N	43%	3.8	61.5	0.9	3.9	0.0
Hexane	N	49%	11.8	431.6	3.2	16.8	0.0
Toluene	A	38%	5.0	116.8	1.2	5.4	0.0
diMethylpentane		16%	2.3	36.3	0.4	2.0	0.0
2&3-Methylhexane		21%	6.7	86.4	1.2	5.2	0.0
Heptane		19%	3.8	41.4	0.7	3.2	0.0
NAPTHA	N	71%	51.7	6050.1	16.7	140.0	3.4
AROMATIC	A	45%	6.2	125.0	1.5	5.8	0.0
SUM_ID		73%	94.2	8450.8	27.5	192.8	7.8
HEAVY	H	0%	-	-	-	-	-

Figure 19: Hourly Variation in sum of Naphtha, Aromatic and Heavy MW Species (ppbC) from PFGC at Bertha Ganter – 2013 (Note: naphtha values over 500 not shown).

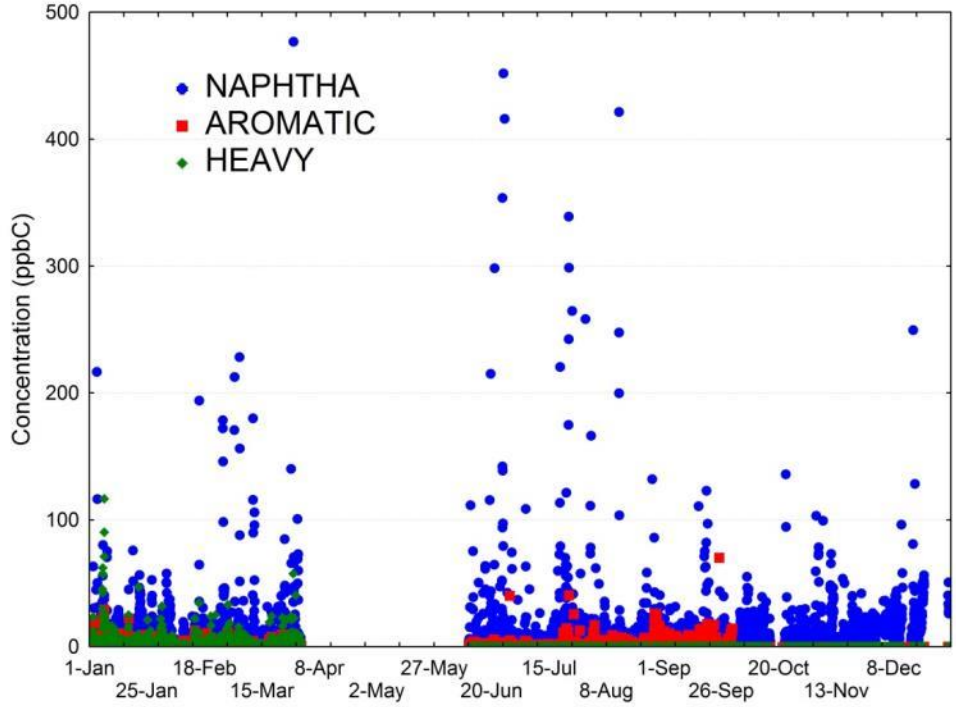


Figure 20: Hourly Variation in sum of Naphtha and Aromatic Species (ppbC) from PFGC at AMS#104 – 2013 (Note: Naphtha values over 1,000 not shown).

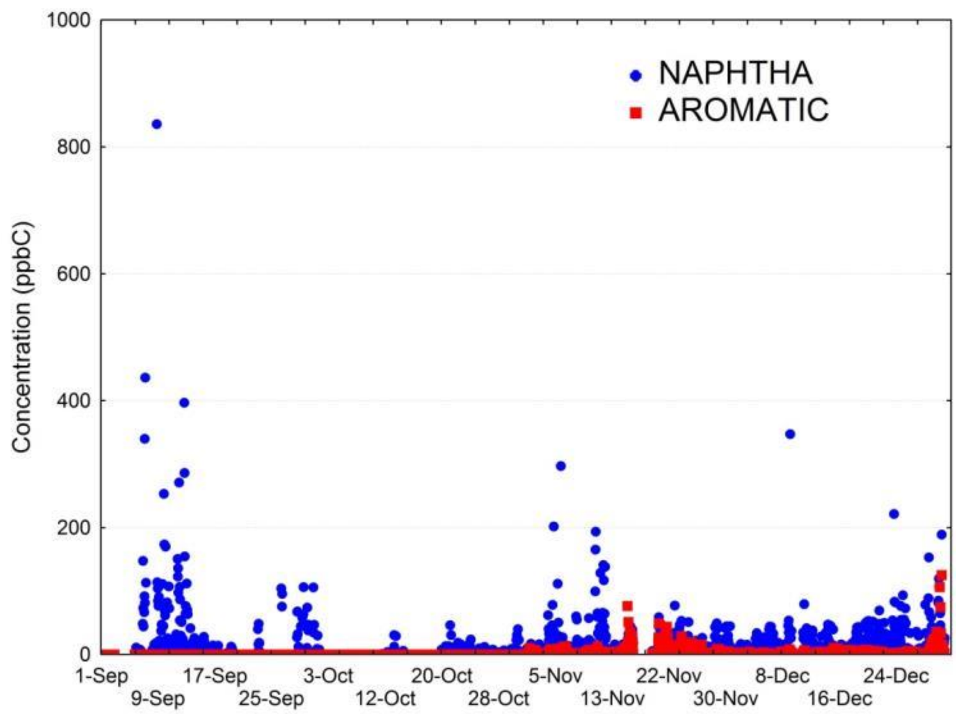


Figure 21: Comparison of hourly NMHC (ppbC) and PFGC sum of species (ppbC) at Bertha Ganter for Sep. – Dec. 2013.

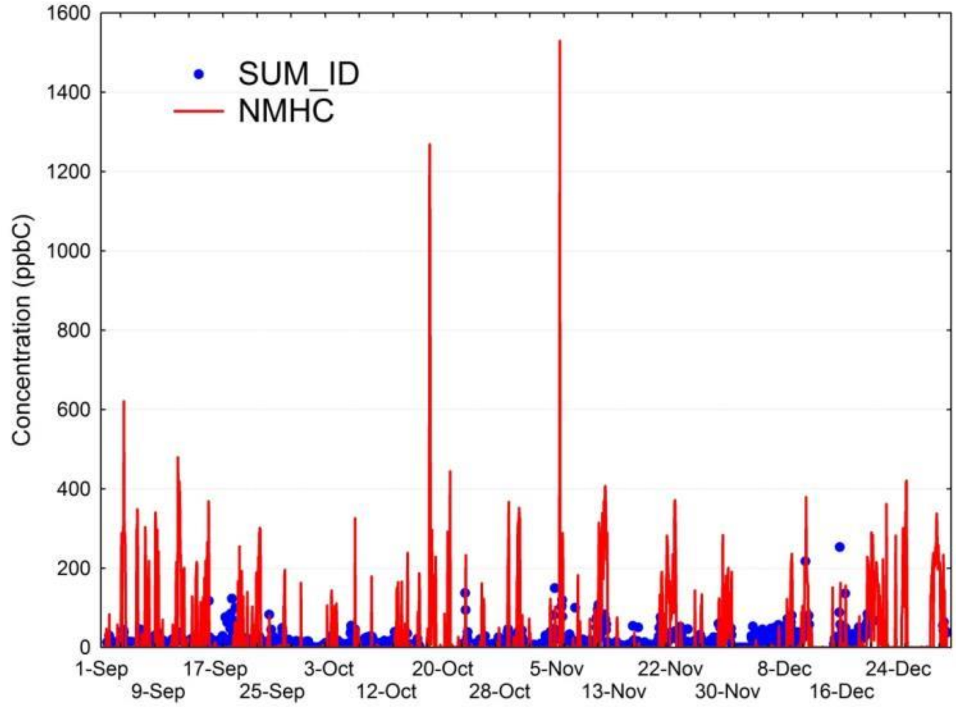
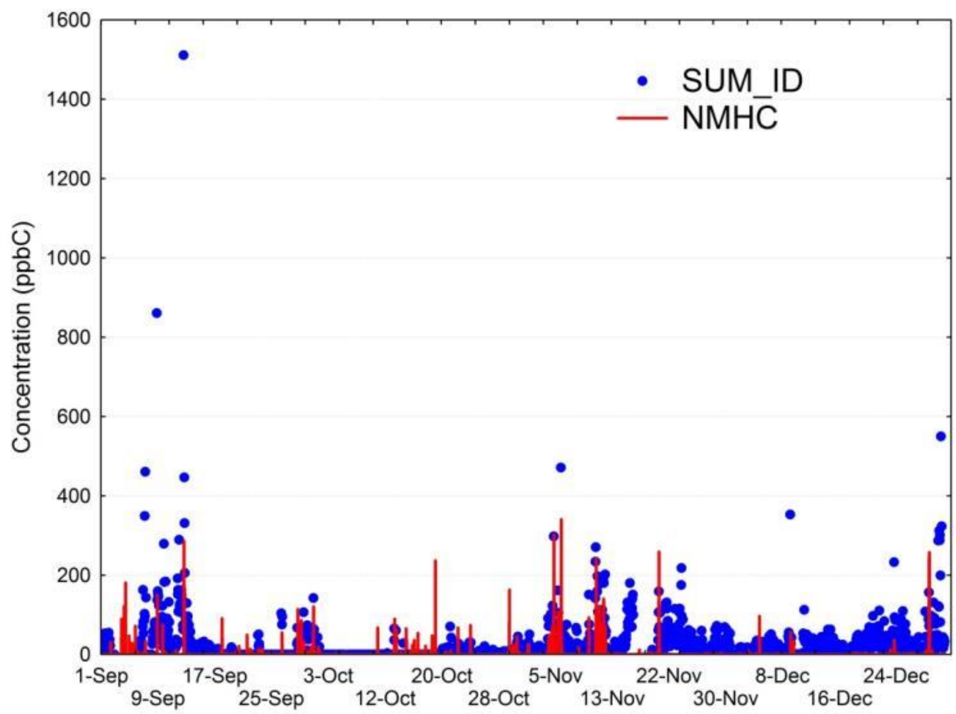


Figure 22: Comparison of hourly NMHC (ppbC) and PFGC sum of species (ppbC) at AMS#104 for Sep. – Dec. 2013.



Summary statistics for carbonyl sulphide and carbon disulphide from the SCD measurements at Bertha Ganter are provided in Tables 19 (values below detection were set to zero). The other target species: 2-methyl thiophene, 3-methyl thiophene, 2-ethyl thiophene, 2,5-dimethyl thiophene and 2,4-dimethyl thiophene were never found above detection during the year. No values above detection for carbonyl sulphide, carbon disulphide or the thiophenes were recorded at the AMS#104 site. A plot of carbonyl sulphide and carbon disulphide concentrations by hour for June to December, 2013 for Bertha Ganter is provided in Figure 23. The species were not detected until the change in instruments in late August.

In Figure 24 the carbonyl sulphide and carbon disulphide data from Bertha Ganter are plotted along with hourly TRS concentrations. As noted in the VOCTEC annual report there are periods where COS and CS_2 concentrations are much higher than TRS (primarily early in September). These species should be detected by TRS instruments but their conversion efficiency is not known at this time.

As shown in Table 5 COS plus CS_2 are estimated to represent almost 50% of TRS emissions from Syncrude and Suncor. The co-location of the AMS#104 site with the Mildred Lake site allows hourly TRS and H_2S data to be compared as shown in Figure 25. On average the H_2S values were 83% of TRS and a similar ratio was measured during peak periods also. This suggests again that the TRS instrument may not be responding to COS and CS_2.

Table 19: Carbonyl sulphide and carbon disulphide frequency of detection and summary statistics (ppb) – all measurements at Bertha Ganter (total of 3,194 reported measurements).

Compound	**Frequency of Detection**	**95^{th} Percentile**	**Max.**	**Mean**	**Std. Dev.**	**Median**
Carbonyl sulphide	47%	1.1	21.9	0.3	1.0	0.00
Carbon disulphide	44%	1.2	6.9	0.2	0.6	0.00

Figure 23: Hourly Variation in carbonyl sulphide (COS) and carbon disulphide (CS_2) (ppb) from SCD at Bertha Ganter – 2013.

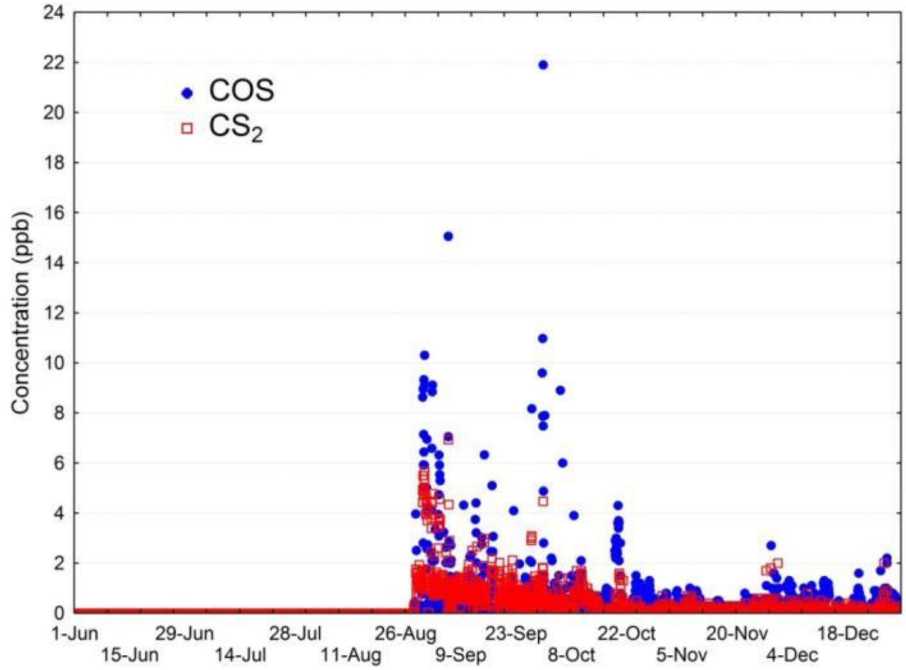


Figure 24: Hourly Variation in carbonyl sulphide (COS), carbon disulphide (CS_2) and TRS (ppb) at Bertha Ganter – 2013.

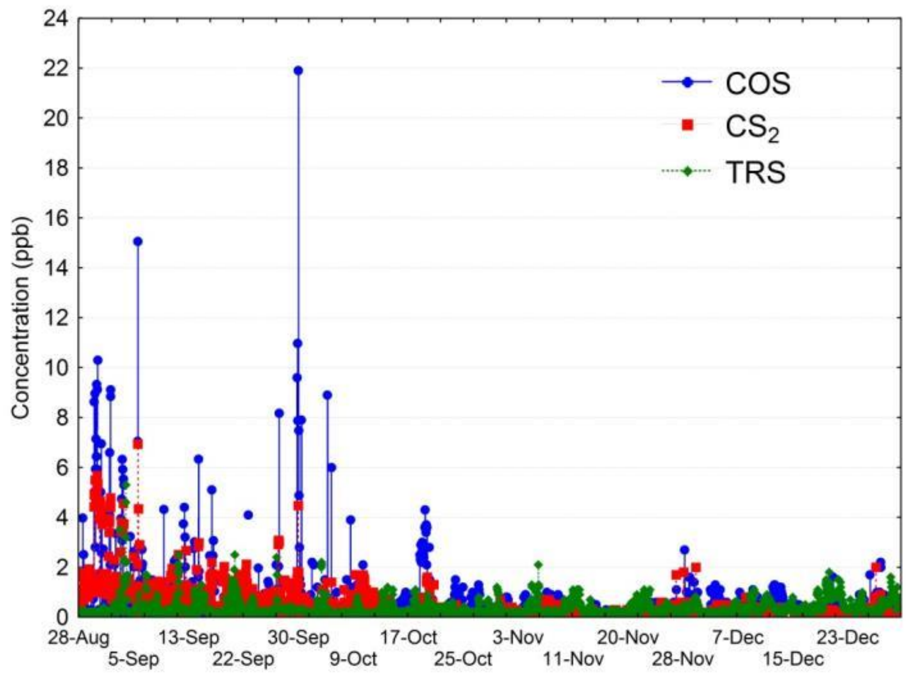
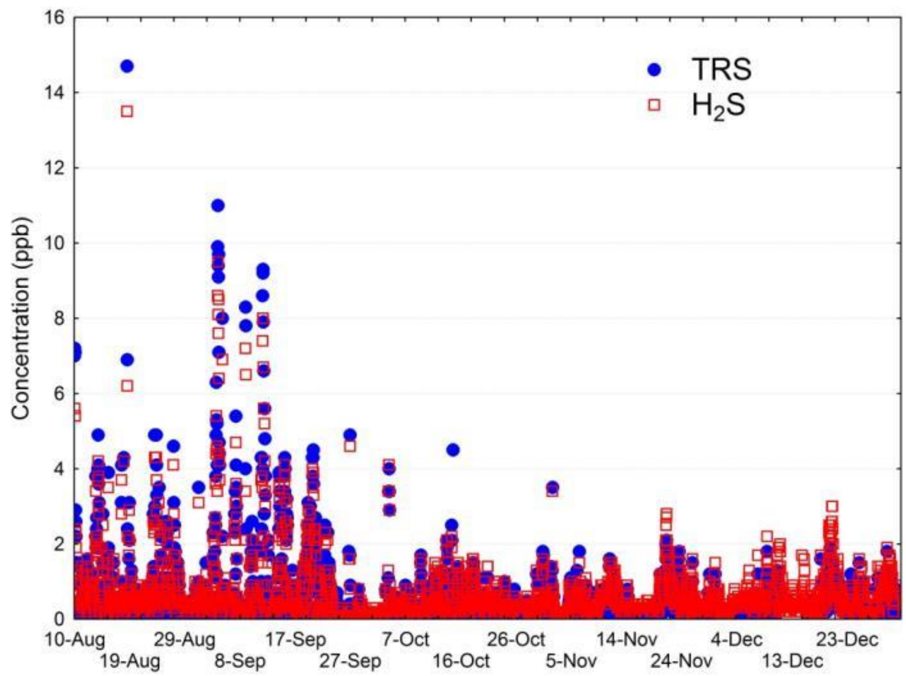


Figure 25: Hourly Variation in TRS (AMS#104) and H_2S (Mildred Lake) for August – December, 2013.



4.6 Canister VOC and RSC data

Twenty-four hour canister samples were also collected at a number of the sites (see Table 8) and analyzed for VOC and RSC by gas chromatography/mass spectrometry. For the Bertha Ganter site measured RSC species and summary statistics for 2013 are provided in Table 20 and measured VOC and summary statistics are provided in Table 21. Because detection limits (DLs) were provided with each sample, the averages have been calculated by substituting 0.5 * DL when the value was below DL. Detection levels were typically 0.03 ppb for VOC and 1 ppb for RSC's.

Environment Canada also collects VOC canister samples at Fort McKay South (AMS#13) and measures some VOC species not measured in the WBEA program that are of potential interest. Summary statistics for these species for 2013 are provided in Table 22. An additional VOC site was operated in Fort McKay from August 29 to December 31, 2013 as part of the Environment Canada field study. The location of this site is shown in Figure 26 and summary statistics for selected VOC are provided in Table 23.

A comparison of mean and maximum hydrogen sulphide, carbonyl sulphide and carbon disulphide concentrations from all canister sites is provided in Figure 27. There were few detectable concentrations of the other sulphur species (mercaptans, sulphides and thiophenes) at any of the sites. At AMS#9 tert-butyl mercaptan was detected in 1 sample and dimethyl disulphide was detected in 2 samples.

Carbonyl sulphide was the most frequently reported RSC in the canister results. Carbonyl sulphide is the most abundant sulfur compound naturally present in the atmosphere because it is emitted from oceans, volcanoes and deep sea vents. It is a significant compound in the global sulfur cycle and its reported background level in the atmosphere is 0.5±0.05 ppb (Kettle, 2002).

A comparison of mean and maximum concentrations of some selected VOC (pentane, hexane, benzene and toluene) is provided in Figure 28 for all canister sites. Mean concentrations of benzene ranged from 0.1 to 0.3 ppb across the sites with the highest mean recorded at AMS#15. Mean toluene concentrations showed more variability ranging from 0.1 ppb at AMS#9 to 3 ppb at AMS#13. Mean hexane concentrations ranged from 0.03 ppb at AMS#7 to 1.1 ppb at AMS#14.

Since some of the same species are reported by both the PFGC and the canisters, a comparison of calculated 24 h average PFGC concentrations (at least 12 samples required for the day) for days with canister measurements was made for Bertha Ganter and the results are shown in Figure 29 for selected VOC and for carbonyl sulphide and carbon disulphide in Figure 30. The comparisons are quite mixed with suggestions that both the canister and PFGC results are uncertain during some periods of the data record.

Table 20: RSC species and Reported 24 h Concentrations (ppb) in Canister Samples at Bertha Ganter for 2013 (a total of 63 samples - detection limit was 1 ppb).

Compound	% Detect	95th Percentile	Max.	Mean	Std. Dev.	Median
Hydrogen sulphide	5%	0.0	0.7	0.0	0.1	0.0
Carbonyl sulphide	63%	2.0	2.0	0.6	0.6	0.8
Carbon disulphide	41%	0.6	1.0	0.2	0.2	0.0
Methyl mercaptan	0%					
Ethyl mercaptan	0%					
Dimethyl sulphide	0%					
Isopropyl mercaptan	0%					
tert-Butyl mercaptan	0%					
Propyl mercaptan	0%					
Thiophene	0%					
Isobutyl mercaptan	0%					
sec-Butyl mercaptan	0%					
Ethyl sulphide	0%					
Butyl mercaptan	0%					
tert-Pentyl mercaptan	0%					
Dimethyl disulphide	0%					
2-methyl Thiophene	0%					
3-methyl Thiophene	0%					
Pentyl mercaptan	0%					
2-ethyl Thiophene	0%					
Allyl sulphide	0%					
2,5-dimethyl Thiophene	0%					

Table 21: VOC species and Reported 24 h Concentrations (ppb) in Canister Samples at Bertha Ganter for 2013 (a total of 63 samples - detection limit was 0.03 ppb).

Compound	% Detect	95th Percentile	Max.	Mean	Std. Dev.	Median
Formaldehyde	0%					
Isobutane	54%	1.1	2.3	0.3	0.4	0.1
1-Butene	6%	0.2	1.5	0.1	0.3	0.0
Acetaldehyde	48%	12.5	15.4	3.2	4.3	0.0
Butane	54%	3.5	6.6	0.8	1.3	0.3
Methanol	52%	15.7	25.1	3.4	5.1	1.0
trans-2-Butene	2%	0.0	0.2	0.0	0.0	0.0
cis-2-Butene	0%					
3-Methyl-1-butene	0%					
Isopentane	78%	2.5	10.0	0.9	1.6	0.4
1-Pentene	0%					
Acetone	71%	4.9	5.9	1.8	1.7	1.2
Pentane	43%	3.1	11.7	0.8	1.7	0.0
Isoprene	27%	1.4	2.7	0.2	0.6	0.0
trans-2-Pentene	0%					
cis-2-Pentene	0%					
2-Methyl-2-butene	0%					
2,2-Dimethylbutane	35%	0.2	0.2	0.0	0.1	0.0
Cyclopentene	0%					
4-Methyl-1-pentene	0%					
2,3-Dimethylbutane	37%	0.3	0.5	0.1	0.1	0.0
Cyclopentane	17%	0.3	0.3	0.0	0.1	0.0
2-Methylpentane	52%	0.8	1.2	0.2	0.3	0.1
3-Methylpentane	51%	0.4	0.9	0.1	0.2	0.0
2-Methyl-1-pentene	0%					
Hexane	49%	0.5	0.7	0.1	0.2	0.0
Methyl ethyl ketone	0%					
cis-2-Hexene	0%					
trans-2-Hexene	0%					
2,4-Dimethylpentane	0%					
Methylcyclopentane	27%	0.2	0.3	0.0	0.1	0.0
Cyclohexane	30%	0.4	3.4	0.1	0.5	0.0
Benzene	73%	0.4	0.6	0.1	0.1	0.1
2-Methylhexane	16%	0.1	0.2	0.0	0.0	0.0
2,3-Dimethylpentane	6%	0.1	0.1	0.0	0.0	0.0
3-Methylhexane	29%	0.2	0.3	0.0	0.1	0.0
2,2,4-Trimethylpentane	0%					
Heptane	52%	0.7	1.1	0.2	0.2	0.1
Methylcyclohexane	38%	0.4	0.7	0.1	0.2	0.0
Methyl isobutyl ketone	0%					
2,3,4-Trimethylpentane	2%	0.0	0.0	0.0	0.0	0.0
2-Methylheptane	22%	0.3	0.8	0.0	0.1	0.0
Toluene	84%	4.6	53.9	1.8	7.8	0.2

3-Methylheptane	11%	0.1	0.2	0.0	0.0	0.0
Octane	25%	0.7	1.9	0.1	0.3	0.0

Table 21: cont'd

Compound	% Detect	95th Percentile	Max.	Mean	Std. Dev.	Median
Ethyl benzene	32%	0.3	1.2	0.1	0.2	0.0
m,p-Xylene	56%	1.3	2.7	0.2	0.5	0.1
Styrene	3%	0.0	0.0	0.0	0.0	0.0
Nonane	13%	0.1	0.4	0.0	0.1	0.0
o-Xylene	38%	0.6	1.2	0.1	0.2	0.0
Isopropylbenzene	5%	0.0	0.2	0.0	0.0	0.0
alpha Pinene	60%	0.5	1.2	0.1	0.2	0.1
n-Propylbenzene	2%	0.0	0.4	0.0	0.1	0.0
1,3,5-Trimethylbenzene	2%	0.0	0.1	0.0	0.0	0.0
beta Pinene	0%					
Decane	10%	0.1	0.1	0.0	0.0	0.0
1,2,4-Trimethylbenzene	11%	0.0	0.4	0.0	0.1	0.0
Undecane	2%	0.0	0.0	0.0	0.0	0.0
Dodecane	0%					
Naphthalene	11%	0.4	5.1	0.1	0.7	0.0

Table 22: Selected VOC Species and reported 24 h Concentrations (ppb) in Canister Samples at AMS#13 for 2013 from Environment Canada sampling (a total of 58 samples).

Compound	Frequency of Detection	Max.	Mean	Std. Dev.	Median
Ethylene	100%	2.46	0.54	0.45	0.41
1,3-Butadiene	100%	0.06	0.01	0.01	0.01
Benzene	100%	0.35	0.11	0.07	0.09
Chloromethane	100%	0.74	0.56	0.06	0.56
Dichloromethane	100%	0.32	0.09	0.04	0.08
1,2-Dichloroethane	100%	0.03	0.02	0.00	0.02
Carbon tetrachloride	100%	0.10	0.08	0.01	0.08
Trichloroethylene	96%	0.01	0.00	0.00	0.00
Tetrachloroethylene	100%	0.02	0.01	0.00	0.01
1,4-Dichlorobenzene	100%	0.04	0.00	0.01	0.00

Figure 26: Location of the Environment Canada CAM 1 Special Study Site in Fort McKay.

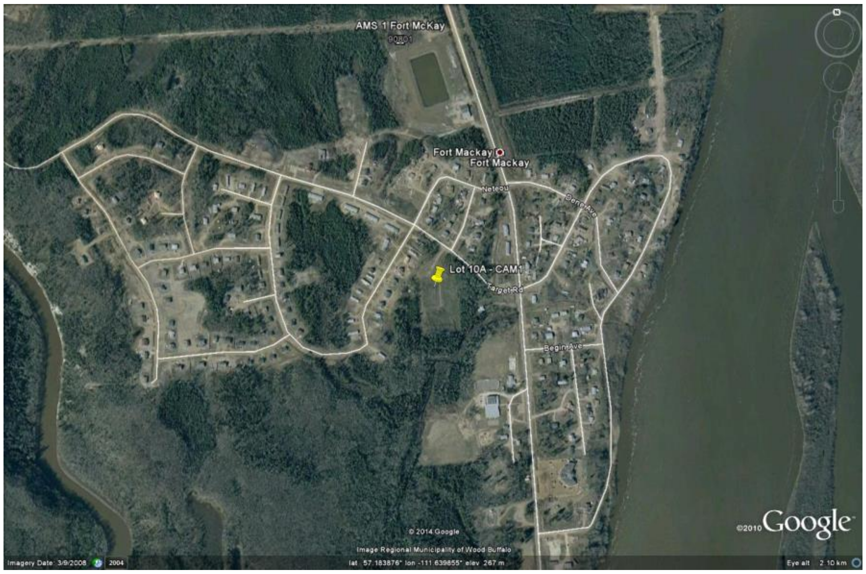


Table 23: Selected VOC Species and reported 24 h Concentrations (ppb) in Canister Samples at CAM1 for Aug-Dec 2013 from Environment Canada sampling (a total of 44 samples).

Compound	Frequency of Detection	Max.	Mean	Std. Dev.	Median
Ethylene	100%	3.40	0.83	0.77	0.52
1,3-Butadiene	100%	0.08	0.02	0.02	0.01
Benzene	100%	0.41	0.12	0.09	0.10
Chloromethane	100%	0.65	0.55	0.04	0.55
Dichloromethane	100%	0.09	0.07	0.01	0.07
1,2-Dichloroethane	100%	0.03	0.01	0.00	0.01
Carbon tetrachloride	100%	0.09	0.07	0.02	0.07
Trichloroethylene	100%	0.01	0.00	0.00	0.00
Tetrachloroethylene	100%	0.05	0.01	0.01	0.01
1,4-Dichlorobenzene	100%	0.02	0.00	0.00	0.00

Figure 27: Minimum, mean and maximum hydrogen sulphide, carbonyl sulphide and carbon disulphide concentrations (ppb) from all canister sites – 2013.

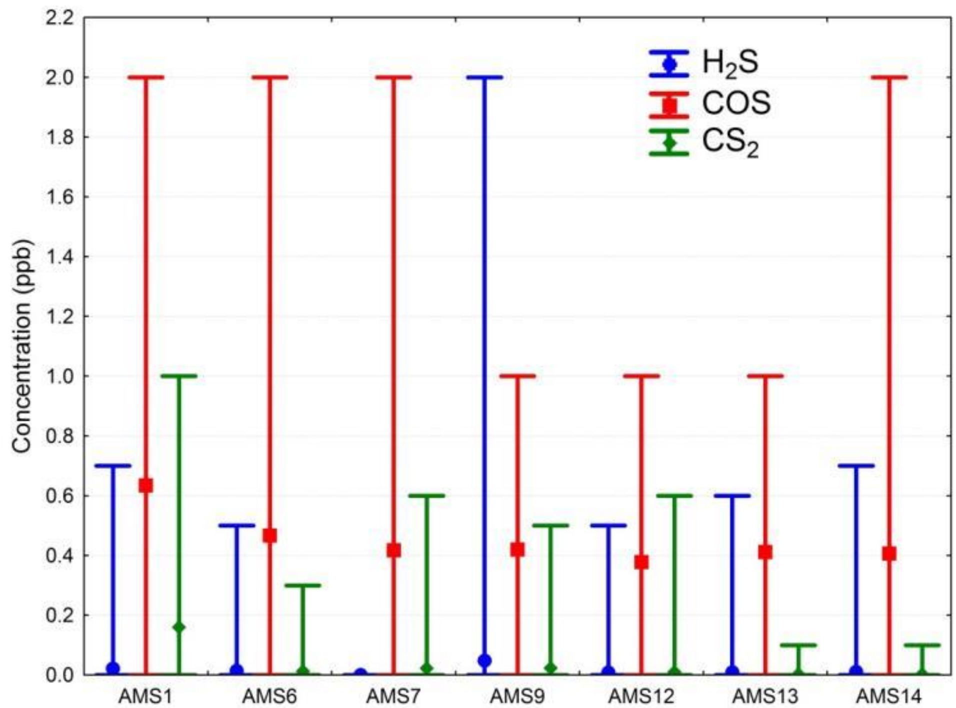


Figure 28: Minimum, mean and maximum concentrations (ppb) of selected VOC from all canister sites – 2013.

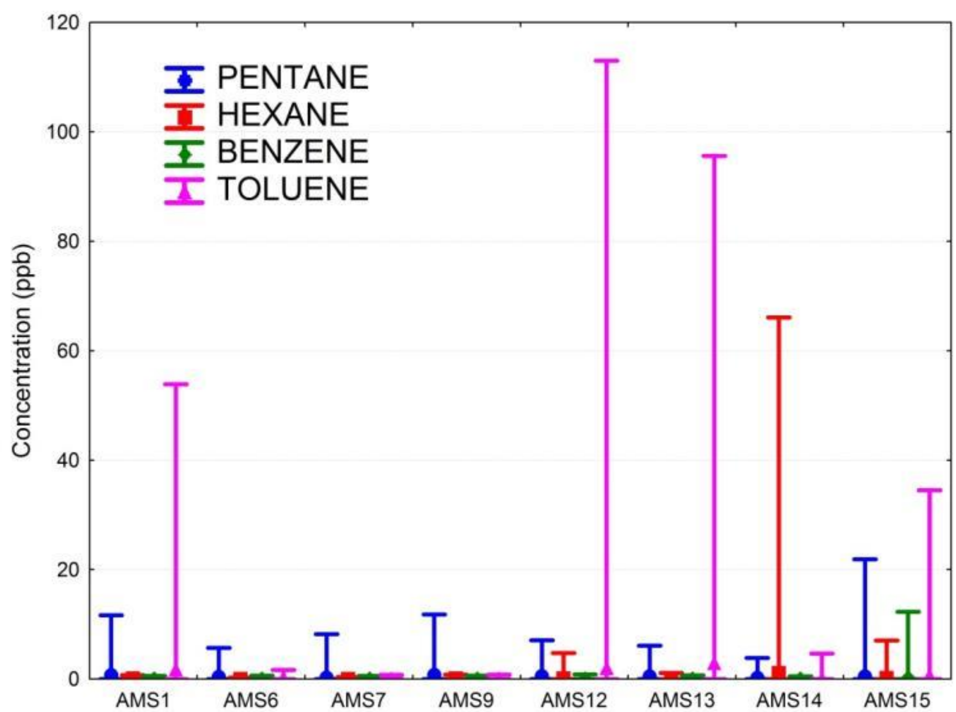


Figure 29: Comparison of 24h canister VOC with PFGC 24-h averages (ppbC) for selected species at Bertha Ganter for all days with coincident measurements in 2013 (Note: Different scales used for each plot).

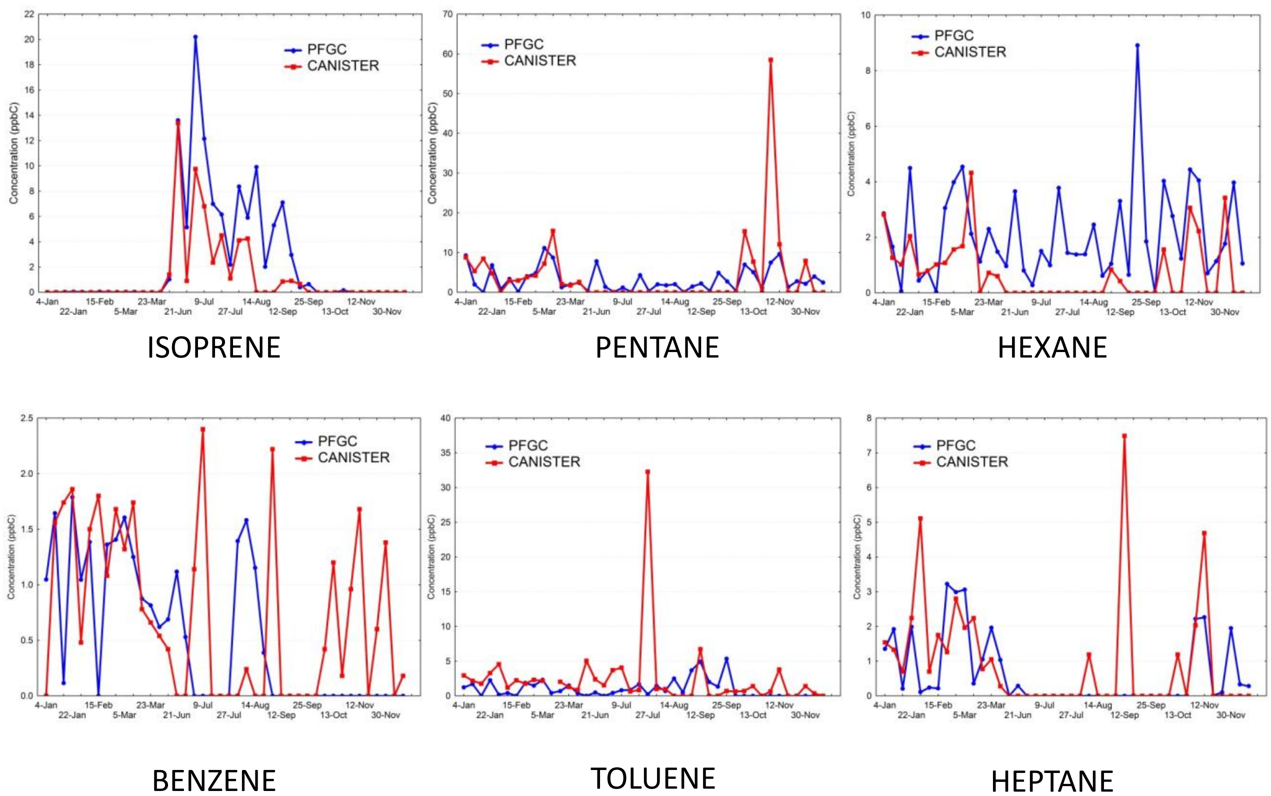
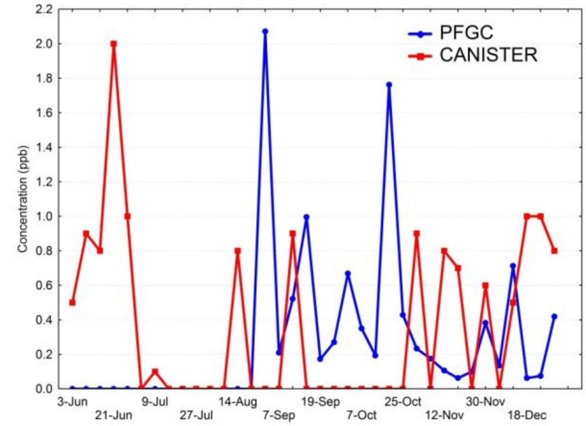
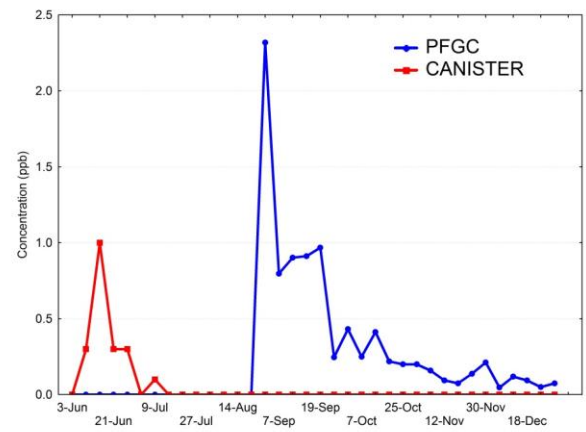


Figure 30: Comparison of 24h canister carbonyl sulphide and carbon disulphide with PFGC 24-h averages (ppb) at Bertha Ganter for all days with coincident measurements in 2013 (Note: Different scales used for each plot).



CARBONYL SULPHIDE



CARBON DISULPHIDE

4.7 Odour Complaints

4.7.1 Community Odour Monitoring Project

In 2013 HEMP began a community-based odour monitoring project. For this initiative, WBEA recruited volunteer participants from the community of Fort McMurray. The main objective of the Community Odour Monitoring Project (COMP) is to involve the community in identifying and monitoring odours in the air in order to determine the impact on residents. The project was launched in February and training for the volunteers was conducted in May 2013. Odour observations started in June 2013 and will continue until the end of May 2014. The odour committee is based on the participation of volunteers from the region that supply specific information about the various odours they perceive during their day-to-day activities. They provide observations through a designated website, by mail or through a cell phone application. The committee meets on a quarterly basis to review the results of their observations. There are currently 35 participants registered as volunteers (HEMP, 2014).

All recorded observations for the months of June through December were received in an electronic file which included the parameters noted in Table 24. The recorded latitude and longitude of each complaint were used to identify the nearest WBEA monitoring site (Patricia McInnes or Athabasca Valley) and the distance from the participant to the monitoring site. There were 108 observations recorded between June 1 and December 31, 2013 (none in December). Some of these observations spanned multiple hours and the total hours with potential odour complaints amounted to 118 over the 6 month period. Of the approximately 35 participants in the program, fifteen reported odours between June and August and seven between September and December. It's not clear if all participants were actually active in the program.

As shown in Table 24 for each observation, the participant can report one or more types of odour perceived. For the overall period of June to December the percentage of odour types reported is provided in Table 25. The participants also reported on intensity of odour (weak, medium, high, very high) and on odour appreciation (neutral, unpleasant, very unpleasant). Approximately half of the observations identified the odour as asphalt/tar or hydrocarbon/solvent.

Since odour observations are provided by volunteers during their day to day activities, observations are more likely to coincide with daytime and evening than nighttime and also reflect the time for which the volunteer remains at the location of the odour perceived (HEMP, 2014). Time spent outdoors is very seasonal. The distributions of complaints by hour of day and by month are shown in Figure 31. Specific odour episodes will be discussed and analyzed further in Section 5.2.

A wind rose has been constructed for all complaint hours as shown in Figure 32.

Table 24: Information Contained in Odour Complaint Logs for COMP.

Parameters Recorded	
Date	Q1. Current Physical State of Respondent
User Name	Q2. Weather Condition
Time From	Q3. Wind Condition
Time to	Q4. Type of Odour Perceived
Comments	Q5. Intensity of Odour Perceived
Source: Website/e-mail	Q6. Odour Appreciation
Latitude	
Longitude	

Table 25: Percentage Distribution of Types of Odours Reported in Odour Complaint Logs for COMP for June to December, 2013.

Type of Odour Perceived	Percent
Asphalt / tar	29
Fuel/solvent/hydrocarbon	25
Burnt/smoke	19
Fecal/septic/sewage	13
Ammonia/Cat's pee	7
Other	5
Rotten Egg	2

Figure 31: Number of Complaint Hours by COMP participants by Time of Day and by Month for 2013.

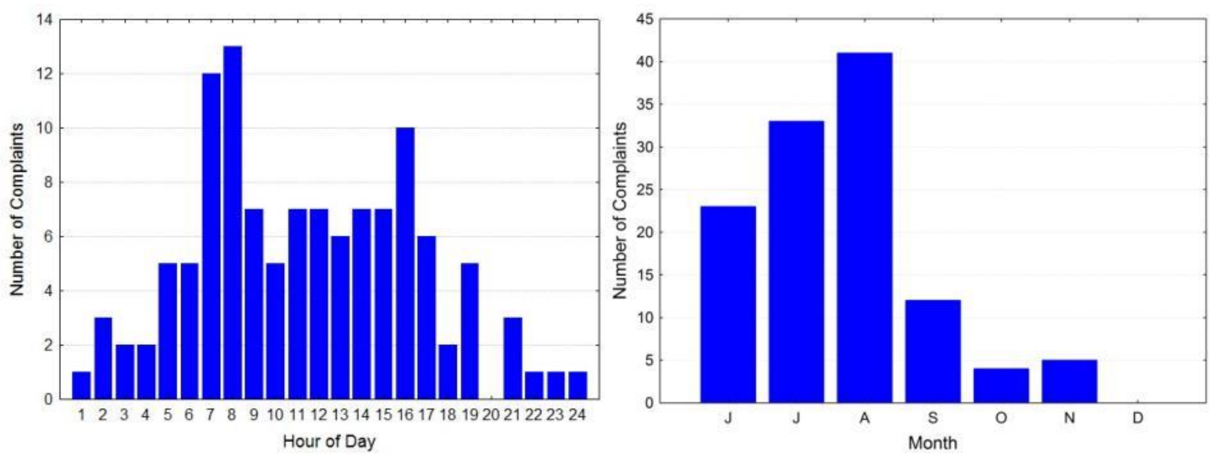
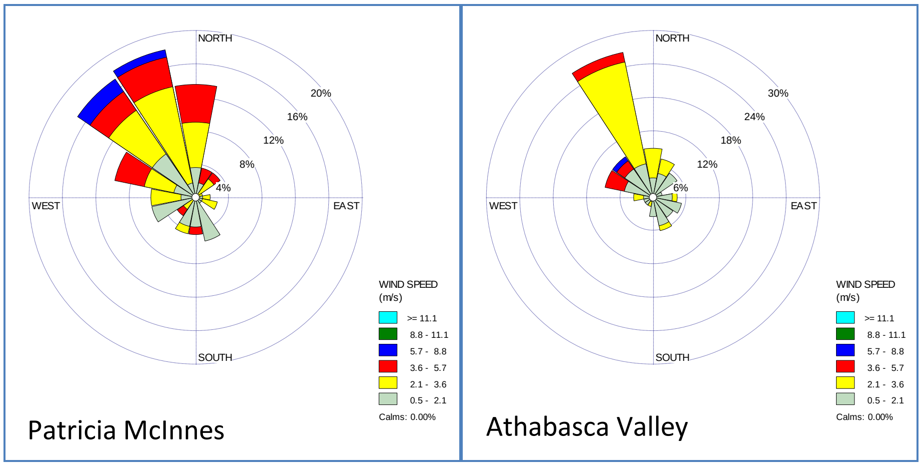


Figure 32: Wind Roses for COMP Complaint Hours at Patricia McInnes and Athabasca Valley monitoring sites.



4.7.2 Alberta Ministry of Environment Hotline

The quantification of offensive odour is often inherently difficult because it seeks to relate concentrations of chemical species in air to human sensory perception. For the most part, members of the public will not complain about a specific compound but of a generally foul odour.

The Alberta Ministry of Environment and Sustainable Resource Development operates a 24-hour hotline where residents can call and report any odour complaints. Logs of complaints dealing with odours in the Fort McMurray, Fort McKay and Anzac area were obtained in hard copy form and all details were entered into a spreadsheet and stored by date and hour. These were then entered into the integrated data base. There were a total of 93 unique complaints recorded on 66 separate dates with the location of complaints shown in Table 26. Only two of the Alberta hotline complaint days in Fort McMurray coincided with COMP complaint days. The log also contained a description of odour but responses were not standardized as in COMP. Table 27 contains the percentage of odour types reported. A breakdown of complaints by hour and month is provided in Figure 33. Wind roses for each community and for the other cases for complaint hours are shown in Figure 34.

For comparison, in 2012 there were a total of 76 complaints to the Alberta hotline recorded on 53 separate dates. An analysis of individual odour complaints in the communities and especially of episode days for which there were multiple complaints will be provided in Section 5.2.

Table 26: Number of Complaints to Alberta Hotline by Location in 2013.

Location	Number
Fort McKay	26
Fort McMurray	30
Anzac	12
Other (mostly Hwy 63)	25

Table 27: Percentage Distribution of Types of Odours Reported in Alberta Environment Hotline Odour Complaints for January to December, 2013.

Type of Odour Perceived	Percent
Hydrocarbon/oil	35
Sulphur/sulphur + hydrocarbon	22
Hydrogen sulphide/Rotten Egg	11
Ammonia/Cat's pee	9
Asphalt / tar	3
Other/not specified	20

Figure 33: Number of Complaints to Alberta Hotline by Time of Day and by Month for 2013.

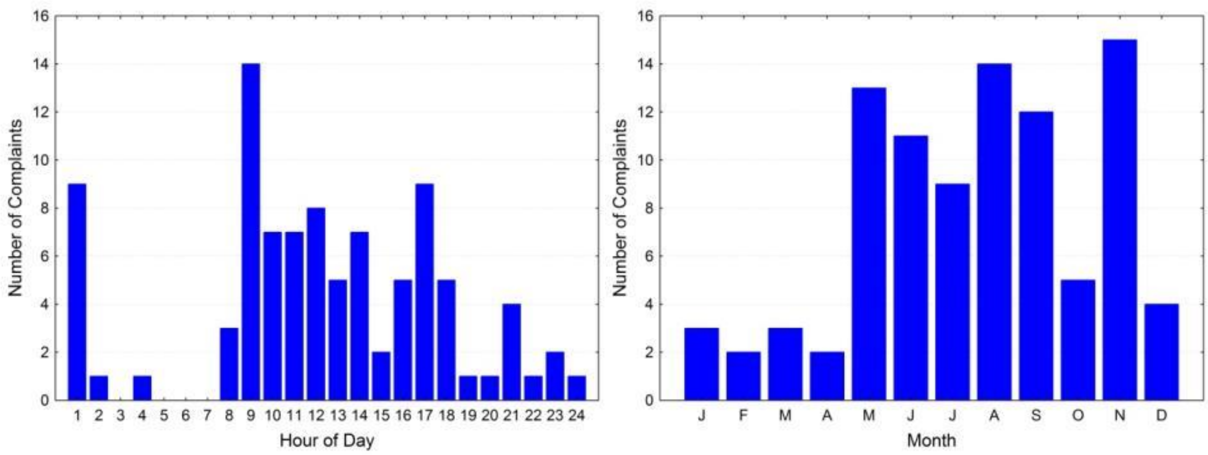
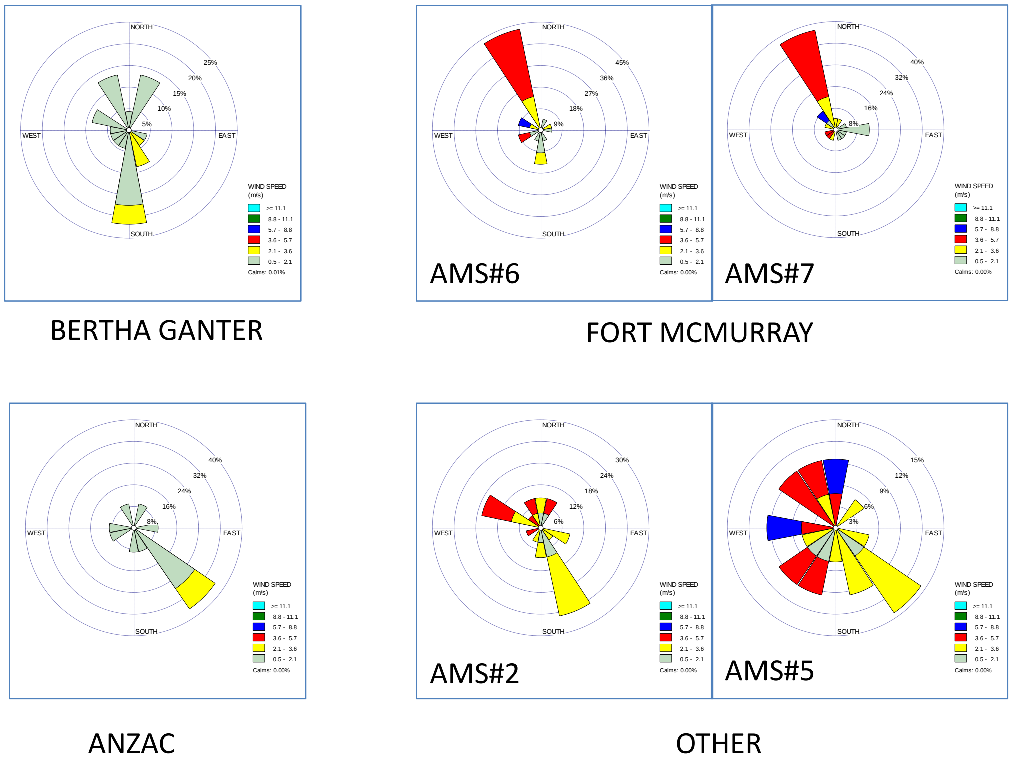


Figure 34: Wind Rose for Complaint Hours for Bertha Ganter, Fort McMurray (AMS#6 and AMS#7), Anzac and Other (AMS#2 and AMS#5) for Alberta Hotline Complaints 2013.



5 Data Analysis

5.1 Parameters by Wind Direction

5.1.1 TRS and H_2S by Concentration Value and Wind Direction

All community sites were characterized in terms of occurrences of TRS concentrations greater than 1.5, 3, 5 and 10 ppb for 2013 and the results are shown in Table 28. Although 10 ppb is the 1h Alberta ambient air quality objective for H_2S, previous work in Fort McKay had suggested that odour complaints could occur with TRS levels much lower than this value. For this report a lower threshold was used than in 2012 (1.5 ppb vs. 3 ppb) because TRS levels overall were much lower in 2013 than in 2012 (see Table 14). The results are further subdivided into occurrences by average wind direction (previous 6 hours) in Table 29.

A visual representation of occurrences of TRS values greater than 1.5, 3, 5 and 10 ppb are shown in Figures 35 to 38 for the community sites of Fort McKay Bertha Ganter, Fort McMurray Patricia McInnes, Fort McMurray Athabasca Valley and Anzac.

Figure 39 shows H_2S concentrations by wind direction for the Mannix site (which had the highest frequency of elevated H_2S) for the years 2012 and 2013 – note that the scale for this Figure is different (3, 5, 10 and 15 ppb) in order to be compatible with the 2012 plot. Figures for all the other monitoring sites for either TRS or H_2S are found in Appendix A. Figure 40 shows TRS/H_2S dose (the product of concentration times the frequency of wind direction) for all hours in 2013.

Table 28: Number of Hours with TRS Concentration Values greater than 1.5, 3, 5 and 10 ppb for Community Sites.

ID	SITE NAME	1.5 to 3 (ppb)	3 to 5 (ppb)	5 to 10 (ppb)	> 10 (ppb)	Sum
1	FORT MCKAY BERTHA GANTER	108	15	1	0	124
6	PATRICIA MCINNES	29	1	0	0	30
7	ATHABASCA VALLEY	27	1	0	0	28
14	ANZAC	83	13	10	0	106

Table 29: Count of Occurrences of TRS Concentrations by Average Wind Direction and Location.

SITE	TRS (ppb)	*	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
BERTHA GANTER	1.5-3	2	0	1	1	0	1	0	1	3	43	32	12	5	4	0	2	1
	3-5	0	0	0	0	0	0	0	0	0	5	9	1	0	0	0	0	0
	5-10	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	>10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PATRICIA MCINNES	1.5-3	1	10	4	2	0	1	1	0	0	0	0	0	0	0	1	5	4
	3-5	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	>10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ATHABASCA VALLEY	1.5-3	0	1	1	2	0	4	2	0	1	0	0	0	1	2	3	0	10
	3-5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	5-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	>10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANZAC	1.5-3	10	0	0	0	1	0	4	50	10	2	2	0	0	1	3	0	0
	3-5	1	0	0	0	0	0	2	7	1	0	1	0	0	0	0	1	0
	5-10	5	0	0	0	0	0	1	2	2	0	0	0	0	0	0	0	0
	>10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* Missing wind direction data

Figure 35: Counts of TRS Values greater than 1.5, 3, 5 and 10 ppb by Wind Direction at Fort McKay Bertha Ganter.

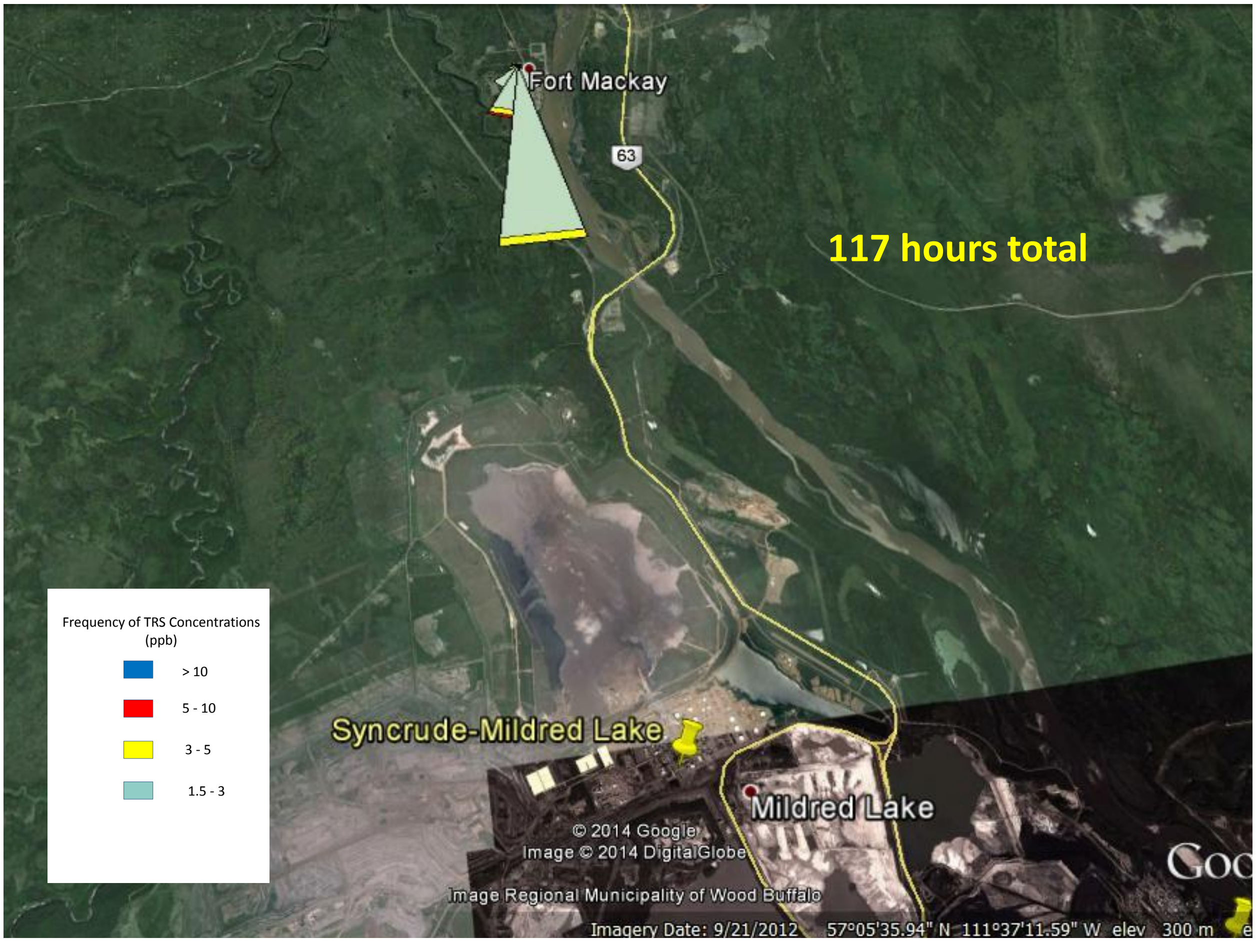


Figure 36: Counts of TRS Values greater than 1.5, 3, 5 and 10 ppb by Wind Direction at Fort McMurray Patricia McInnes.

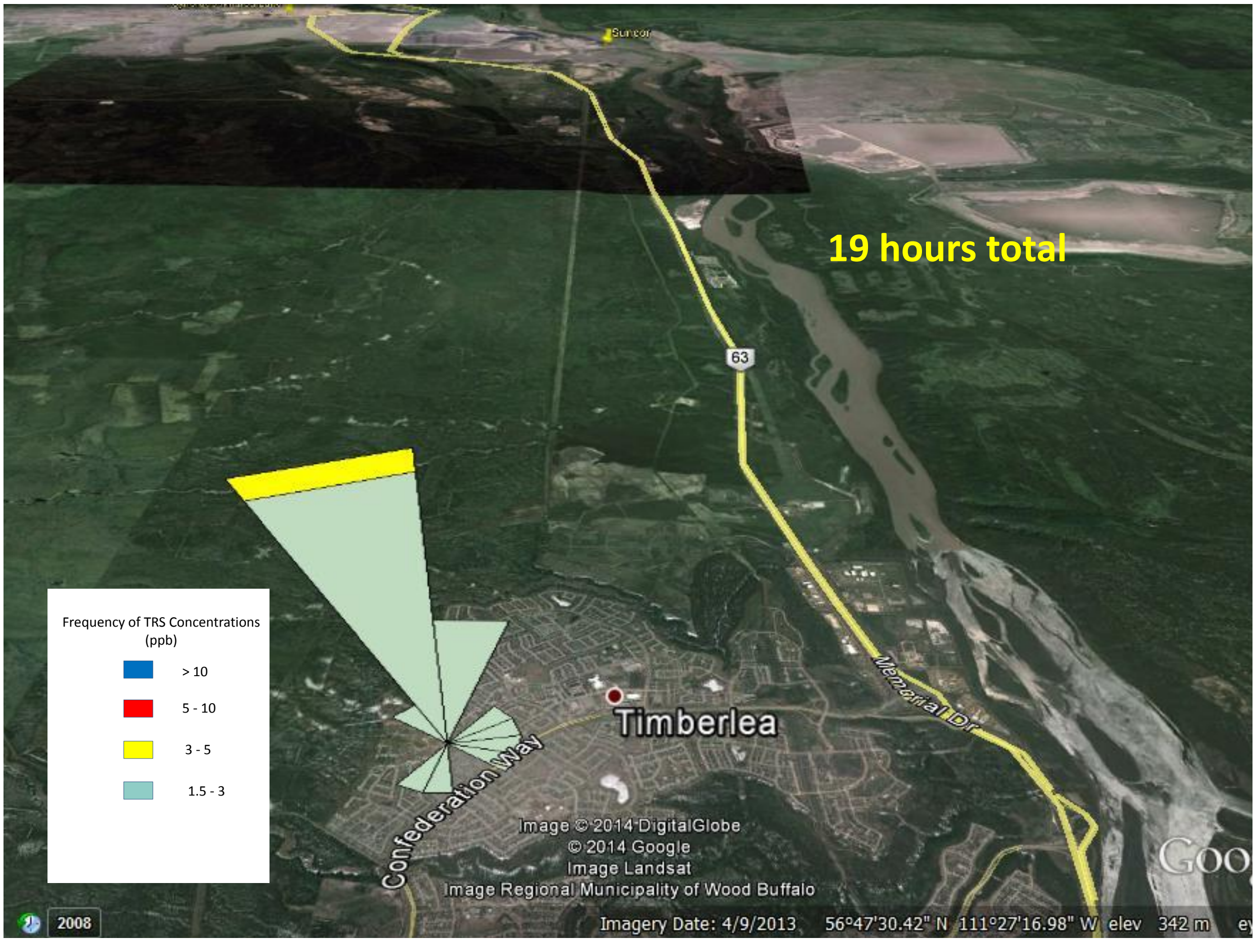


Figure 37: Counts of TRS Values greater than 1.5, 3, 5 and 10 ppb by Wind Direction at Fort McMurray Athabasca Valley.

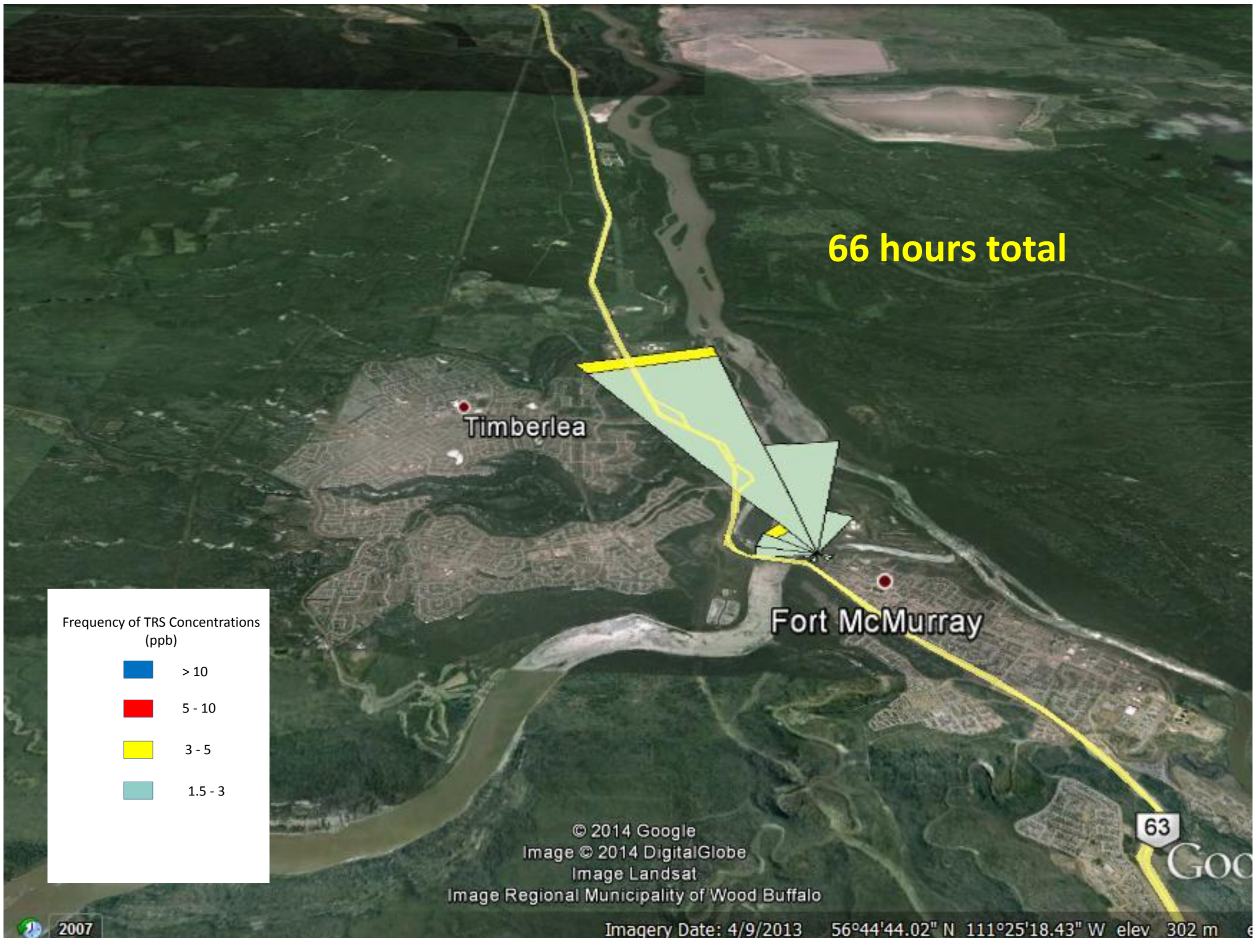


Figure 38: Frequency of TRS Values greater than 1.5, 3, 5 and 10 ppb at Anzac.

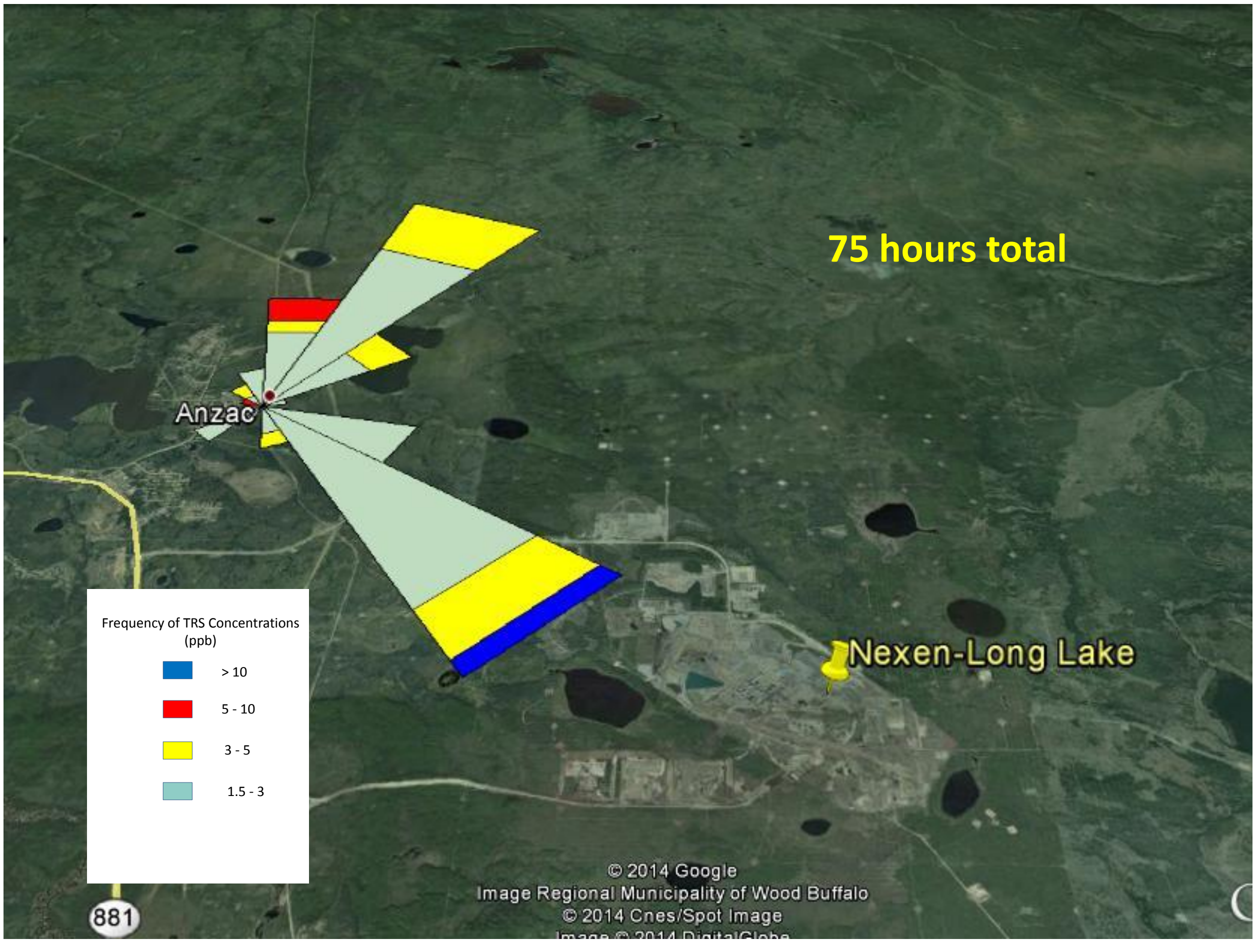


Figure 39: Counts of TRS Values greater than 3, 5, 10 and 15 ppb by Wind Direction at Mannix for 2012 and 2013.

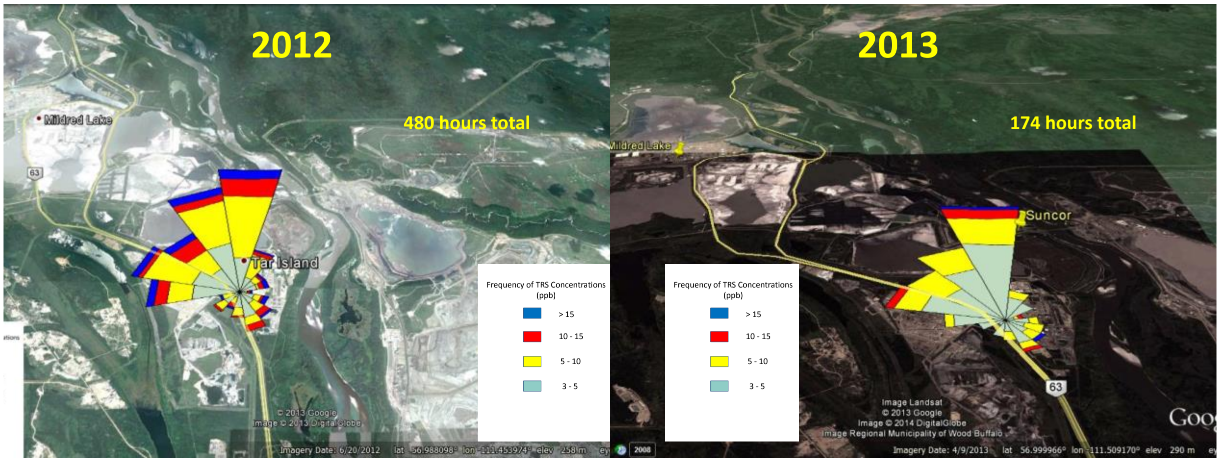
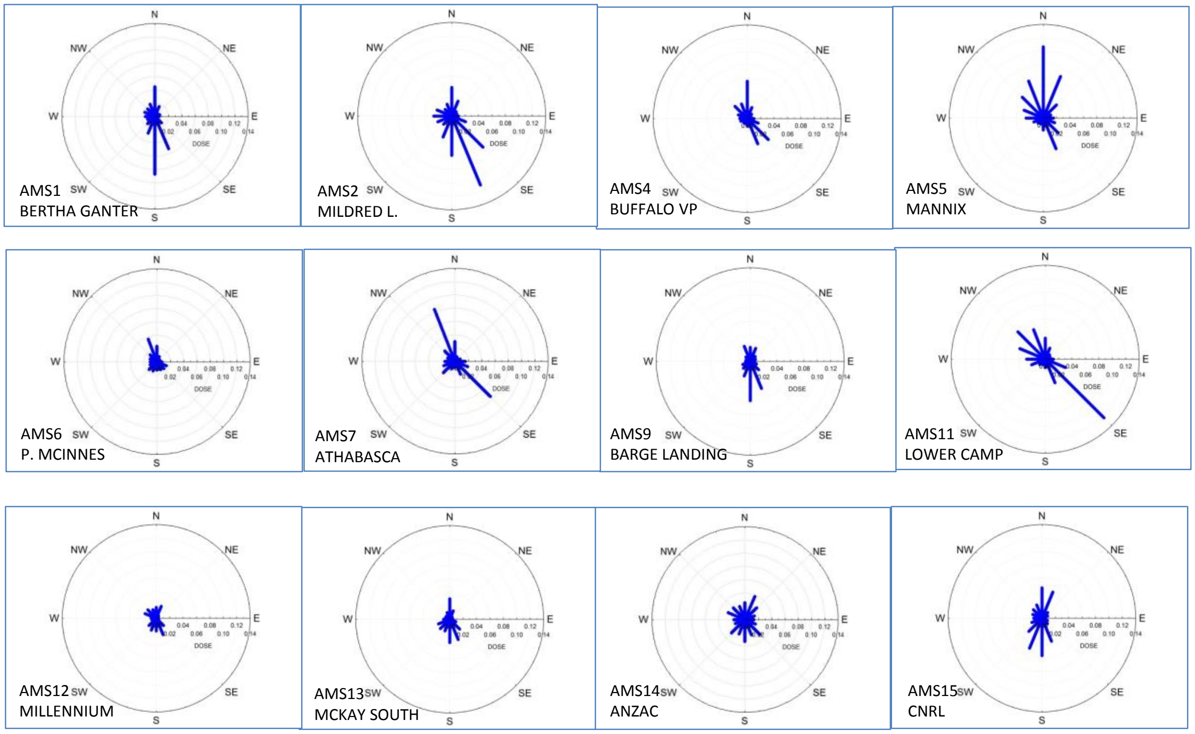


Figure 40: TRS/H_2S Dose (ppb) at WBEA Monitoring Sites for 2013 (All Hours).



5.1.2 SO_2, NMHC, derived NMHC, nitric oxide and SO_2 to TRS/H_2S Ratio by Wind Direction

A similar analysis of SO_2, NMHC (for community sites) and dNMHC (other sites) and nitric oxide dose is found in Figures 41 to 43. The ratio of mean SO_2 to TRS/H_2S Concentration by wind direction for each site is shown in Figure 44. Despite an NPRI estimated emission ratio of SO_2 to TRS of greater than 200 (molar basis) the ambient ratios were never higher than 20 for any specific wind direction at any site and more typically in the range of 2 to 5. This suggests that SO_2 emissions may be overestimated or that TRS emissions are underestimated.

Figure 41: SO_2 Dose (ppb) at WBEA Monitoring Sites for 2013 (All Hours).

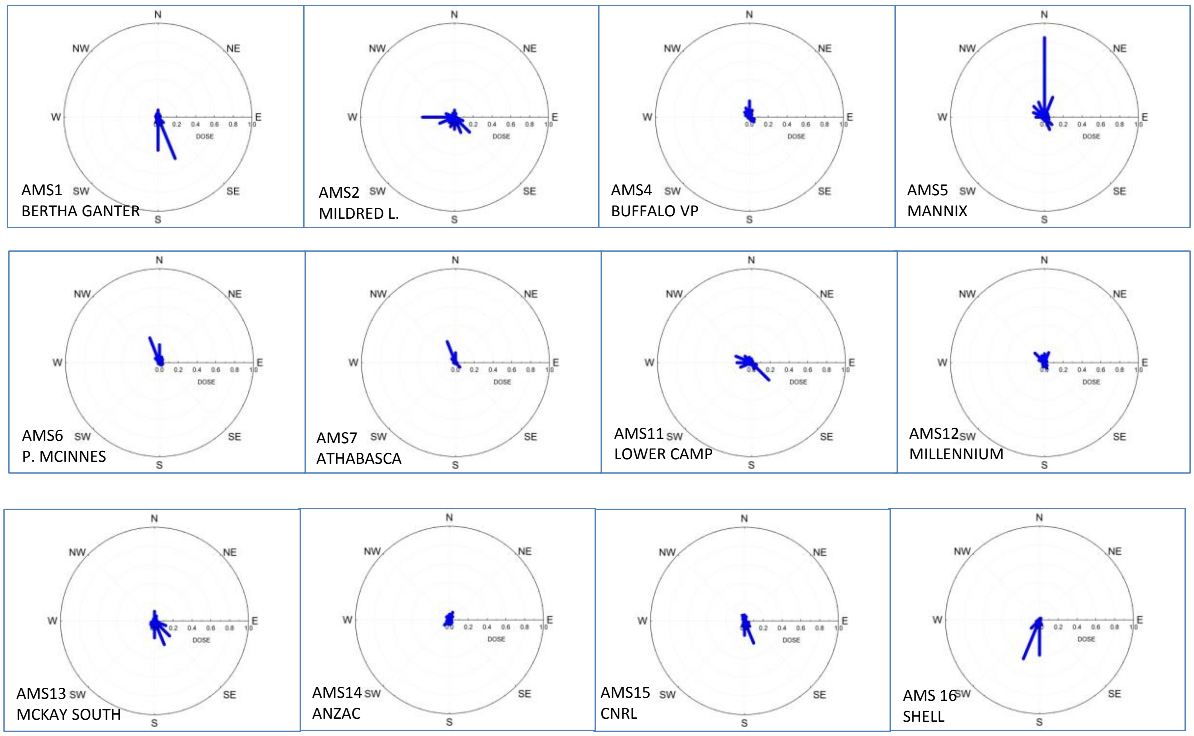


Figure 42: NMHC or dNMHC Dose (ppm) at WBEA Monitoring Sites for 2013 (All Hours).

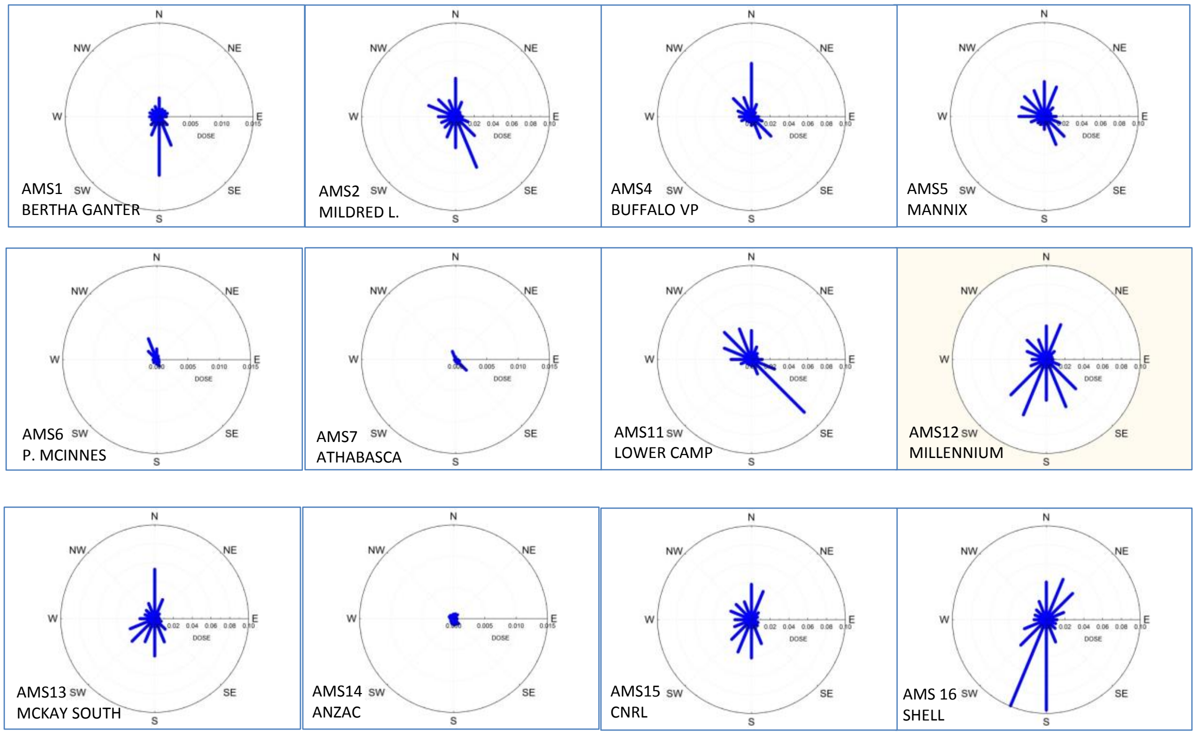


Figure 43: Nitric Oxide Dose (ppb) at WBEA Monitoring Sites for 2013 (All Hours).

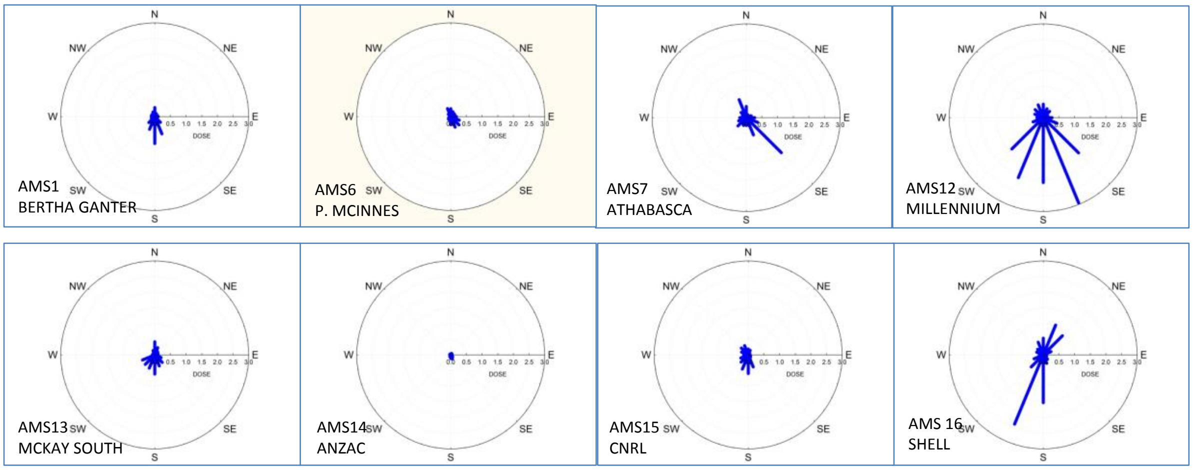
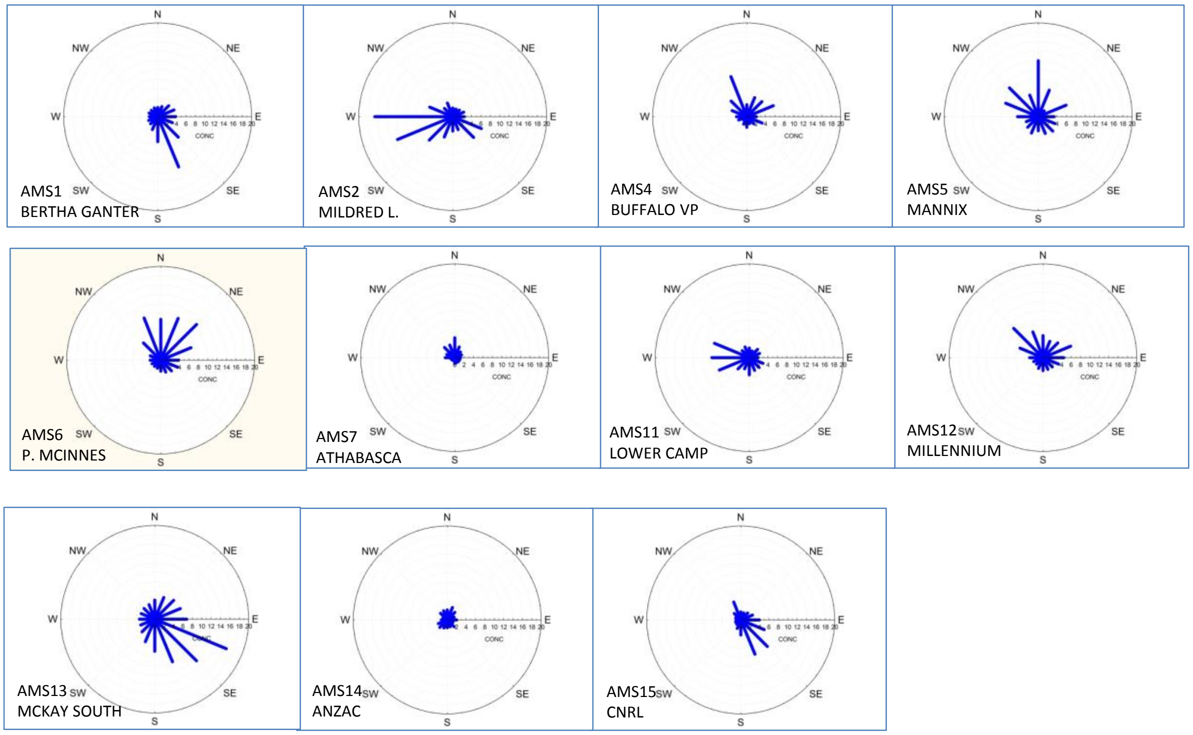


Figure 44: Ratio of Mean SO_2 to Mean TRS/H_2S by Wind Direction at WBEA Monitoring Sites for 2013 (All Hours).



5.1.3 PFGC and eNose Readings by Wind Direction

For the eNose system a graphical comparison of maximum odour units, DELTA and CV by wind direction are provided in Figure 45. The data was segregated based on discontinuities in the units output as shown in Figures 16 to 18. The data for March 27 to April 11 was not used at all and the three time periods examined were January 1 to May 31, June 1 to August 14 and August 15 to December 31. The amount of 'directionality' in the plots is quite variable with the DELTA plots tending to show the most variation with wind direction.

For the PFGC, the concentration of the sum of naphtha species by wind direction and the sum of aromatic species (benzene plus toluene) by wind direction are provided in Figure 46. Results are broken into two time periods: before and after replacement of the PFGC in August. After replacement, aromatics were not detected consistently but the naphtha plots show the same directionality for the entire year. COS and CS_2 began to be detected after the August replacement and concentration with wind direction for these parameters is shown in Figure 47.

Figure 45: Maximum eNose Reading (odour units), mean DELTA and mean CV at Bertha Ganter by wind direction for specified time periods (note different scales for different periods).

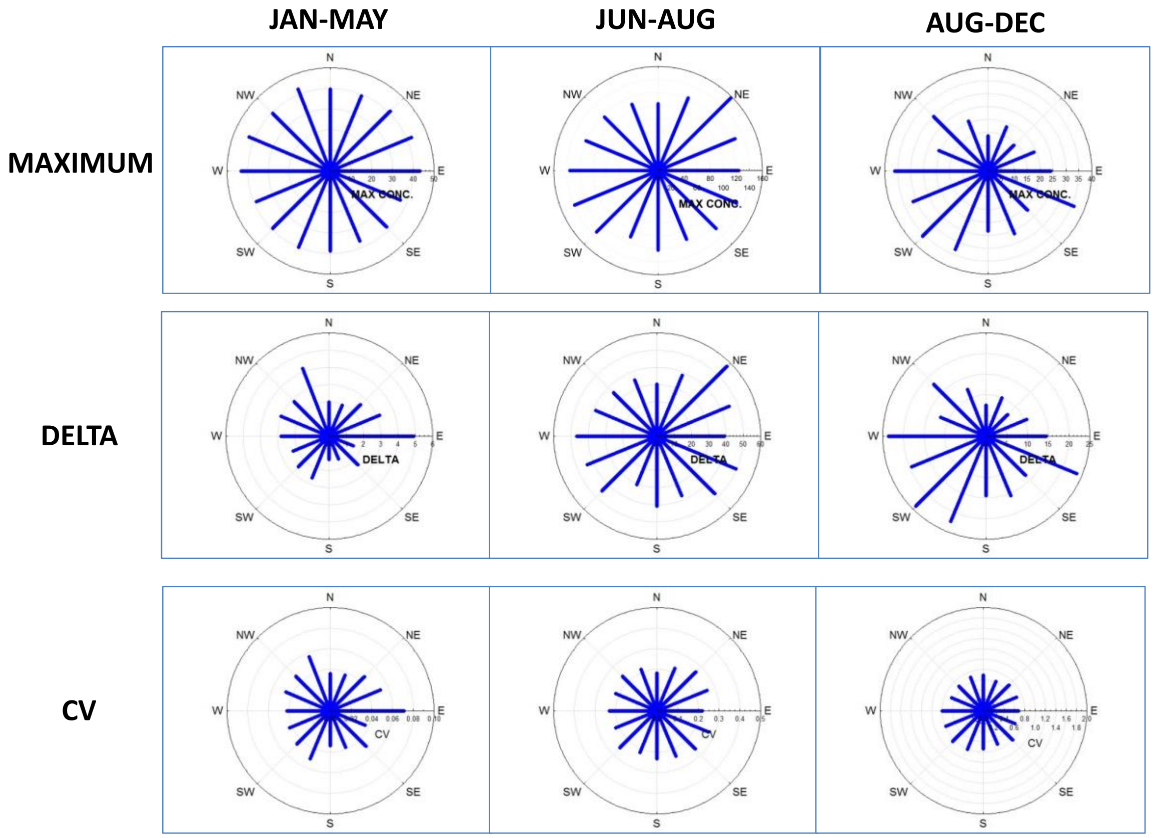


Figure 46: Mean Naphtha and Aromatics (ppbC) by wind direction at Bertha Ganter for specified time periods.

JAN-DEC **JAN-AUG**

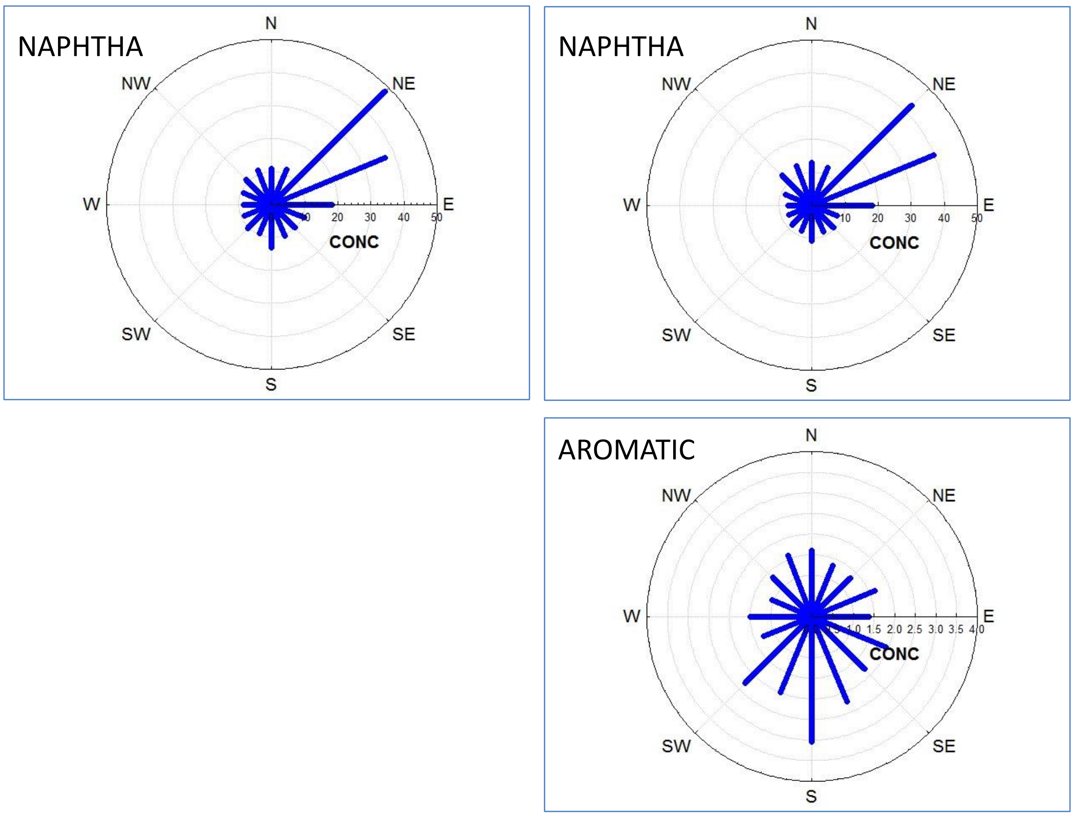
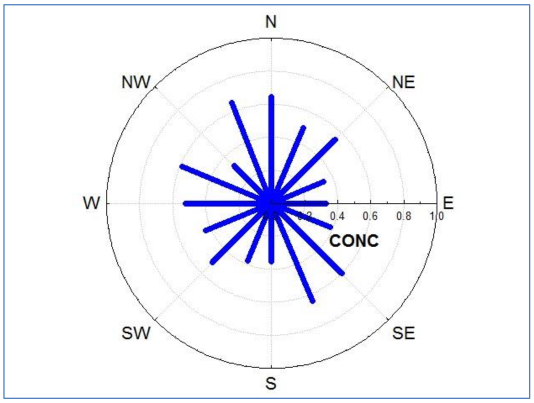
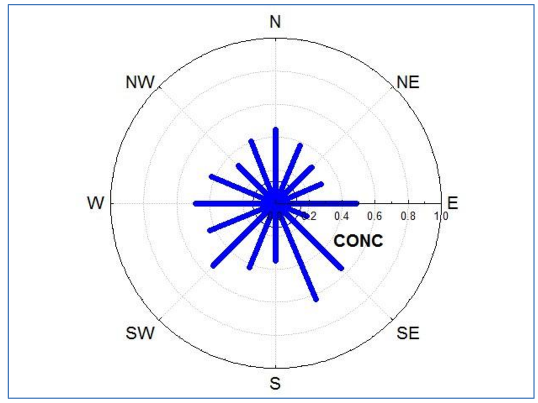


Figure 47: Mean carbonyl sulphide and carbon disulphide (ppb) by wind direction at Bertha Ganter for specified time period.

AUG-DEC





CARBONYL SULPHIDE **CARBON DISULPHIDE**

5.2 Integration of Data to Aid in Odour Complaint Characterization

5.2.1 Alberta Hotline Complaints

These will be discussed first because they cover the entire year and involve all communities in the WBEA area. As noted in Section 4.7 all complaint hours from the Alberta Hotline have been catalogued and assigned to a community (or to the other category). For each of these hours by community the prevailing average wind direction, wind speed and wind standard deviation (previous 6 hours) have been determined. The average wind direction for the Lower Camp Tower (100 m) and inversion strength were also determined. In addition the concentrations of the air quality parameters TRS, SO_2, NMHC, nitric oxide and NO_2 were determined for each hour for the nearest monitoring site(s). For the Bertha Ganter site results from the eNose and the PFGC were also used.

FORT McKAY: A listing of all hours with complaints to the Alberta Hotline from Fort McKay is shown in Table 30. The table includes the concentration of the parameters measured at the Bertha Ganter monitoring site including the PFGC (naphtha and aromatics) and eNose measurements. The highlighted values are equal to or greater than the 95th percentile of all hourly measurements for the year. For the PFGC and eNose measurements the 95th percentile was computed for separate time periods as discussed in Section 5.1.3.

Although there were 117 hours at the site with TRS concentrations greater than 1.5 ppb only two of these hours were associated with a complaint. There was no consistent association between any of the other measured parameters and reported odours although the 95th percentile values were most commonly reached for NMHC.

As shown in Figure 48 for a number of episode dates there was an increase in SO_2 and or NMHC at the site either preceding or just after the complaint. When the data were available, naphtha levels also increased in conjunction with NMHC. In many cases there was not a sudden change in wind direction associated with the increasing pollution levels and the hour of complaint.

Detailed meteorological data for the episode hours are found in Table B-1 of Appendix B. The wind roses from Bertha Ganter and Lower Camp Tower (100 m) for complaint hours are shown in Figure 49. Most complaints were associated with SSE or N wind directions and with light to moderate wind speeds. There were no occurrences of precipitation during episode hours and temperature inversions of 1 °C or greater at the Lower Camp Tower were recorded on 3 of the 26 hours with 18 hours showing an inversion of 0.1 to 1°C.

Figure 48: Hourly Variation in SO_2, TRS, NMHC, Naphtha Concentrations and Wind Direction at Bertha Ganter for Selected Episode dates in Fort McKay.

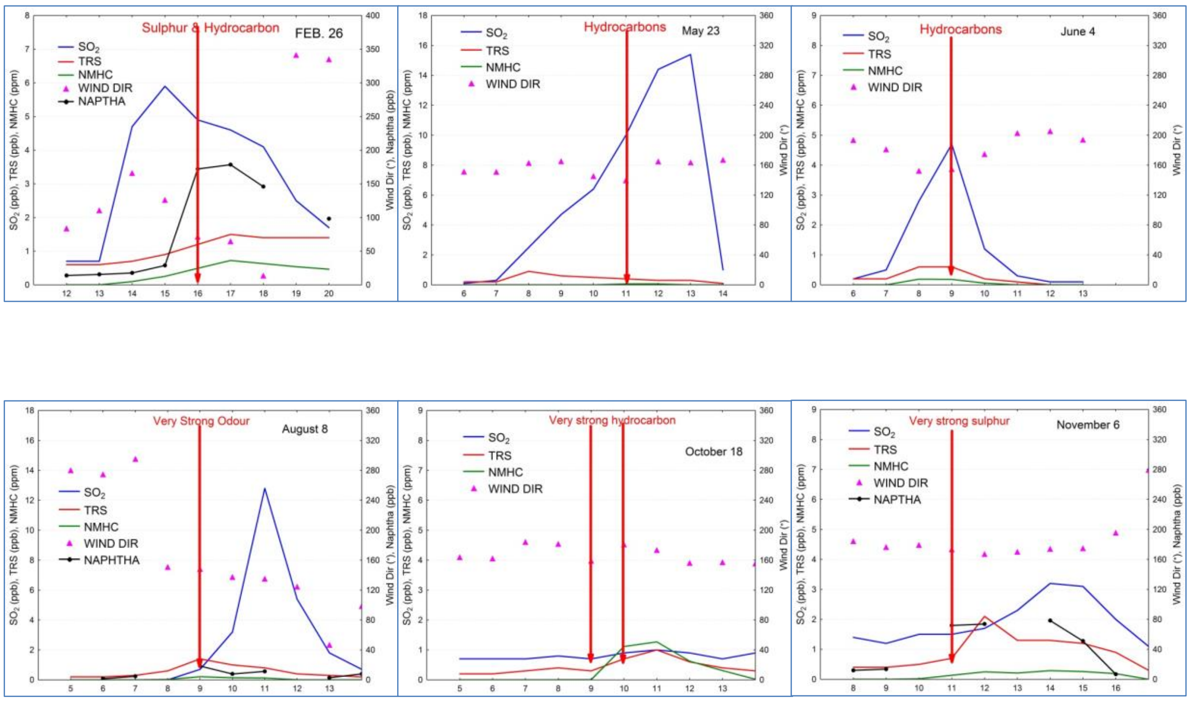


Figure 49: Wind Roses at Bertha Ganter and Lower Camp Tower (100 m) monitoring sites for complaint hours in Fort McKay.

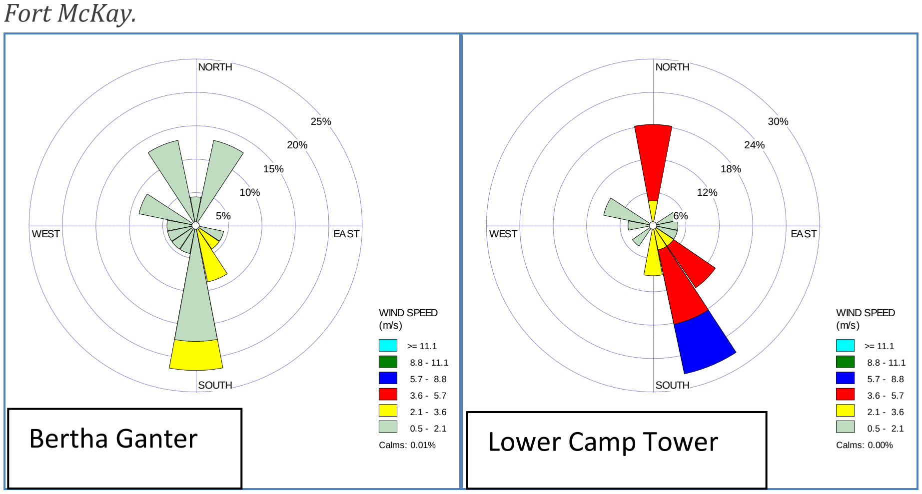


Table 30: Concentrations of Air Quality Parameters for Alberta Hotline Complaint Hours in Fort McKay (measurements greater than 95th percentile are highlighted).

Incident Date	Incident Time	Reported Odour by Complainant	TRS (ppb)	NMHC (ppm)	SO_2 (ppb)	NO (ppb)	NO_2 (ppb)	PFGC/SCD				eNose		
								NAPTHA (ppbC)	AROMATIC (ppbC)	COS (ppb)	CS_2 (ppb)	DELTA	MAX CONC (o.u.)	CV
2/26/13	16	Sulphur and hydrocarbon	1.2	0.49	4.9	47.5	33.7	172.2	5.3			6	42.9	0.2
3/27/13	8	Hydrocarbons	0.6	0.01	2.1	6.3	26.4					0	31.4	0.0
5/3/13	20	Very strong sulphur smell strength 10/10	0.1	0.00	0.0	0.0	3.7					0	28.5	0.0
5/3/13	21	Very strong sulphur smell strength 10/10	0.1	0.21	0.0	0.1	13.7					0	29.3	0.0
5/3/13	22	Strong sulphur	0.1	0.26	0.0	0.0	11.6					0	29.2	0.0
5/23/13	11	Hydrocarbons	0.4	0.06	10.0	3.3	8.6					1	32.4	0.0
6/4/13	9	Hydrocarbon	0.6	0.18	4.7	2.7	9.7					9	53.9	0.1
6/14/13	9	Hydrocarbons	0.5	0.19	3.2	5.6	6.2					17	67.6	0.2
6/20/13	23	Hydrogen sulphide	0.2	0.00	0.1	0.0	1.1	4.8	0.6	0	0	88	192.9	0.5
6/25/13	8	Hydrocarbon and sulphur	0.5	0.56	0.5	10.7	11.2	353.7	3.3	0	0	96	218.8	0.4
7/9/13	10	Hydrocarbon and sulphur	0.6	0.12	3.1	3.3	7.6	6.7	1	0	0	4	41.3	0.0
7/9/13	13	Hydrocarbons	0.3	0.01	6.2	0.6	3.0					6	66.9	0.1
7/26/13	8	Oil Odour	1.1	0.00	2.3	2.1	7.1	6.8	1.5	0	0	11	48.7	0.2
7/30/13	8	Oil odour	0.3	0.26	0.1	6.3	3.4	19.2	1.4	0	0	10	52.6	0.2
7/30/13	15	Sour gas odour	0.2	0.12	0.1	1.1	2.1	258.3	1.4	0	0	21	75.1	0.2
8/2/13	8	Hydrocarbons	0.7	0.00	0.3	9.1	5.5	11.2	1.7	0	0	13	50.0	0.1
8/8/13	9	Very strong odour	1.4	0.21	0.7	5.6	9.7	18.5	2.5	0	0	11	51.6	0.2
8/24/13	10	Sulphur or hydrocarbon	3.4	0.39	0.6	6.0	9.0	14.3	3.9	0	0	194	270.4	1.1
9/15/13	8	Sulphur or benzene	0.2	0.02	0.3	4.8	2.2	6.6	-	0.09	0.97	2	5.5	0.6
9/29/13	13	Strong hydrocarbon	0.3	0.00	0.3	3.6	4.1	2.4	-	0.01	0.45	3	6.6	0.6
10/18/13	10	Very strong hydrocarbon	0.7	1.12	0.9	9.4	15.9					1	3.0	0.7
10/18/13	9	Very strong hydrocarbons	0.3	0.00	0.7	21.5	16.7			0.6	0	1	3.0	0.4
11/6/13	11	Very strong sulphur/pungent chemical **(4 Complaints)**	0.7	0.14	1.5	10.6	15.6	71.9	-	0.2	0.4	10	14.2	1.5

FORT McMURRAY: A listing of all hours with complaints to the Alberta Hotline from the Fort McMurray area is shown in Table 31. The table includes the concentration of the parameters measured at both the Athabasca Valley (AMS#7) and Patricia McInnes (AMS#6) monitoring sites. Hours which also resulted in a COMP complaint are noted.

There was only one hour greater than 1.5 ppb of TRS associated with a complaint despite 66 hours greater than 1.5 ppb recorded at the Athabasca Valley site over the entire year. There was no consistent association between any of the other measured parameters and reported odours although 95th percentiles for TRS and SO_2 were reached most frequently.

Detailed meteorological data for the episode hours are found in Table B-2 of Appendix B. The wind roses from Athabasca Valley and Patricia McInnes for complaint hours are shown in Figure 50. Most complaints were associated with NW-NNW wind directions and wind speeds greater than 8 km/h. There was only one occurrence of precipitation during episode hours and temperature inversions of 1 °C or greater at the Lower Camp Tower were recorded on 3 of the 30 hours with 7 hours showing an inversion of 0.1 to 1°C.

Figure 50: Wind Roses at Athabasca Valley and Patricia McInnes monitoring sites for complaint hours in Fort McMurray.

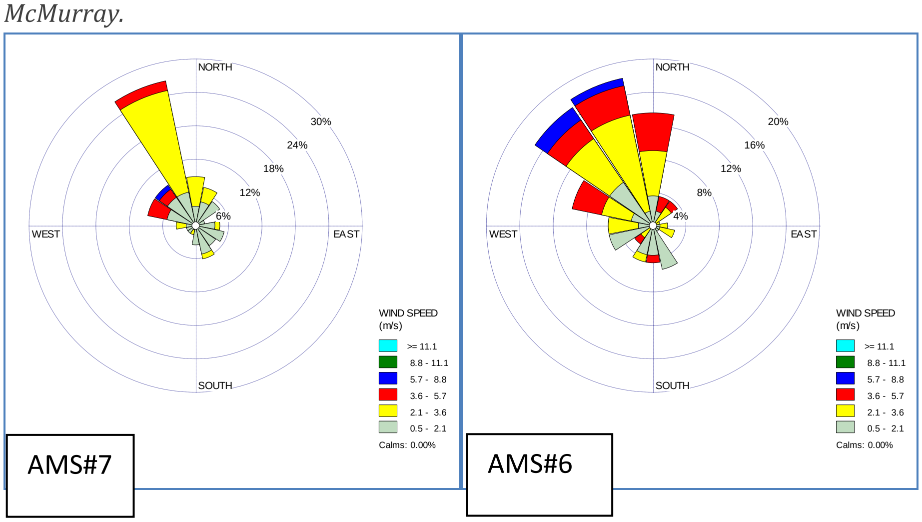


Table 31: Concentrations of Air Quality Parameters for Alberta Hotline Complaint Hours in Fort McMurray (measurements greater than 95th percentile are highlighted).

Incident Date	Incident Time	Reported Odour by Complainant	AMS7 TRS (ppb)	AMS6 TRS (ppb)	AMS 7 NMHC (ppm)	AMS6 NMHC (ppm)	AMS7 SO_2 (ppb)	AMS6 SO_2 (ppb)	AMS7 NO (ppb)	AMS6 NO (ppb)	AMS7 NO_2 (ppb)	AMS6 NO_2 (ppb)	COMP
2/12/13	1	Natural gas line leakage as seen in newspaper	0.3		0.00		0.3		0.1		2.3		
3/14/13	1	Very strong smell of oil	0.6		0.00		0.3		0.0		3.5		
5/6/13	10	Very strong hydrocarbons	0.3		0.00		0.3		3.8		7.9		
5/31/13	7	Strong hydrocarbons		0.7		0.10		0.6		3.7		8.1	
6/20/13	13	Freon release	0.1	0.1	0.00	0.00	0.0	0.4	0.0	11.7	1.5	4.0	
6/21/13	12	Smoke and odour	0.2	0.1	0.00	0.00	0.0	0.2	0.4		1.8		X
6/21/13	12	Oil odours	0.2	0.1	0.00	0.00	0.0	0.2	0.4		1.8		X
6/21/13	12	Chemical odour	0.2	0.1	0.00	0.00	0.0	0.2	0.4		1.8		X
7/18/13	21	Hydrocarbons	0.2		0.00		0.4		0.3		1.8		
7/26/13	9	Hydrocarbons	0.1	0.2	0.00	0.00	0.2	0.1	2.0	0.5	4.5	1.4	
8/14/13	17	Oil odour	0.5	0.2	0.04	0.00	0.6	0.2	2.0	0.0	6.2	1.5	
8/21/13	20	Like Cat/ammonia	0.2	0.2	0.01	0.00	0.0	0.0	4.1	0.3	7.1	1.7	
8/25/13	17	Rubber and sulphur	0.8	1.1	0.03	0.10	1.9	2.3	1.3	1.6	4.3	4.1	
8/26/13	1	Gas/oil smell	0.7	0.3	0.05	0.00	0.3	0.0	1.6	0.0	6.1	1.2	
8/26/13	15	Plants	1.9	1.7	0.18	0.50	22.9	15.3	15.6	21.7	18.7	18.4	X
8/30/13	1	Tar/oil	0.9		0.03		0.9		0.6		8.3		
8/30/13	1	Tar/oil	0.9	0.5	0.03	0.00	0.9	1.0	0.6	0.2	8.3	6.5	
8/30/13	1	Tar/oil	0.9	0.5	0.03	0.00	0.9	1.0	0.6	0.2	8.3	6.5	
9/3/13	10	Sulphur smell		0.1	0.00	0.00	0.0	0.2	2.6	1.1	3.3	1.5	
9/10/13	17	Hydrocarbon and sulphur	0.1	0.0	0.00	0.00	0.0	0.0	0.0	0.2	0.8	0.2	
9/27/13	10	Strong burning gas or electricity	0.3	0.2	0.00	0.00	0.0	0.2	10.3	6.6	4.0	3.7	
11/19/13	1	Stinky	0.4	0.2	0.00	0.00	0.0	0.9	0.0	0.4	12.2	6.2	
11/19/13	11	Cat pee	0.5	0.3	0.00	0.00	0.6	6.0	2.5	3.4	8.1	7.7	
11/19/13	12	Oil and gas	0.3	0.3	0.00	0.00	0.3	7.3	2.2	4.7	5.0	7.3	
11/19/13	13	Ammonia or cat pee	0.5	0.3	0.00	0.00	4.0	5.1	3.6	2.8	7.1	4.5	
11/19/13	13	Cat pee	0.5	0.3	0.00	0.00	4.0	5.1	3.6	2.8	7.1	4.5	
11/19/13	14	Propane/gassy smell	0.6	1.2	0.00	0.00	9.0	4.5	5.0	4.0	8.8	6.0	
11/19/13	16	Cat pee	0.5	0.4	0.00	0.00	2.7	3.0	0.9	3.0	9.4	11.7	
12/9/13	16	Smelly oil and rotten eggs	1.0	1.0	0.01	0.20	1.0	5.0	90.5	12.6	29.7	29.9	
12/24/13	1	Stinky	0.4	0.2	0.00	0.00	0.3	0.2	0.6	0.0	4.2	0.6	

ANZAC: A listing of all hours with complaints to the Alberta Hotline from the Anzac area is shown in Table 32. The table includes the concentration of the parameters measured at the Anzac (AMS#14) monitoring site.

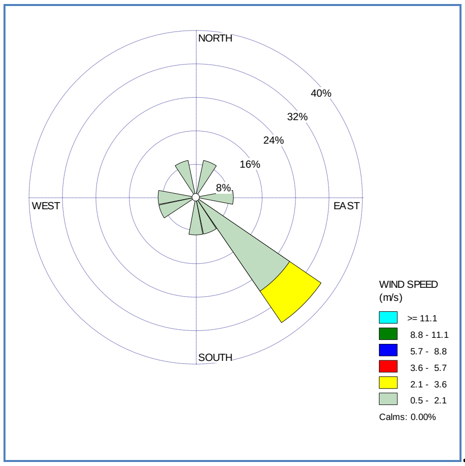
There were only two hours greater than or equal to 1.5 ppb of TRS associated with a complaint despite 82 hours greater than 1.5 ppb recorded at the site over the entire year. The highest TRS concentration of 11.8 ppb was not associated with a recorded complaint. There was no consistent association between any of the other measured parameters and reported odours.

Detailed meteorological data for the episode hours are found in Table B-3 of Appendix B. The wind rose for Anzac complaint hours is shown in Figure 51. Most complaints were associated with SE wind directions and light wind speeds. There were no occurrences of precipitation during episode hours and temperature inversions of 1 °C or greater at the Lower Camp Tower were recorded on all but one of the hours.

Table 32: Concentrations of Air Quality Parameters for Alberta Hotline Complaint Hours in Anzac (measurements greater than 95th percentile are highlighted).

Incident Date	Incident Time	Reported Odour by Complainant	TRS (ppb)	NMHC (ppm)	SO_2 (ppb)	NO_2 (ppb)	NO (ppb)
1/27/13	12	Very strong sulphur odour	1.8	0.20	0.5	12.5	14.1
1/28/13	1	Smell like pulp mill	0.6	0.10	1.8	24.4	12.9
3/19/13	11	Hydrocarbons	0.4	0.00	1.1	4.1	1.7
4/15/13	9	Very strong oil sands smell	0.4	0.00	0.8	1.5	0.5
9/23/13	14	Very strong odour	0.7	0.00	0.5	2.4	0.0
11/12/13	11	Very strong chemical	0.4	0.00	0.1	7.4	3.4
11/12/13	13	Very strong odour of burning oil, crude oil and sulphur	1.5	0.10	0.1	9.9	4.5
11/12/13	15	Rotten egg		0.20	0.4	10.6	2.9
11/26/13	7	Strong odour	0.6	0.00	0.9	4.5	0.0
11/30/13	10	Burning Sulphur	0.6	0.00	0.0	4.7	0.0
12/29/13	9	Very strong hydrocarbons	0.8	0.00	0.0	9.3	0.5
12/30/13	11	Strong gassy smell	0.5	0.00	0.2	9.4	6.1

Figure 51: Wind Rose for Anzac monitoring site for complaint hours.



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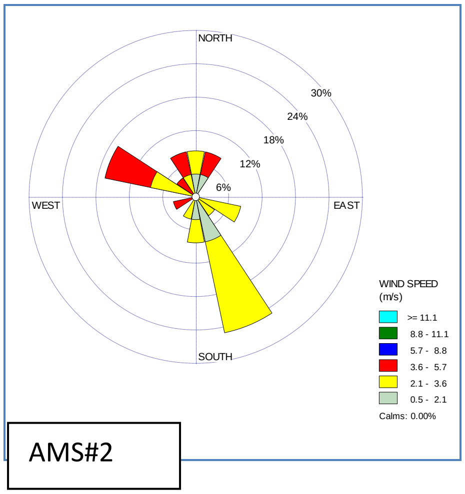
OTHER: A listing of all hours with complaints to the Alberta Hotline from sites other than the communities of Anzac, Fort McMurray and Fort McKay is provided in Table 33. The table includes the concentration of the parameters TRS and derived NMHC measured at the Mildred Lake (AMS#2) and Mannix (AMS#5) monitoring sites since these were usually the closest locations to the reported complaints which were mostly from Highway #63.

There were only two hours greater than or equal to 3 ppb of H_2S at Mildred Lake and one hour at Mannix associated with a complaint despite 137 hours greater than 3 ppb recorded at Mildred Lake and 243 hours at Mannix over the entire year. The highest H_2S concentration of 13.5 ppb at Mildred Lake was associated with a recorded complaint but the odour was described as "oil odour". There was no consistent association between H_2S or dNMHC and reported odours.

Detailed meteorological data for the episode hours for Mildred Lake are found in Table B-4 of Appendix B. The wind roses for complaint hours for Mildred Lake and Mannix are shown in Figure 52. Most complaints are associated with moderate to high wind speeds. There were three occurrences of precipitation during episode hours and 3 of 26 hours with a temperature inversions of 1 °C or greater at the Lower Camp Tower.

Figure 52: Wind Rose for Mildred Lake and Mannix monitoring sites for complaint hours.



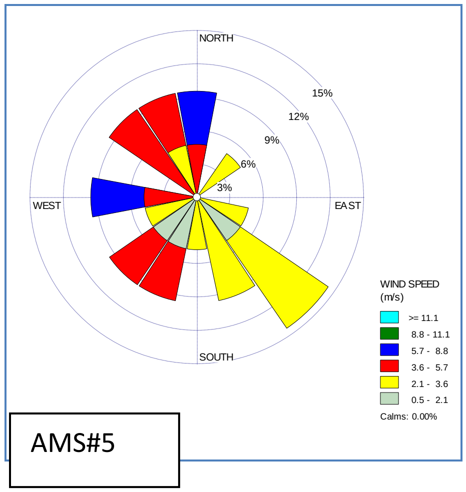


Table 33: Concentrations of Air Quality Parameters at Mildred Lake (AMS#2) and Mannix (AMS#5) for Alberta Hotline Complaint Hours (measurements greater than 95th percentile are highlighted).

Incident Date	Incident Time	Reported Odour by Complainant	General Location of Complaint	AMS2 $H2_S$ (ppb)	AMS5 $H2_S$ (ppb)	AMS DNMHC (ppm)	AMS 5 DNMHC (ppm)
1/24/13	16	Mix of sulphur and hydrocarbon	Hwy 63 south at Heavy Hauler Truck cross the Highway	0.5	0.3	0.4	0.3
4/18/13	8	Strong hydrocarbons	Hwy 63 Northbound near Suncor entrance gate		1.1		0.4
5/5/13	22	Very strong benzene	Driving towards Fort McKay at Hwy 63N near Suncor and Syncrude area	0.1	1.3	0.2	0.5
5/9/13	7	Strong oily smell	Hwy 63 15 Km South of Fort McKay	0.1	1	0.1	0.4
5/9/13	16	Very strong cat pee	South on Hwy 63 near Syncrude Plant area	0.1	0.2	0.1	0.2
5/15/13	8	Strong hydrocarbons	Heading south on Hwy 63 between Syncrude and Fort McKay	0.6		0.3	
5/15/13	16	Strong hydrocarbons	Driving South on Hwy 63 passing Suncor	0.1	0.3	0.3	0.6
5/24/13	3	Very strong odour of SO_2 THC and H_2S	Driving Hwy 63N near Syncrude area			0.4	0.6
6/5/13	16	Ammonia	Hwy 63 South of Fort McKay turnoff	0.3		0.2	
6/6/13	17	Ammonia	Driving Hwy 63 SB in between Fort McKay and Syncrude	0.2		0.3	
6/22/13	19	Hydrocarbon and sulphur	Driving South on Hwy 63 passing Suncor	0.4	1.7	0.2	0.7
7/15/13	20	Total hydrocarbons	Driving Hwy 63 North in between Suncor and Syncrude	0.2	1.2	0.1	0.4
7/16/13	1	Hydrogen sulphide	Driving Hwy 63 North in between Suncor and Syncrude	0.2	1.7	0.1	0.4
8/19/13	8	Oil odour	Driving Hwy 63N next to Syncrude	13.5		0.9	
8/22/13	8	Transmission oil	In b/w Hwy 63 N and Syncrude	0.4	0.2	0.1	0.1
8/26/13	13	Sulphur	Driving south on Hwy 63 near Syncrude and Suncor	1.3	3.3	0	0.7
9/4/13	8	Hydrocarbons	Driving Hwy 63N near Syncrude Tailings	7.6	0.3	1.2	0
9/4/13	18	Oily smell	Driving Hwy 63S near Syncrude Tailings	0.2	0.2	0.2	0.2
9/11/13	8	Transmission oil	Driving Hwy 63N near Syncrude	0.4	0.4	0.1	0.3
9/25/13	17	Strong sulphur	Driving Hwy 63S near Suncor	0.2		0.2	
9/30/13	8	Sulphur and hydrocarbons	Driving Hwy 63N near Suncor	0.1	1.9	0.3	0.2
9/30/13	16	Strong sulphur	Driving Hwy 63S	0.1	1.8	0.2	0.2
10/7/13	8	Hydrocarbon and sulphur	Hwy 63S in between Syncrude and Suncor	0.2	0.2	0.1	0.2
10/15/13	15	Total Hydrocarbons and H_2S	Hwy 63S near Suncor	0.2	0.4	0.7	0.4
10/16/13	15	Very strong rotten egg odour	Near Syncrude site	0.1	0.2	0.4	0.4

5.2.2 Community Odour Monitoring Project (COMP) Complaints

As discussed in Section 4.7.1 the COMP project odour observations started in June 2013 and a total of 108 odour observations were recorded between June 1 and December 31, 2013 (none in December). The latitude and longitude of the response were used to identify the nearest WBEA monitoring site (Patricia McInnes or Athabasca Valley) and the distance from the participant to the monitoring site. Some of the observations spanned multiple hours and the total hours with potential odour complaints amounted to 118 over the 6 month period. Table 34 provides a listing of the observations and TRS, SO_2, NMHC, NO and NO_2 concentrations at the Patricia McInnes (AMS#6) and Athabasca Valley (AMS#7) monitoring sites for each hour. Eight of the complaint hours were associated with TRS values greater than or equal to 1.5 ppb at one or more of the sites. Approximately half (55 of 118) of complaint hours were associated with one of the air quality parameters at the 95th percentile value or higher.

Detailed meteorological data for the episode hours are found in Table B-5 of Appendix B. The wind roses for the two sites for COMP complaint hours are shown in Figure 32. Most complaints were associated with NNE or NE wind directions and with wind speeds greater than 8 km/h. There were 11 complaint hours with precipitation and temperature inversions of 1 °C or greater at the Lower Camp Tower were recorded on 12 of the 118 hours with 29 hours showing an inversion of 0.1 to 1°C.

Table 34: Concentrations of Air Quality Parameters for COMP Complaint Hours in Fort McMurray (measurements greater than 95th percentile are highlighted).

DATE	HOUR	Type of Odour Perceived	Intensity of Odour Perceived	Odour Appreciation	TRS		NMHC		SO_2		NO		NO_2	
					AMS6	AMS7	AMS6	AMS7	AMS6	AMS7	AMS6	AMS7	AMS6	AMS7
6/1/13	9	Other: specify sewage	Medium	Unpleasant	0.2	0.3	0.00	0.00	0.3	0.2	2.0	0.9	3.7	4.5
6/9/13	4	hydrocarbon	Medium	Unpleasant	0.3	0.5	0.00		1.3		0.0		2.9	
6/9/13	8	Asphalt / tar	Medium	Unpleasant	0.4	0.4	0.00	0.00	1.0	0.3	0.0	0.4	2.0	2.9
6/9/13	10	Asphalt / tar	Medium	Unpleasant	0.3	0.8	0.00	0.00	0.2	0.7	0.0	1.8	1.0	4.1
6/9/13	12	Rotten egg	Weak	Unpleasant	0.3	0.5	0.00	0.00	0.1	0.8	0.1	1.3	1.5	3.3
6/11/13	6	Asphalt / tar	Medium	Unpleasant	0.2	0.5	0.00	0.00	1.2	0.2	1.6	1.5	6.0	6.0
6/11/13	7	Asphalt / tar	Weak	Neutral	0.2	0.9	0.00	0.00	0.7	0.2	1.0	1.1	4.0	4.1
6/15/13	7	Other: hydro carbons	High	Unpleasant	0.3	0.9	0.00	0.00	0.7	0.4	0.1	0.9	3.7	7.0
6/15/13	17	Fuel / solvent	Very Weak	Neutral	0.1	0.1	0.00	0.00	0.4	0.0	0.1	0.4	2.5	3.9
6/19/13	6	Other: hydrocarbons	Medium	Unpleasant	0.9	1.0	0.20	0.00	2.3	0.3	4.9	3.2	13.0	10.8
6/19/13	7	Rotten egg	Medium	Unpleasant	0.8	1.0	0.20	0.00	4.1	1.1	6.4	5.2	11.6	11.1
6/19/13	12	Fecal / septic	Medium	Very Unpleasant	0.1	0.1	0.00	0.00	0.3	0.0		0.3		1.3
6/19/13	18	Fecal / septic	Medium	Very Unpleasant	0.1	0.2	0.00	0.00	0.1	0.0	1.8	0.4	3.4	1.5
6/20/13	12	Other: Fertilizer	Medium	Unpleasant	0.1	0.2	0.00	0.00	0.4	0.1	13.5	0.0	6.6	1.5
6/21/13	10	chemical earthy	Medium	Unpleasant	0.2	0.4	0.00	0.00	0.3	0.0		2.7		6.7
6/21/13	11	Fecal / septic	Medium	Unpleasant	0.1	0.2	0.00	0.00	0.2	0.0		1.7		4.9
6/21/13	12	hydrocarbon	Weak	Unpleasant	0.1	0.2	0.00	0.00	0.2	0.0		0.4		1.8
6/23/13	9	Asphalt / tar	Weak	Unpleasant	0.1	0.3	0.00	0.00	0.2	0.0	2.2	2.0	2.7	3.0
6/25/13	16	Fecal / septic	Medium	Unpleasant	0.1	0.3	0.00	0.00	0.2	0.1	1.4	0.2	2.9	0.8
6/26/13	7	Fecal / septic	Medium	Unpleasant	0.2	0.1	0.00	0.00	0.1	0.0	3.8	0.1	8.7	1.6
6/26/13	7	Other: hydrocarbons	Medium	Unpleasant	0.2	0.1	0.00	0.00	0.1	0.0	3.8	0.1	8.7	1.6
6/29/13	16	Fecal / septic	Medium	Unpleasant	0.0	0.4	0.00	0.01	0.4	0.1	0.3	0.8	2.2	8.0
6/30/13	13	Fecal / septic	Medium	Unpleasant	0.1	0.2	0.00	0.01	0.1	0.0	0.0	0.4	0.2	1.9
7/3/13	5	Burnt / smoke	High	Unpleasant	0.3		0.00	0.00	0.1	0.0	0.2	0.6	0.4	3.8
7/4/13	10	Burnt / smoke	High	Unpleasant	0.2	0.4	0.00	0.01	0.2	0.0	0.1	2.0	0.9	3.6
7/4/13	14	Burnt / smoke	Medium	Unpleasant	0.2	0.3	0.00	0.00	0.2	0.0	3.5	0.0	3.6	1.1
7/4/13	15	Burnt / smoke	Weak	Unpleasant	0.1	0.3	0.00	0.00	0.2	0.0	0.3	0.0	1.2	1.7
7/4/13	16	Burnt / smoke	Medium	Unpleasant	0.2	0.2	0.00	0.00	0.2	0.0	0.2	0.2	0.9	1.8
7/4/13	17	Burnt / smoke	Medium	Unpleasant	0.1	0.3	0.00	0.00	0.2	0.0	0.0	0.5	0.7	5.3
7/4/13	20	Burnt / smoke	Medium	Unpleasant	0.3	0.4	0.00	0.04	0.8	0.3	1.3	0.1	6.1	5.0

Table 34: continued

DATE	HOUR	Type of Odour Perceived	Intensity of Odour Perceived	Odour Appreciation	TRS		NMHC		SO_2		NO		NO_2	
					AMS6	AMS7	AMS6	AMS7	AMS6	AMS7	AMS6	AMS7	AMS6	AMS7
7/5/13	5	Burnt / smoke	Weak	Unpleasant	0.9		0.00	0.00	0.4	0.2	0.9	2.5	2.8	11.2
7/5/13	6	Burnt / smoke	Weak	Unpleasant	0.6	0.8	0.00	0.00	0.5	0.3	2.9	7.3	6.8	20.1
7/5/13	9	Burnt / smoke	High	Unpleasant	0.3	0.5	0.00	0.02	0.6	0.3	3.4	4.4	5.2	10.2
7/5/13	13	Burnt / smoke	Very High	Very Unpleasant	0.2	0.4	0.00	0.00	0.4	0.0	0.4	2.9	2.7	9.3
7/5/13	14	Burnt / smoke	Very High	Very Unpleasant	0.2	0.4	0.00	0.02	0.4	0.0	0.5	3.2	2.5	11.7
7/5/13	15	Burnt / smoke	Weak	Unpleasant	0.2	0.4	0.00	0.02	0.3	0.0	1.8	1.4	6.8	7.3
7/7/13	14	Fecal / septic	Medium	Unpleasant	0.1	0.1	0.00	0.00	0.3	0.1	0.0	0.8	0.8	2.9
7/16/13	7	Fuel / solvent	Weak	Unpleasant	0.2	0.5	0.00	0.00	0.4	7.6	0.1	2.6	0.5	5.0
7/18/13	18	Burnt / smoke	Weak	Unpleasant	0.3	0.4	0.00	0.01	9.4	7.7	0.8	0.2	4.1	4.2
7/21/13	8	Asphalt / tar	Weak	Unpleasant	0.2	0.3	0.00	0.00	2.7	0.0	3.2	4.4	4.5	2.7
7/21/13	13	Fuel / solvent	Weak	Unpleasant	0.1	0.3	0.00	0.00	9.0	7.7	0.4	0.0	4.0	3.5
7/21/13	15	Fecal / septic	Medium	Unpleasant	0.2	0.3	0.00	0.00	5.5	3.4	0.2	0.0	4.2	3.0
7/23/13	6	Fuel / solvent	Medium	Unpleasant	0.5	0.7	0.00	0.00	0.3	0.0	1.1	0.8	5.4	11.0
7/23/13	7	Ammonia / cat's pee	High	Very Unpleasant	0.6	0.5	0.00	0.01	0.3	0.0	1.3	2.4	4.1	9.5
7/23/13	10	Fuel / solvent	Medium	Unpleasant	0.6	0.6		0.01		0.9	3.3	2.4	3.5	4.0
7/23/13	16	Fuel / solvent	Weak	Unpleasant	0.4	0.0	0.00	1.3	2.4	0.3	0.3	1.4	2.3	
7/24/13	5	Asphalt / tar	Medium	Unpleasant	0.3		0.10	0.00	0.8	0.4	0.6	2.9	8.1	17.6
7/24/13	6	Fecal / septic	Medium	Unpleasant	0.5	0.7	0.00	0.00	0.8	0.3	0.8	5.1	4.5	15.8
7/28/13	4	Ammonia / cat's pee	Medium	Unpleasant	0.3	0.5	0.00		0.1		0.1		1.0	
7/28/13	5	Ammonia / cat's pee	Very High	Very Unpleasant	0.3		0.00	0.00	0.1	0.0	0.3	0.2	1.4	6.1
7/28/13	8	Asphalt / tar	High	Very Unpleasant	0.8	0.8	0.10	0.01	0.2	0.0	2.1	2.7	5.6	9.4
7/28/13	15	Fuel / solvent	Medium	Unpleasant	0.3	0.5	0.00	0.02	0.6	0.3	0.0	0.2	1.4	4.2
7/29/13	6	Ammonia / cat's pee	Medium	Unpleasant	0.1	0.3	0.00	0.00	0.1	0.0	0.0	0.0	0.0	1.9
7/30/13	6	Fuel / solvent	High	Unpleasant	0.2	0.4	0.10	0.00	0.2	0.1	18.5	6.6	8.9	4.8
8/1/13	1	Asphalt / tar	Medium	Unpleasant	0.5	0.7	0.00	0.00	0.3	0.1	0.0	3.8	4.6	12.7
8/1/13	6	Fuel / solvent	Medium	Unpleasant	0.5	0.8	0.10	0.02	0.4	0.2	5.1	11.8	7.2	10.6
8/1/13	14	Fuel / solvent	Weak	Unpleasant	0.2	0.7		0.00		6.5	4.9	1.2	5.0	4.4
8/5/13	11	Fuel / solvent	Medium	Unpleasant	0.5	0.7	0.30	0.13	2.8	0.9	5.4	5.1	9.6	11.2
8/5/13	13	Burnt / smoke	Medium	Unpleasant	0.1	0.3	0.00	0.01	0.3	0.2	0.4	0.3	1.8	1.2
8/5/13	14	Burnt / smoke	Medium	Unpleasant	0.1	0.2	0.00	0.01	0.2	0.1	0.6	0.3	2.1	1.0
8/5/13	15	Burnt / smoke	High	Unpleasant	0.3	0.3	0.00	0.03	0.3	0.1	0.7	0.2	2.7	2.4

Table 34: continued

DATE	HOUR	Type of Odour Perceived	Intensity of Odour Perceived	Odour Appreciation	TRS		NMHC		SO_2		NO		NO_2	
					AMS6	AMS7	AMS6	AMS7	AMS6	AMS7	AMS6	AMS7	AMS6	AMS7
8/5/13	15	Burnt / smoke	Weak	Unpleasant	0.3	0.3	0.00	0.03	0.3	0.1	0.7	0.2	2.7	2.4
8/7/13	11	Fecal / septic	Weak	Unpleasant	0.3	0.2	0.00	0.00	0.2	0.2	29.0	0.6	6.8	1.5
8/22/13	21	Fuel / solvent	Weak	Unpleasant	0.3	0.4	0.10	0.05	0.1	0.4	3.9	1.3	9.8	9.6
8/23/13	8	Asphalt / tar	High	Very Unpleasant	0.2	0.2	0.00	0.02	0.1	0.1	0.3	7.1	0.8	4.1
8/23/13	9	Fecal / septic	Very High	Very Unpleasant	0.3	0.2	0.00	0.04	2.9	0.3	2.0	7.1	3.9	6.0
8/23/13	10	Ammonia / cat's pee	Medium	Unpleasant	0.2	0.2	0.00	0.00	3.9	4.4	2.3	1.3	3.9	3.2
8/24/13	14	Other: sewage	Weak	Unpleasant	0.2	0.3	0.00	0.02	0.0	0.1	0.6	0.0	2.4	2.7
8/25/13	10	Asphalt / tar	Medium	Unpleasant	0.2	0.4	0.00	0.03	0.0	0.0	0.3	3.3	0.7	3.3
8/25/13	13	Fuel / solvent	High	Unpleasant	0.9	1.6	0.30	0.14	3.4	5.4	5.4	7.9	11.0	15.4
8/26/13	3	Asphalt / tar	Very High	Very Unpleasant	0.5	0.0	0.03	0.10	0.2	0.2	1.0	2.3	5.1	
8/26/13	4	Asphalt / tar, chemical / Plastic,	Very High	Very Unpleasant	0.3	0.5	0.00		0.0		0.3		1.9	
8/26/13	15	Fuel / solvent	Medium	Unpleasant	1.7	1.9	0.50	0.18	15.3	22.9	21.7	15.6	18.4	18.7
8/26/13	16	Other: specify smoke	Medium	Unpleasant	1.2	1.7	0.30	0.13	20.9	32.7	10.1	10.8	14.1	18.4
8/27/13	1	Asphalt / tar, natural gas,	High	Very Unpleasant	0.4	0.8	0.20	0.07	1.0	2.6	1.1	0.0	13.2	13.1
8/27/13	2	Asphalt / tar, natural gas,	High	Very Unpleasant	0.4	0.6		0.04		2.2		2.1		11.7
8/27/13	3	Asphalt / tar, natural gas,	High	Very Unpleasant	0.6	0.2	0.04	1.4	2.8	1.2	5.2	9.5	11.0	
8/27/13	4	Asphalt / tar, natural gas,	High	Very Unpleasant	0.7	1.0	0.20		1.2		1.5		8.4	
8/27/13	5	Asphalt / tar, natural gas,	High	Very Unpleasant	0.5		0.20	0.06	1.0	2.2	1.5	5.9	6.9	10.0
8/28/13	10	Asphalt / tar	Weak	Unpleasant	0.1	0.2	0.00	0.00	0.0	0.0	0.4	2.5	0.2	3.4
8/28/13	11	Ammonia / cat's pee	High	Very Unpleasant	0.1	0.3	0.00	0.01	0.1	0.0	0.1	1.4	0.2	2.8
8/28/13	16	Fuel / solvent	Medium	Unpleasant	0.2	0.2	0.00	0.01	0.5	0.9	0.0	0.1	1.3	3.9
8/29/13	1	Ammonia / cat's pee	Very High	Very Unpleasant	0.5	0.6	0.20	0.08	0.9	0.9	0.1	0.0	5.8	9.9
8/29/13	2	Ammonia / cat's pee	Very High	Very Unpleasant	0.3	0.5		0.06		0.6		0.7		11.3
8/29/13	9	Asphalt / tar	High	Very Unpleasant	0.2	0.2	0.00	0.00	0.1	0.0	1.7	3.3	3.2	4.3
8/29/13	15	Fuel / solvent	Weak	Unpleasant	0.3	0.6	0.00	0.03	2.6	4.6	0.8	0.9	2.4	3.0
8/29/13	18	Other: gas	High	Very Unpleasant	0.2	0.2	0.00	0.02	1.3	0.4	1.3	0.5	4.9	4.5
8/29/13	22	Asphalt / tar	High	Very Unpleasant	1.2	1.2	0.10	0.04	2.0	1.9	0.8	0.1	4.8	7.8
8/29/13	23	Asphalt / tar	High	Very Unpleasant	1.2	1.1	0.20	0.08	1.6	1.5	1.0	0.1	6.7	7.5
8/29/13	24	Asphalt / tar	High	Very Unpleasant	0.8	1.1	0.10	0.05	1.1	1.5	0.4	0.4	5.7	8.2
8/30/13	6	Asphalt / tar	Medium	Unpleasant	1.8	1.4	0.30	0.09	1.8	1.3	6.4	11.2	8.0	8.7
8/30/13	6	Asphalt / tar	Very High	Very Unpleasant	1.8	1.4	0.30	0.09	1.8	1.3	6.4	11.2	8.0	8.7
8/30/13	7	Asphalt / tar	Very High	Very Unpleasant	2.7	1.1	0.30	0.06	3.9	1.0	9.5	15.8	7.2	8.2
8/30/13	8	Asphalt / tar	Very High	Very Unpleasant	3.1	1.3	0.30	0.06	5.4	1.6	12.7	15.3	6.8	8.0

Table 34: continued

DATE	HOUR	Type of Odour Perceived	Intensity of Odour Perceived	Odour Appreciation	TRS		NMHC		SO_2		NO		NO_2	
					AMS6	AMS7	AMS6	AMS7	AMS6	AMS7	AMS6	AMS7	AMS6	AMS7
8/30/13	14	Fuel / solvent	Medium	Unpleasant	1.8	1.9	0.10	0.04	30.6	23.8	4.4	2.9	5.1	5.8
9/9/13	15	Asphalt / tar	Very Weak	Neutral	0.0	0.1	0.00	0.00	0.1	0.1	0.1	0.0	0.1	1.1
9/11/13	6	Burnt / smoke	Weak	Unpleasant	0.1	0.2	0.00	0.00	0.0	0.1	9.0	14.2	6.8	8.7
9/13/13	11	Asphalt / tar	High	Very Unpleasant	1.0	1.4	0.00	0.03	14.3	5.9	4.2	2.6	6.9	6.5
9/13/13	12	Fecal / septic	Medium	Unpleasant	0.8	1.0	0.00	0.01	10.0	5.4	3.0	1.7	6.1	6.0
9/13/13	12	Fuel / solvent	Weak	Unpleasant	0.8	1.0	0.00	0.01	10.0	5.4	3.0	1.7	6.1	6.0
9/13/13	18	Asphalt / tar			0.3	0.4	0.00	0.00	3.6	3.6	1.7	0.7	11.0	9.9
9/13/13	20	Rotten Egg	Medium	Very Unpleasant	0.2	0.5	0.00	0.03	0.8	1.0	1.3	6.1	8.7	24.6
9/25/13	18	Fuel / solvent	Weak	Unpleasant	0.6	0.4	0.20	0.00	5.3	4.7	1.9	0.4	8.5	8.5
9/26/13	11	Fuel / solvent	Weak	Unpleasant	0.3	0.5	0.00	0.02	0.1	0.1	2.4	3.8	4.1	7.1
9/26/13	20	Asphalt / tar, Fuel / solvent,	High	Very Unpleasant	0.2	0.4	0.00	0.00	0.1	0.0	0.5	3.4	5.9	14.0
9/29/13	11	Asphalt / tar	High	Very Unpleasant	0.2	0.1	0.00	0.00	0.2	0.0	3.1	2.9	4.0	5.5
9/29/13	13	Fuel / solvent	Medium	Unpleasant	0.3	1.1	0.10	0.08	0.2	0.4	6.0	7.1	6.3	10.9
10/2/13	4	Chemical / plastic	Medium	Unpleasant	0.1	0.3	0.00		0.0		0.4		5.4	
10/8/13	13	Fuel / solvent	Weak	Unpleasant	0.2	0.6	0.00		0.3		1.3		2.9	
10/19/13	8	Asphalt / tar	Medium	Unpleasant	0.6	0.7	0.50	0.01	1.5	0.1	26.7	28.7	14.7	12.9
10/31/13	15	Asphalt / tar	High	Very Unpleasant	0.2	0.9	0.00	0.17	25.4	9.0	1.9	11.5	9.8	24.9
11/13/13	7	Burnt / smoke	Weak	Unpleasant	0.2	0.2	0.00	0.00	0.1	0.0	0.2	0.0	1.3	5.3
11/18/13	6	Fuel / solvent	Weak	Unpleasant	0.3	0.6	0.10	0.04	0.9	0.3	1.3	10.3	14.0	21.7
11/18/13	7	Fuel / solvent	Weak	Unpleasant	0.4	0.6	0.00	0.33	1.4	0.3	1.6	1.0	14.8	21.7
11/18/13	7	Fuel / solvent	Weak	Unpleasant	0.4	0.6	0.00	0.33	1.4	0.3	1.6	1.0	14.8	21.7
11/29/13	7	Burnt / smoke	Weak	Unpleasant	0.1	0.3	0.00	0.00	0.2	0.0	0.9	1.1	2.9	4.2

5.2.3 Back Trajectories associated with some of the higher concentration episode for Alberta Hotline and COMP complaint hours

1. Fort McKay, August 24: 10:00 – TRS of 3.4 ppb and NMHC of 0.39 ppm and one complaint of “sulphur or hydrocarbon – see Figure 53.
2. Fort McKay, September 4: 07:00 & 08:00 – two highest TRS values of the year recorded (4.6 and 5.3 ppb) – no recorded complaint – see Figure 54.
3. Fort McKay, November 6: 11:00 – 4 complaints of “very strong sulphur”, TRS of 0.7 ppb and NMHC of 0.14 ppm and with high PFGC naphtha and high eNose CV – see Figure 55.
4. Fort McMurray, June 21: 12:00 – 3 COMP complaints and a Alberta Hotline complaint but all measured air quality parameters at low concentration – see Figure 56 and Figure 57.
5. Fort McMurray, July 4 and 5 – many complaints of “burnt/smoke” – see Figure 58.
6. Fort McMurray, August 30 – many complaints of “asphalt/tar” and high measured concentrations of TRS and NMHC at both sites – see Figure 59.
7. Anzac, November 12: 11:00 – 15:00 – 3 complaints of very strong odour with TRS maximum of 1.5 ppb – see Figure 609.

Figure 53: Six-hour back trajectories for Fort McKay at 50m (green) and at 100 m (blue) for August 24, 2013 at 10:00 from AirNow-Tech Navigator.

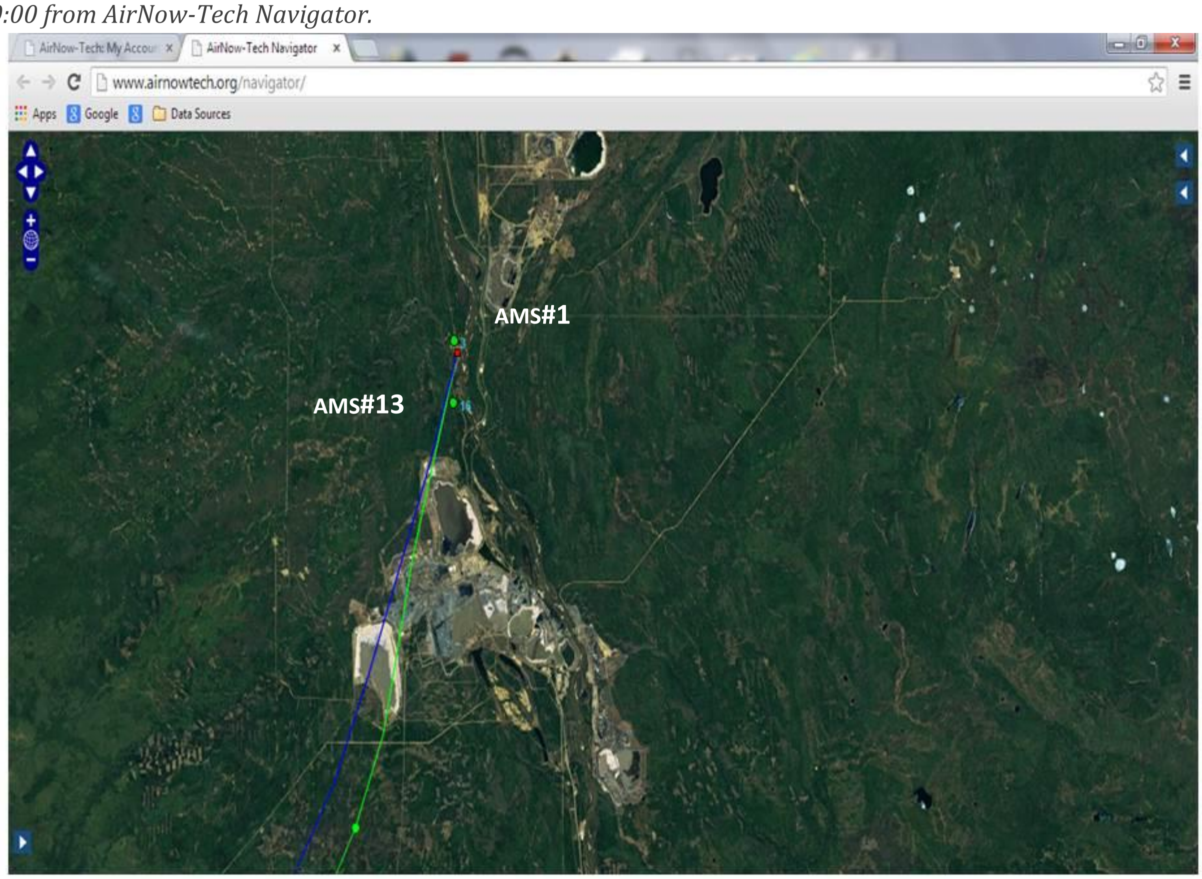


Figure 54: Six-hour back trajectories for Fort McKay at 50m (green) and at 100 m (blue) for September 4, 2013 at 08:00 from AirNow-Tech Navigator.

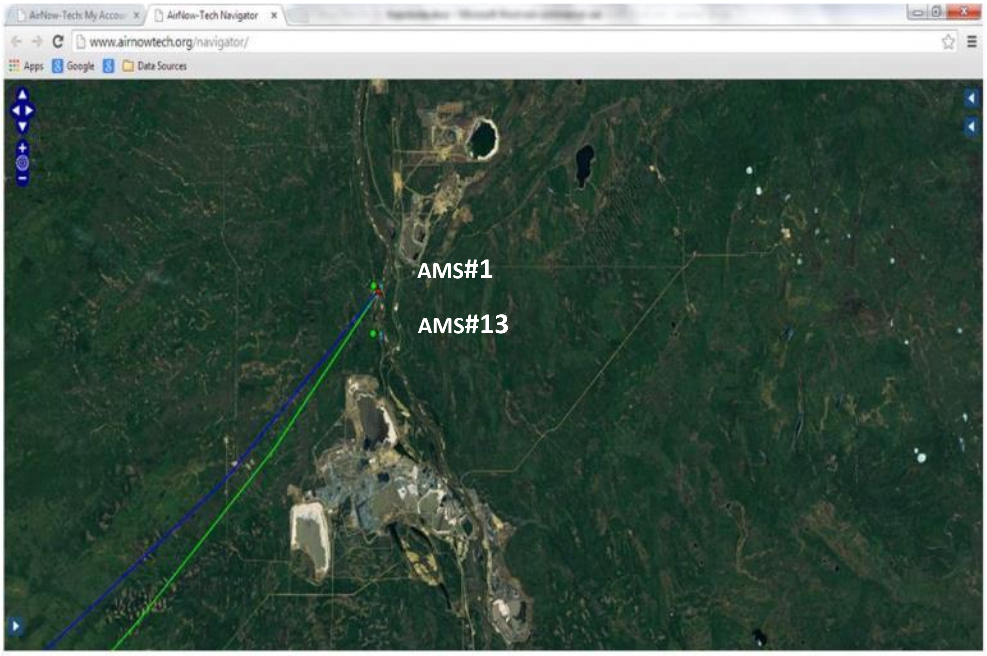


Figure 55: Six-hour back trajectories for Fort McKay at 50m (green) and at 100 m (blue) for November 6, 2013 at 11:00 from AirNow-Tech Navigator.

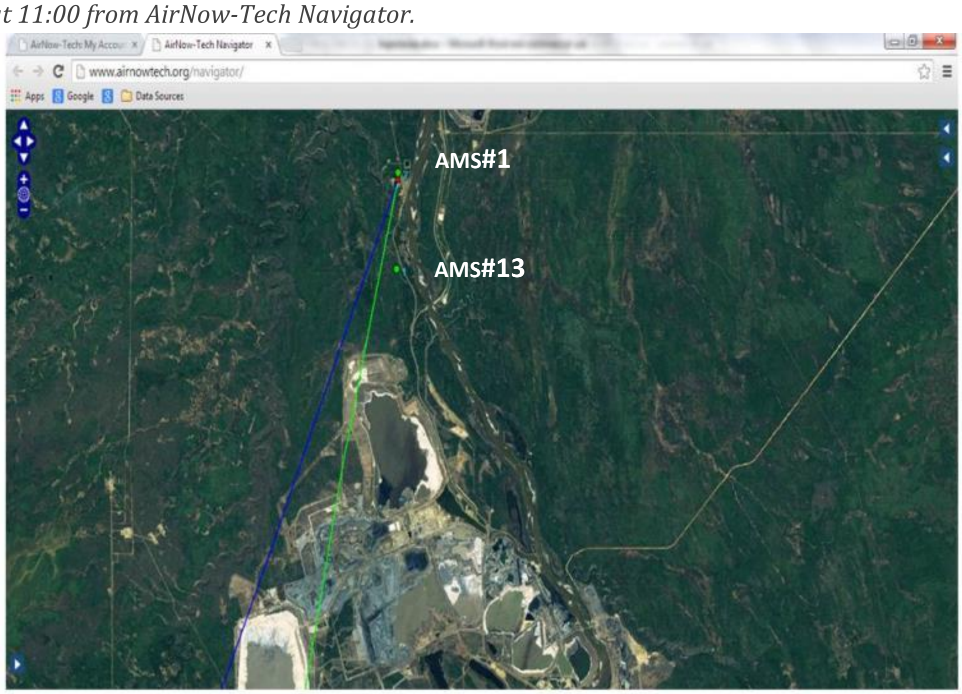


Figure 56: Six-hour back trajectories for Fort McMurray at 50m (green) and at 100 m (blue) for June 21, 2013 at 12:00 from AirNow-Tech Navigator.

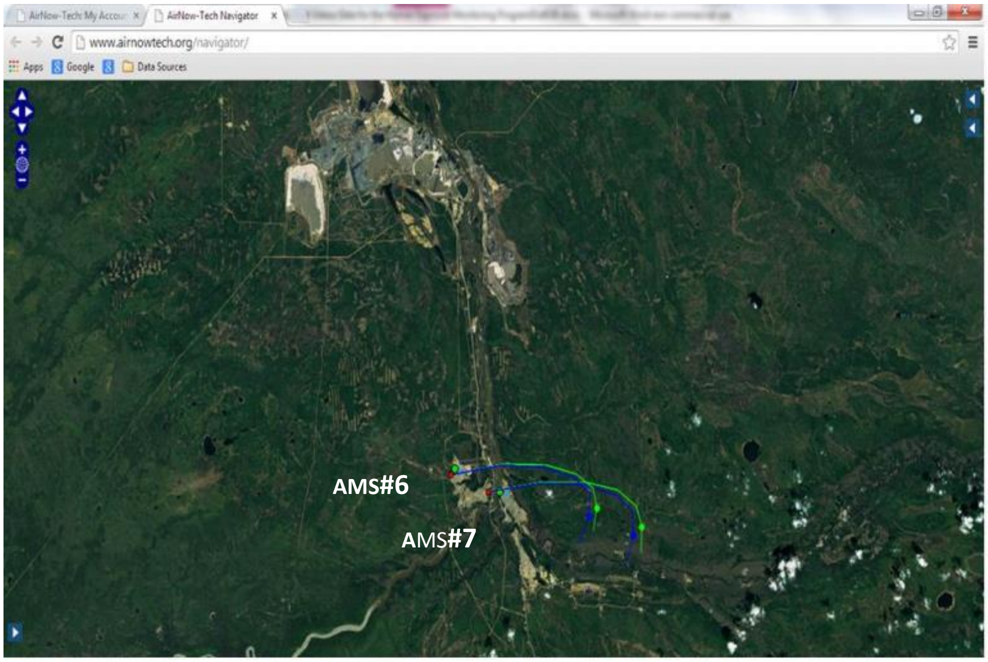


Figure 57: Twenty four-hour back trajectories for Fort McMurray at 50m (green) and at 100 m (blue) for June 21, 2013 at 12:00 from AirNow-Tech Navigator. Expanded view to show fire locations (red triangles) and smoke plumes.

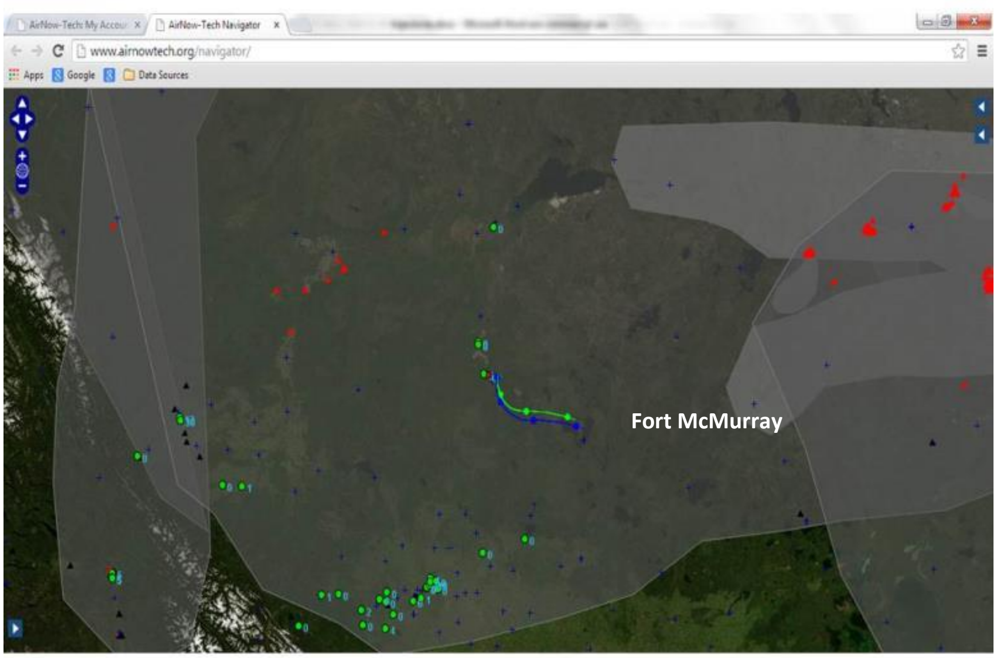


Figure 58: Twenty four-hour back trajectories for Fort McMurray at 50m (green) and at 100 m (blue) for July 5, 2013 at 12:00 from AirNow-Tech Navigator. Expanded view to show fire locations (red triangles) and smoke plumes.

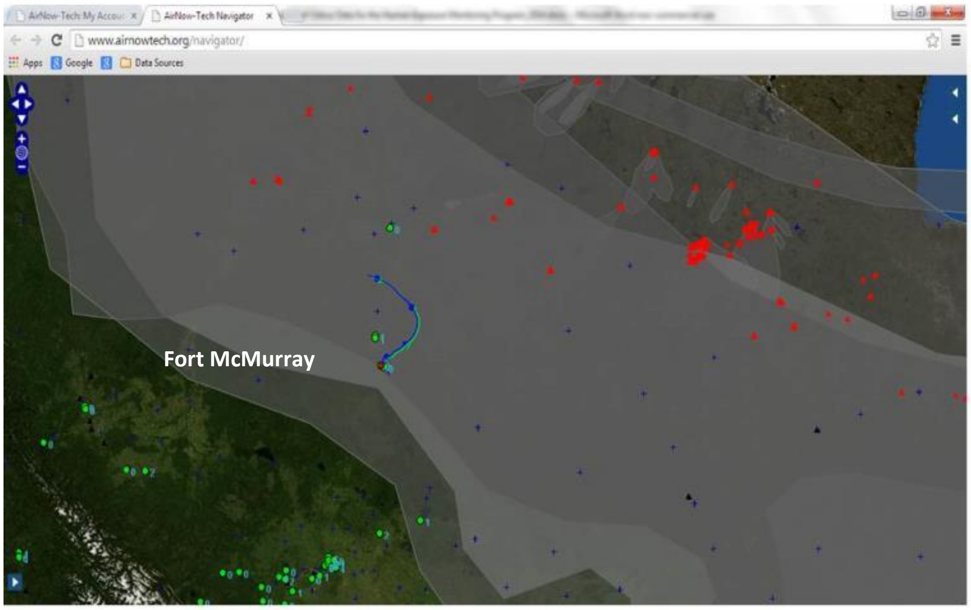


Figure 59: Six-hour back trajectories for Fort McMurray at 50m (green) and at 100 m (blue) for August 30, 2013 at 12:00 from AirNow-Tech Navigator.

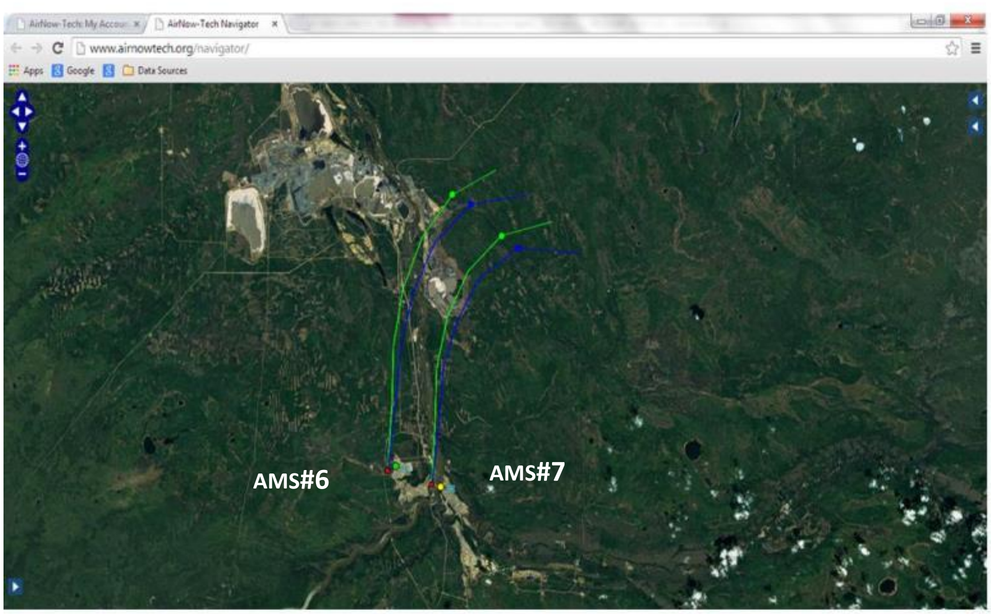
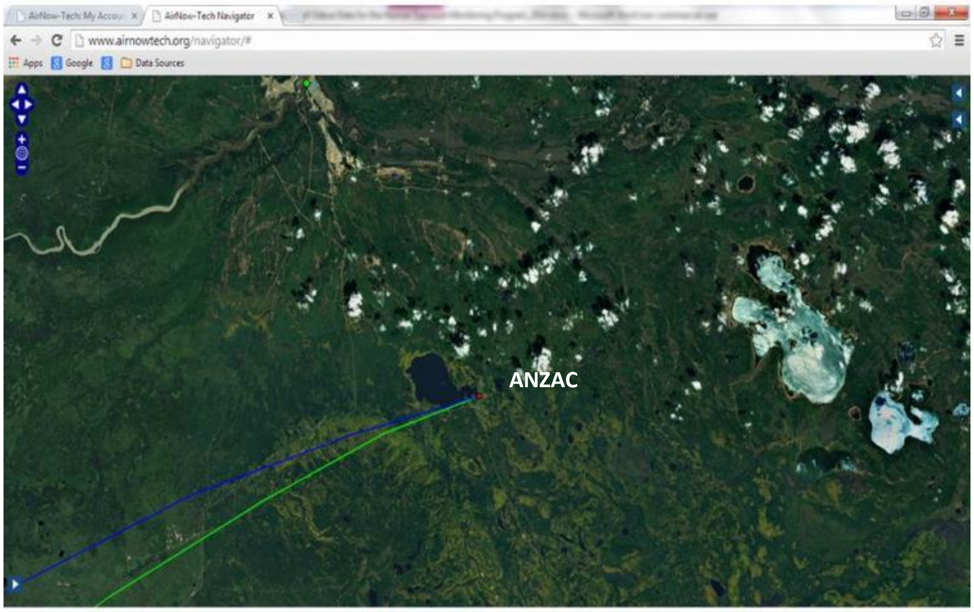


Figure 60: Six-hour back trajectories for Anzac at 50m (green) and at 100 m (blue) for November 12, 2013 at 15:00 from AirNow-Tech Navigator.



5.3 Correlation Analysis

5.3.1 Correlations between Sites for Selected Parameters

Correlations between the individual monitoring sites for TRS/H_2S, SO_2, derived NMHC (no NMHC correlations were greater than 0.3), NO and NO_2 are provided in Table 35 for all hours. Only the instances with correlation coefficients (r) greater than 0.4 (for NO_2 a cutoff of 0.5 was used) are shown in the Table. The distance between site pairs is also provided.

Not surprisingly the highest correlations for TRS were between Bertha Ganter and Barge Landing and Fort McKay South. As shown previously, the TRS from AMS#104 is very highly correlated with the H_2S from Mildred Lake and interestingly the next best correlations for TRS for Bertha Ganter are with these two sites. The Bertha Ganter and Fort McKay South sites also are well correlated for SO_2, NO and NO_2. The two Fort McMurray sites are well correlated for TRS, SO_2 and NO_2 but not for NO or NMHC. The parameter NO_2 showed the highest correlation over distances greater than 50 km.

5.3.2 Correlations between Parameters at Selected Sites

In Table 36 the correlations between parameter pairs for TRS/H_2S, SO_2, THC, methane, NMHC, NO, NO_2, and temperature (all other meteorological parameters were also investigated) for community sites are shown for all hours (only correlations > 0.5 are shown). The analysis was also carried out for hours with TRS concentrations equal to or greater than 1.5 ppb but there were no instances of TRS correlations greater than 0.3 with any parameter. The highest correlations were between THC and methane/NMHC, between NO and NO_2 and between NO_2 and temperature (inverse correlation).

In Table 37 correlations between selected parameters for all hours and for hours with an odour complaint are shown for the Fort McKay Bertha Ganter site including the eNose and the PFGC/SCD results. Correlations for PFGC and eNose data were conducted for different time periods as discussed in Section 5.1.3. Many of the VOC species were highly correlated with one another and with NMHC, sum of naphtha species and sum of aromatic species.

Table 38 shows correlation between parameters measured at the Patricia McInnes and Athabasca Valley sites for all COMP complaint hours.

Table 39 shows the correlation between the two PFGC instruments located at Bertha Ganter and AMS#104 for the time period both were operational. Also included are the hourly NMHC results. Since there was no correlation in NMHC between the two sites a good correlation between individual VOC at the sites would not be expected. The exceptions however were acetone and isoprene which are predominantly due to natural sources and were well correlated. There was also a modest correlation between 2&3-methylbutane at the sites suggesting that these species may also have a natural or area source.

Table 35: Correlation between Monitoring Sites for TRS/H_2S, SO_2, derived NMHC, NO and NO2 for All Hours (only correlations > 0.4 are shown).

SITE 1	SITE 2	DISTANCE BETWEEN SITES (km)	CORRELATION COEFFICIENT
TRS/H_2S			
AMS104	MILDRED LAKE	0	0.980
BERTHA GANTER	FORT MCKAY SOUTH	4	0.699
BERTHA GANTER	BARGE LANDING	3	0.686
BARGE LANDING	FORT MCKAY SOUTH	6	0.532
ATHABASCA VALLEY	PATRICIA MCINNES	6	0.505
BERTHA GANTER	AMS104	16	0.496
FORT MCKAY SOUTH	AMS104	12	0.416
SO_2			
BERTHA GANTER	FORT MCKAY SOUTH	4	0.751
ATHABASCA VALLEY	PATRICIA MCINNES	6	0.667
BERTHA GANTER	SHELL MUSKEG	10	0.500
CNRL HORIZON	FORT MCKAY SOUTH	18	0.491
BUFFALO VIEWPOINT	LOWER CAMP	6	0.468
BERTHA GANTER	CNRL HORIZON	14	0.438
FORT MCKAY SOUTH	SHELL MUSKEG	14	0.407
MILLENNIUM	BUFFALO VIEWPOINT	17	0.404
DERIVED NMHC			
MILDRED LAKE	AMS104	0	0.920
BUFFALO VIEWPOINT	MANNIX	7	0.541
MILLENNIUM	LOWER CAMP	17	0.414
NITRIC OXIDE			
BERTHA GANTER	FORT MCKAY SOUTH	4	0.812
BERTHA GANTER	SHELL MUSKEG	10	0.492
FORT MCKAY SOUTH	SHELL MUSKEG	14	0.446
BERTHA GANTER	MILLENNIUM	37	0.433
BERTHA GANTER	PATRICIA MCINNES	50	0.404
NITROGEN DIOXIDE			
BERTHA GANTER	FORT MCKAY SOUTH	4	0.861
BERTHA GANTER	MILLENNIUM	37	0.655
ATHABASCA VALLEY	PATRICIA MCINNES	6	0.625
ATHABASCA VALLEY	MILLENNIUM	17	0.617
BERTHA GANTER	CNRL HORIZON	14	0.599
BERTHA GANTER	PATRICIA MCINNES	50	0.590
CNRL HORIZON	MILLENNIUM	51	0.586
BERTHA GANTER	ATHABASCA VALLEY	53	0.581
FORT MCKAY SOUTH	PATRICIA MCINNES	45	0.557
FORT MCKAY SOUTH	MILLENNIUM	33	0.554
PATRICIA MCINNES	MILLENNIUM	16	0.539
FORT MCKAY SOUTH	ATHABASCA VALLEY	49	0.527
CNRL HORIZON	FORT MCKAY SOUTH	18	0.514

Table 36: Correlation between Selected Parameter Pairs at Community Sites for All Hours (only correlations > 0.5 or < -0.5 are shown).

Compound 1	Compound 2	CORR. (r)
	Bertha Ganter	
THC	METHANE	0.933
THC	NMHC	0.824
METHANE	NO_2	0.706
TRS	THC	0.656
THC	NO_2	0.653
METHANE	NITRIC OXIDE	0.653
TRS	METHANE	0.637
NITRIC OXIDE	NO_2	0.636
TRS	NO_2	0.621
THC	NITRIC OXIDE	0.614
METHANE	NMHC	0.580
TRS	NMHC	0.508
NO_2	TEMPERATURE	-0.556
	Patricia McInnes	
THC	METHANE	0.934
THC	NMHC	0.742
NITRIC OXIDE	NO_2	0.678
THC	NO_2	0.530
TRS	THC	0.523
METHANE	NO_2	0.517
THC	NITRIC OXIDE	0.513
METHANE	WIND SPEED	-0.425
NO_2	TEMPERATURE	-0.530
	Athabasca Valley	
THC	METHANE	0.946
NITRIC OXIDE	NO_2	0.718
THC	NMHC	0.581
NO_2	TEMPERATURE	-0.563
	Anzac	
THC	METHANE	0.956
THC	NMHC	0.583
NITRIC OXIDE	NO_2	0.561

Table 37: Correlation between Selected Parameters Measured at Fort McKay Bertha Ganter for All Hours (only correlations greater than 0.4 shown) and for Complaint Hours (selected correlations shown).

Compound 1	**Compound 2**	**CORR. (r)**
All Hours		
TRS	2&3MeHexane	0.407
TRS	AROMATIC	0.472
NMHC	Hexane	0.452
NMHC	AROMATIC	0.450
NMHC	SUM IDENTIFIED VOC	0.503
NO_2	Benzene	0.406
NO_2	224dMPentane	0.417
NO_2	2&3MeHexane	0.453
NO_2	Heptane	0.402
NO_2	AROMATIC	0.505
TEMPERATURE	CS_2	0.466
TEMPERATURE	Isoprene	0.519
TEMPERATURE	eNOSE MAX	0.400
COS	CS_2	0.606
Isoprene	eNOSE MEAN	0.410
Pentane	Hexane	0.596
eNOSE MEAN	eNOSE MAX	0.899
eNOSE MEAN	eNOSE DELTA	0.599
Complaint Hours		
SO_2	WIND SPEED	0.496
TRS	METHANE	0.679
TRS	AROMATIC	0.575
TRS	eNOSE DELTA	0.702
METHANE	AROMATIC	0.839

Table 38: Correlation between Selected Parameters Measured at Patricia McInnes and Athabasca Valley for COMP complaint Hours (only correlations greater than 0.4 shown).

Compound 1	**Compound 2**	**CORR. (r)**
Patricia McInnes		
TRS	THC	0.693
NMHC	NITRIC OXIDE	0.692
TRS	NMHC	0.674
THC	NO_2	0.663
TRS	METHANE	0.636
NMHC	NO_2	0.603
THC	NITRIC OXIDE	0.580
METHANE	NITRIC OXIDE	0.550
METHANE	NO_2	0.542
NITRIC_OXIDE	NO_2	0.524
NMHC	WIND SPEED	0.483
SO_2	TRS	0.425
METHANE	REL HUMID	0.406
TRS	NO_2	0.402
Athabasca Valley		
METHANE	NITRIC OXIDE	0.724
THC	NITRIC OXIDE	0.671
THC	NO_2	0.645
TRS	THC	0.619
METHANE	NO_2	0.600
SO2	TRS	0.596
NMHC	NO_2	0.586
TRS	METHANE	0.572
NMHC	METHANE	0.558
TRS	NO_2	0.518
TRS	NMHC	0.504
NITRIC_OXIDE	NO_2	0.495
METHANE	REL HUMID	0.488
TRS	NITRIC OXIDE	0.451
THC	REL HUMID	0.424

Table 39: Correlation between selected PFGC parameters and NMHC at Bertha Ganter and AMS#104 (September-December, 2013).

Compound	CORR (r)
Acetone	0.479
Isoprene	0.628
2&3MeButane	0.370
Pentane	0.045
2MePentane	-0.023
3MePentane	-0.006
Hexane	0.038
Toluene	-0.081
2&3MeHexane	0.015
Heptane	0.155
NAPHTHA	0.070
AROMATIC	-0.091
SUM_ID	0.149
NMHC	0.024

6 Discussion of Results

6.1 Issues Affecting Data Analysis and Integration

1. The eNose results were reprocessed to calculate hourly averages, the integer value of the difference between the maximum four-minute reading and the mean of all readings for each hour (DELTA) and the ratio of the standard deviation of the four-minute averages to their mean (coefficient of variation or CV). These latter two calculated values provide a measure of variability instead of an absolute reading and were also used in subsequent episode analysis. There was large variability in the absolute response and baseline of the eNose system through time and the data were processed in discrete data blocks. There was a notable step change in response for all values after the change of the instrument on August 14.
2. There was no successful calibration of the eNose carried out in 2013.
3. The PFGC response to some compound categories such as aromatics, heavy molecular weight species and sulphur containing species was variable through time at both locations. At the Bertha Ganter site the heavy MW weight species were not detected after a new PFGC was installed on June 11. Benzene was not detected after the change of instrument in August and toluene was not measured above detection for any hour beginning on October 1. At the AMS#104 site aromatics were not measured above zero until November 1. Naphtha species were detected consistently at both sites.
4. For the PFGC SCD measurements the target species: 2-methyl thiophene, 3-methyl thiophene, 2-ethyl thiophene, 2,5-dimethyl thiophene and 2,4-dimethyl thiophene were never found above detection during the year. No values above detection for carbonyl sulphide, carbon disulphide or the thiophenes were recorded at the AMS#104 site. Carbonyl sulphide and carbon disulphide were not detected at Bertha Ganter until the change in instruments in late August.
5. There were periods where COS and CS_2 concentrations were much higher than TRS levels measured at Bertha Ganter.
6. The co-location of the AMS#104 site with the Mildred Lake site allowed hourly TRS and H_2S data to be compared and on average the H_2S values were 83% of TRS and a similar ratio was measured during peak periods. However, emission estimates suggest H_2S only accounts for 7 to 42% of TRS emissions. TRS instruments thus may not respond proportionately to some of the other major sulphur containing species such as COS and CS_2.
7. Except for carbonyl sulphide and carbon disulphide, integrated canister RSC species concentrations were generally below detection at all sites.
8. There are uncertainties in emission estimates from stack and fugitive sources and a lack of correspondence of ambient to source SO_2/TRS ratios.
9. No data were available on process upsets or emission control equipment abnormalities at industrial sources.
10. There were no data on the most odorous VOC/RSC species emissions from sources in the airshed.
11. There are no routine methods currently implemented that are capable of detecting the most odorous VOC/RSC species such as mercaptans and cresols (see Table 1) in ambient air. The

cartridge samples collected by VOC Technologies in 2013 and analyzed by GC-MS have greater sensitivity and do indicate the presence of a number of substituted thiophenes in the air at the Mildred Lake site. These species may have low odour thresholds.

6.2 Main Observations

6.2.1 Air Quality Measurements

1. For the community sites there was only 1 hour with TRS greater than 10 ppb (Alberta AAQO) which occurred at Anzac. For the industrial sites there were 13 hours with H_2S greater than 10 ppb at Mannix and 5 hours at Mildred Lake. Of the community sites, Bertha Ganter recorded the highest hourly maximum SO_2 concentration and the highest annual mean. The peak hourly value recorded at the site did not exceed the Alberta 1h AAQO for SO_2, however.
2. A comparison of 2012 and 2013 TRS results shows that there was a reduction in maximum TRS concentration and in hours greater than 3 ppb at all sites with the largest change (90% reduction) at the Bertha Ganter site and the smallest change (30% reduction) at the Anzac site.
3. When the fifteen year data record (1999 to 2013) for TRS and H_2S data is examined, the year 2009 shows as a peak year in almost all the site records whereas the year 2013 is one of the lowest years in the records. The Anzac site is an exception with the highest values recorded in 2007 with little change in the later years. In 2013 Anzac recorded the highest 99th percentile TRS concentration and most hours greater than 3 ppb of the community sites.
4. Of the community sites, the highest mean and 90th percentile NO concentrations were measured at the Athabasca Valley and Bertha Ganter sites. Of the industrial sites, the highest concentrations were measured at the Millennium and Shell Muskeg River sites.
5. The highest NMHC concentrations were measured at Bertha Ganter but mean NMHC levels were very low at all sites as measured by the continuous method. The calculation of a derived NMHC resulted in much higher means and 90th percentile values possibly because the Fort McKay methane levels are lower than at the industrial sites.
6. For the ammonia measurements, only seven hours were above detection at Bertha Ganter and zero hours at Patricia McInnes.
7. Comparison of wind direction and wind speed in 2012 and 2013 for the Bertha Ganter and Athabasca Valley sites indicates there were no major differences in predominant wind direction between the two years for these sites.
8. Carbonyl sulphide was the most frequently reported RSC in the canister results. Carbonyl sulphide is the most abundant sulfur compound naturally present in the atmosphere because it is emitted from oceans, volcanoes and deep sea vents.
9. Mean concentrations of benzene ranged from 0.1 to 0.3 ppb across the sites with the highest mean recorded at AMS#15. Mean toluene concentrations showed more variability ranging from 0.1 ppb at AMS#9 to 3 ppb at AMS#13. Mean hexane concentrations ranged from 0.03 ppb at AMS#7 to 1.1 ppb at AMS#14.
10. The highest site to site correlations for TRS were between Bertha Ganter and Barge Landing and Fort McKay South. The TRS from AMS#104 was very highly correlated with the H_2S from Mildred Lake and the next best correlations for TRS for Bertha Ganter were with these two sites. The

Bertha Ganter and Fort McKay South sites also are well correlated for SO_2, NO and NO_2. The two Fort McMurray sites are well correlated for TRS, SO_2 and NO_2 but not for NO or NMHC. The parameter NO_2 showed the highest correlation over distances greater than 50 km.

11. The correlation between the two PFGC instruments located at Bertha Ganter and AMS#104 for the time period both was examined. Since there was no correlation in NMHC between the two sites a good correlation between individual VOC at the sites would not be expected. The exceptions however were acetone and isoprene which are predominantly due to natural sources and were well correlated. There was also a modest correlation between 2&3-methylbutane at the sites suggesting that these species may also have a natural or area source.

6.2.2 Odour Complaints

12. For the Community Odour Monitoring Project (COMP) there were 108 odour observations recorded between June 1 and December 31, 2013 (none in December). Some of these observations spanned multiple hours and the total hours with potential odour complaints amounted to 118 over the 6 month period. Of the approximately 35 participants in the program, fifteen reported odours between June and August and seven between September and December. Approximately half of the observations identified the odour as asphalt/tar or hydrocarbon/solvent. Eight of the complaint hours were associated with TRS values greater than or equal to 1.5 ppb at one or more of the sites. Approximately half (55 of 118) of complaint hours were associated with one of the air quality parameters at the 95th percentile value or higher. Most complaints were associated with NNE or NE wind directions and with wind speeds greater than 8 km/h.
13. For the Alberta Hotline complaints there were a total of 93 unique complaints recorded on 66 separate dates. For comparison, in 2012 there were a total of 76 complaints recorded on 53 separate dates. Thirty-five percent of the observations for 2013 identified the odour as hydrocarbon/oil.
14. Although there were 119 hours at the Bertha Ganter site with TRS concentrations greater than 1.5 ppb only two of these hours were associated with a complaint from Fort McKay to the Alberta Hotline. There was no consistent association between any of the other measured parameters and reported odours although the 95th percentile values were most commonly reached for NMHC. Most complaints were associated with SSE or N wind directions and with light to moderate wind speeds.
15. At Bertha Ganter for a number of episode dates there was an increase in SO_2 and or NMHC at the site either preceding or just after the complaint. When the data were available, naphtha levels also increased in conjunction with NMHC. In many cases there was not a sudden change in wind direction associated with the increasing pollution levels and the hour of complaint.
16. In Fort McMurray there was only one hour greater than 1.5 ppb of TRS associated with an Alberta Hotline complaint despite 66 hours greater than 1.5 ppb recorded at the Athabasca Valley site over the entire year. There was no consistent association between any of the other measured parameters and reported odours. Most complaints were associated with NW-NNW wind directions and wind speeds greater than 8 km/h.

17. For Anzac there were two hours greater than or equal to 1.5 ppb of TRS associated with a complaint to the Hotline despite 82 hours greater than 1.5 ppb recorded at the site over the entire year. The highest TRS concentration of 11.8 ppb was not associated with a recorded complaint. There was no consistent association between any of the other measured parameters and reported odours. Most complaints were associated with SE wind directions and light wind speeds.
18. The majority of odour complaints were associated with only a few wind directions at the community sites and are undoubtedly associated with specific sources. Meteorology appears to be an important element in odour complaints with some sites more susceptible to complaints with low wind speeds and stable dispersion conditions and other sites recording complaints with moderate wind speed persisting from a source direction.

6.2.3 Emissions

19. In general, estimated emissions of TRS, SO_2 and VOC increased from most facilities in 2012 as compared to 2011. Final NPRI emission data for 2013 are not yet available but based on a significant decline in ambient air concentrations of TRS, emissions likely decreased from 2012.
20. The lack of correspondence of emission TRS-H_2S/SO_2 ratios to ambient ratios is puzzling and may reflect an underestimation of fugitive TRS sources.
21. Based on NPRI data, for Suncor, total emissions of H_2S are estimated to be 7% of TRS emissions and for Syncrude H_2S emissions are estimated to account for 42% of TRS emissions.

7 Recommendations

The following preliminary recommendations are provided:

1. The recently implemented Community Odour Monitoring Program provides more consistent observations of odours and its renewal for another year should provide a valuable data set. Obtaining a similar record of community complaints from Fort McKay and Anzac would be useful. Some effort should be made to determine if COMP participation is remaining constant and if all volunteers are still active in the program. The reasons for the lack of overlap in the Alberta Hotline vs COMP complaints would be useful to investigate.
2. The performance of the eNose system remains a puzzle and the step changes in response and lack of directionality in results regardless of the processing methods employed resulted in the data being of very limited value.
3. The PFGC system is the only instrument deployed that is capable of producing hourly estimates of specific VOC and RSC that would be useful in identifying specific sources during complaint periods so it is of great value to any odour characterization efforts. A more frequent review of data from the unit is required and data should be better flagged as to when the instrument is not resolving species versus the cases when species are not being detected. Based on the limited amount of useful data from the SCD it may be best to rethink the target list of species for the detector and possibly optimize its response to COS and CS_2. It may also be beneficial to increase the frequency of cartridge GC-MS analyses carried out by VOCTEC in conjunction with the PFGC operation and make the results quantitative instead of qualitative.

4. Detection levels for the canister sampling are too high to identify any of the most odorous target species and either the measurements should be terminated or improvements in detection levels should be sought.
5. The THC measurements are serving no useful purpose for odour identification and it's not clear that the data serve any other purpose. Since many of the complaints refer to hydrocarbon odours, additional effort may be required to identify and routinely measure odorous VOC species.
6. A database for all observations should be developed and maintained to allow easy integration of data. Annual updates in data analysis should be carried out to allow an assessment of changes in odour incidents in the region.
7. The response of TRS instrumentation to other RSC such as carbonyl sulphide and carbon disulphide should be investigated.
8. Data on source and control equipment operations during complaint periods should be obtained to see if there are any linkages.
9. There is a disconnect between odour complaints and elevated levels of currently measured ambient species suggesting that the specific compounds responsible for complaints are not being measured and/or detected. It may be more beneficial to carry out source emission characterization for a list of candidate odorous compounds than to implement more ambient measurement programs. The strong directionality of odour complaints at all community sites suggests that there are specific sources responsible for the odour complaints.

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Appendix A:

Figure A1: Legend for Appendix A Figures.

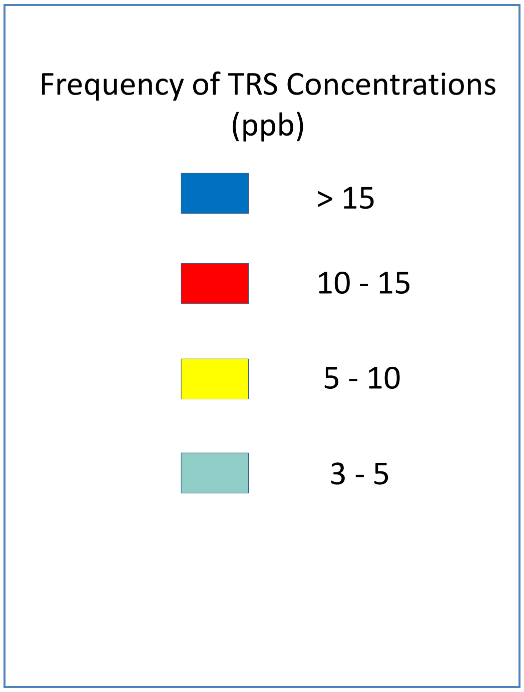


Figure A2: Counts of H_2S Values greater than 3, 5, 10 and 15 ppb by Wind Direction at Mildred Lake.

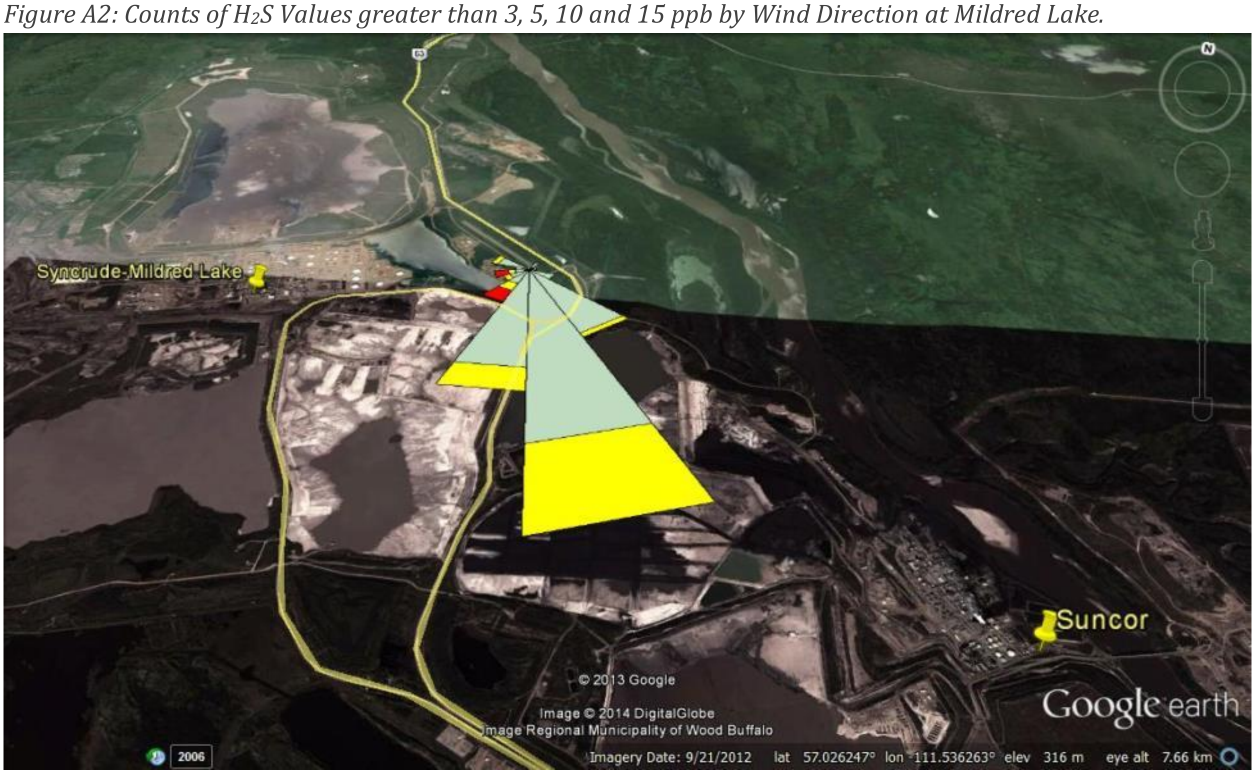


Figure A3: Counts of H_2S Values greater than 3, 5, 10 and 15 ppb by Wind Direction at Buffalo Viewpoint.

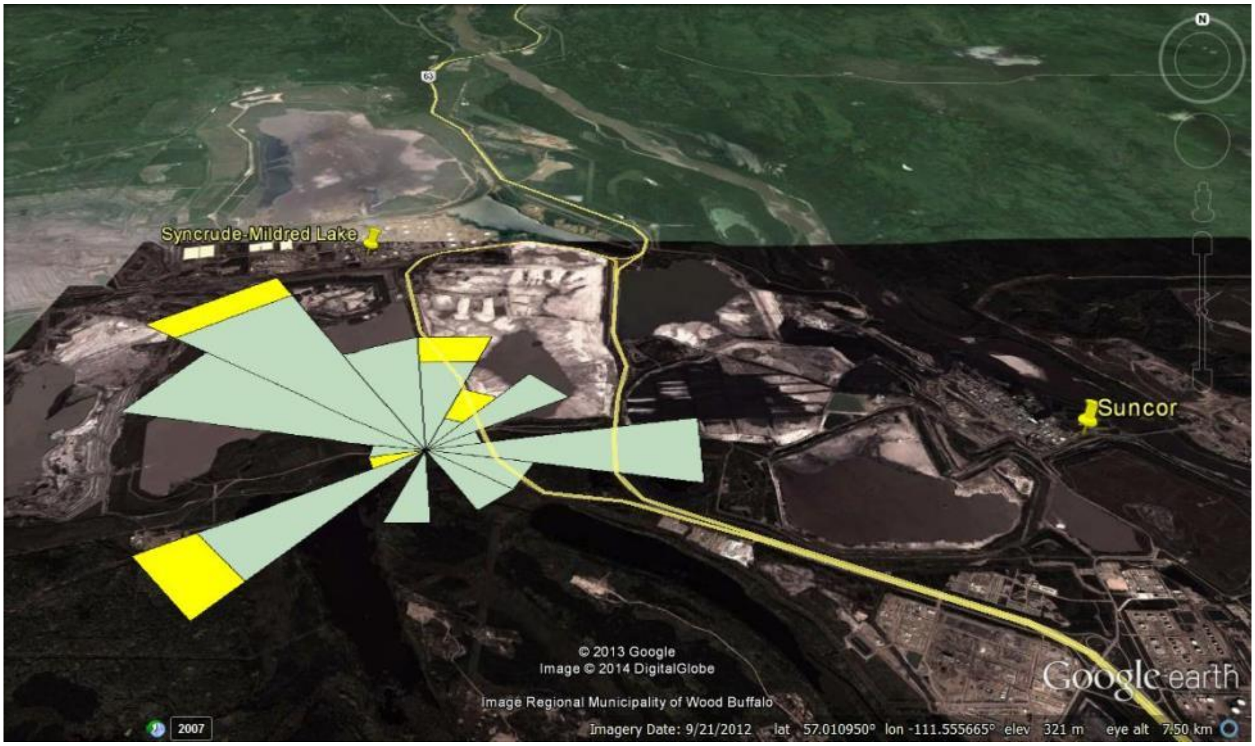


Figure A4: Counts of H_2S Values greater than 3, 5, 10 and 15 ppb by Wind Direction at Mannix.

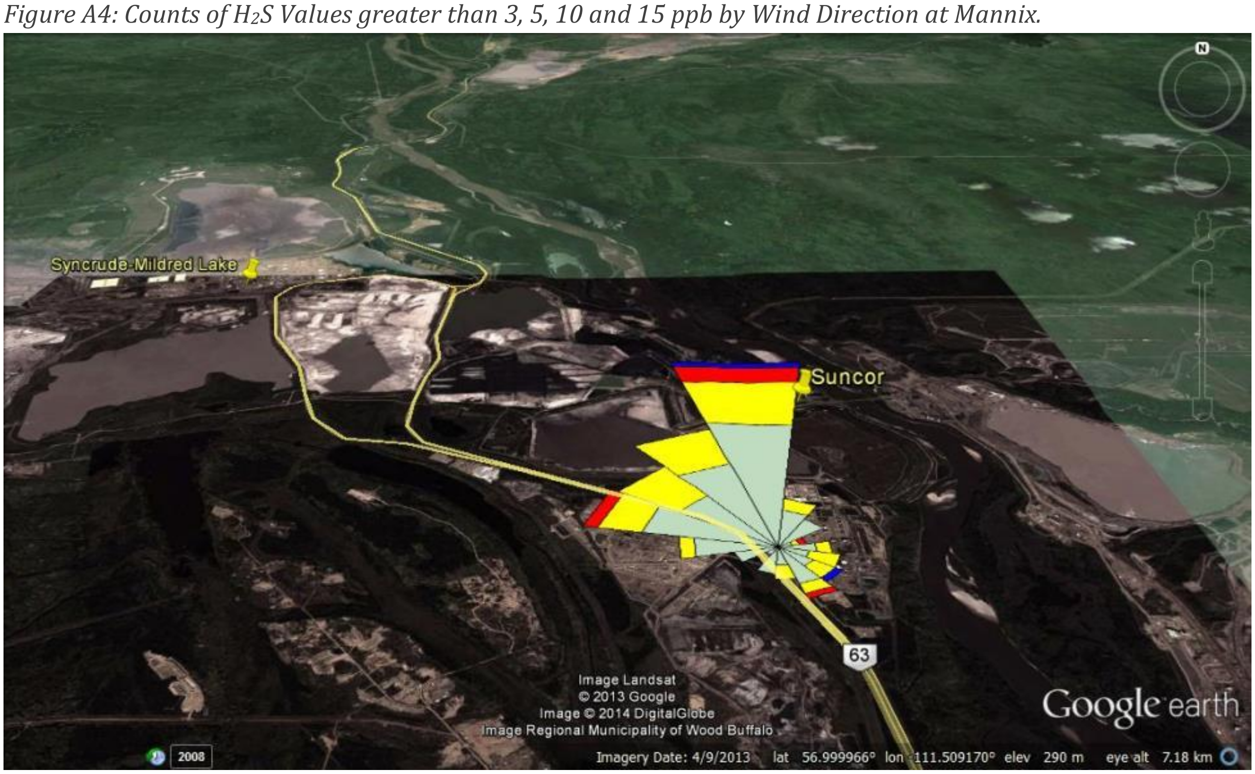


Figure A5: Counts of TRS Values greater than 3, 5, 10 and 15 ppb by Wind Direction at Barge Landing.

Figure A6: Counts of H_2S Values greater than 3, 5, 10 and 15 ppb by Wind Direction at Lower Camp.

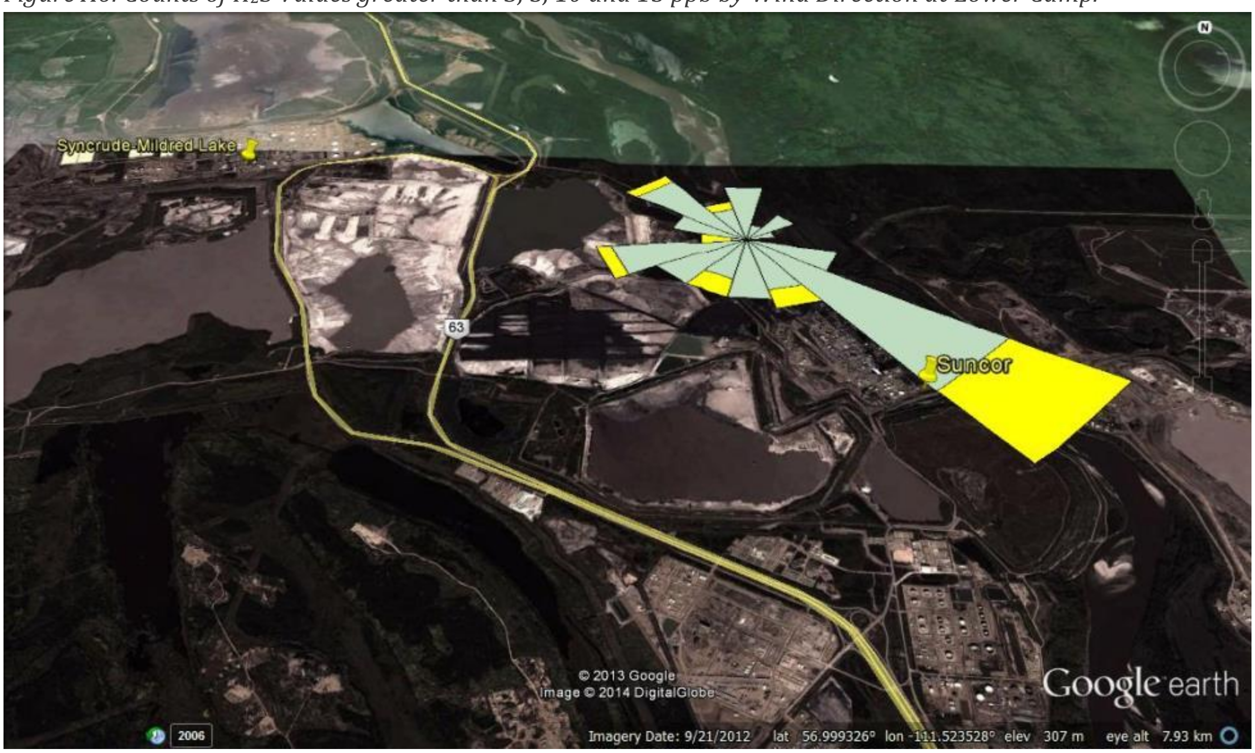
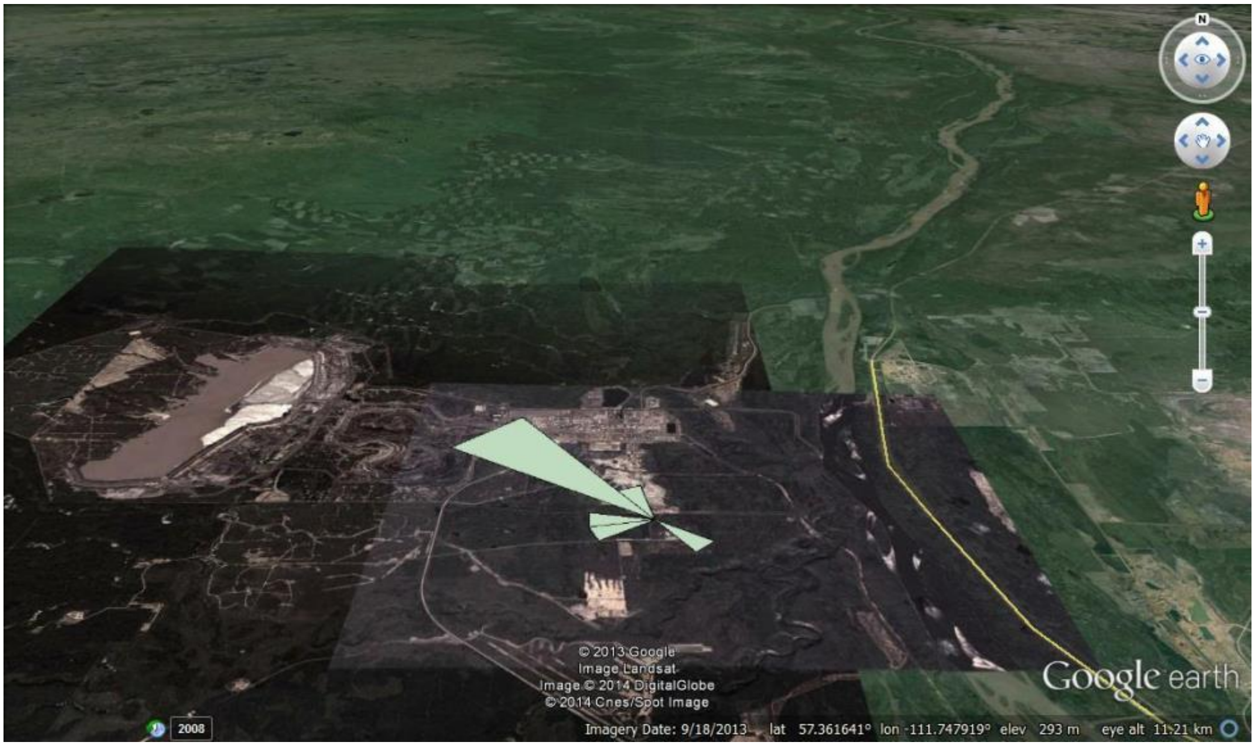


Figure A7: Counts of TRS Values greater than 3, 5, 10 and 15 ppb by Wind Direction at Millenium.

Figure A8: Counts of TRS Values greater than 3, 5, 10 and 15 ppb by Wind Direction at Fort McKay South.

Figure A9: Counts of TRS Values greater than 3, 5, 10 and 15 ppb by Wind Direction at CNRL Horizon.



Appendix B:

Table B1: Meteorological Parameters for Bertha Ganter on Complaint Days.

Incident Date	Incident Time	WIND DIR (°)	WIND SDEV	WIND SPEED (km/h)	TEMP (°C)	PRECIP	LOWER CAMP TOWER	
							DELTA (°C)	WIND DIR (100m)
2/26/13	16	111	29	3	-2	0	0.8	296
3/27/13	8	172	6	5	-2.2	0	0.4	148
5/3/13	20	17	20	6	15.3	0	-1.3	352
5/3/13	21	18	19	6	12.2	0	-1.1	358
5/3/13	22	14	20	5	8	0	-0.6	6
5/23/13	11	143	42	8	25.6	0	-1.4	139
6/4/13	9	186	16	6	24	0	0.5	159
6/14/13	9	276	51	3	19.6	0	0.7	216
6/20/13	23	355	26	6	16.3	0		
6/25/13	8	344	11	4	20.3	0	1.0	82
7/9/13	10	200	49	6	22.5	0	0.5	153
7/9/13	13	160	4	10	27.9	0	-0.4	139
7/26/13	8	159	2	8	19	0	0.7	161
7/30/13	8	280	41	1	13.1	0	0.0	287
7/30/13	15	218	99	7	23.4	0	-1.8	267
8/2/13	8	344	26	3	14.6	0	0.9	123
8/8/13	9	294	56	2	17.2	0	1.4	61
8/24/13	10	246	44	3	21.4	0	1.2	157
9/15/13	8	286	15	3	6.3	0	0.5	144
9/29/13	13	342	10	5	14	0	3.2	9
10/18/13	10	176	16	4	9	0	0.1	186
10/18/13	9	185	19	4	8.3	0	-0.1	179
11/6/13	11	182	4	10	0.1	0	0.1	152

Table B2: Meteorological Parameters for Patricia McInnes (AMS#6) and Athabasca Valley (AMS#7) on Complaint Days.

Incident Date	Incident Time	AMS 7 WIND DIR	AMS 6 WIND DIR	AMS 7 WIND SDEV	AMS 6 WIND SDVEV	AMS 7 WIND SPEED	AMS6 WIND SPEED	TEMP (°C)	PRECIP	LOWER CAMP TOWER	
										WIND DIR (100 m)	DELTA (°C)
2/12/13	1	250		8		16.2		1.4	0	261	1.4
3/14/13	1	341		1		16.5		-19.2	0	2	-1.3
5/6/13	10	77		46		1.9		14.9	0	129	4.2
5/31/13	7		332		7		8.1		0	6	0.3
6/20/13	13	324	29	45	22	2.9	4.6	24.1	0	307	-0.9
6/21/13	12	95	149	25	34	4.5	4.1	24.2	0	134	0.0
6/21/13	12	95	149	25	34	4.5	4.1	24.2	0	134	0.0
6/21/13	12	95	149	25	34	4.5	4.1	24.2	0	134	0.0
7/18/13	21	358		13		8.7		22.1	0	4	-1.1
7/26/13	9	128	178	12	32	3.7	4.4	21.5	0	165	0.5
8/14/13	17	201	177	43	27	8.5	12.6	28.8	0	187	-1.3
8/21/13	20	226	243	29	15	14.8	16.4	18.9	0	245	-1.6
8/25/13	17	328	334	8	21	15.2	16.7	18.2	0	338	-1.0
8/26/13	1	101	251	82	58	3.4	4.1	11.8	0	112	0.4
8/26/13	15	13	60	59	63	8.7	8.1	19	0	355	-1.1
8/30/13	1	339		2		10.1		14.8	0	1	-0.3
8/30/13	1	339	338	2	8	10.1	11.1	14.8	0	1	-0.3
8/30/13	1	339	338	2	8	10.1	11.1	14.8	0	1	-0.3
9/3/13	10	121	206	10	65	4.5	4.1	11.2	0	81	0.4
9/10/13	17	310	293	6	8	22.6	23.1	21.8	0	309	-1.9
9/27/13	10	155	191	5	23	6.2	6.1	6.9	0.25	162	-0.9
11/19/13	1	344	346	3	6	9.2	12.1	-17.6	0	10	-0.6
11/19/13	11	341	341	2	3	13.1	14.0	-19.3	0	6	-1.3
11/19/13	12	341	341	2	3	14.0	14.4	-18.9	0	6	-1.3
11/19/13	13	342	340	2	3	14.3	14.7	-18.4	0	5	-1.4
11/19/13	13	342	340	2	3	14.3	14.7	-18.4	0	5	-1.4
11/19/13	14	342	339	2	2	13.9	14.6	-17.9	0	4	-1.5
11/19/13	16	344	339	3	1	12.8	15.6	-18.1	0	2	-1.6
12/9/13	16	95	81	66	89	4.0	5.2	-16.6	0	103	4.0
12/24/13	1	292	288	36	20	8.2	10.4	-13.1	0	298	-0.1

Table B3: Meteorological Parameters for Anzac on Complaint Days.

Incident Date	Incident Time	WIND DIR	WIND SDEV	WIND SPEED	TEMP (°C)	PRECIP	LOWER CAMP TOWER	
							DELTA	WIND DIR (100 m)
1/27/13	12	26	7	3.5	-7.3	0		167
1/28/13	1	250	54	3.9	-12.1	0	-1.02	3
3/19/13	11	82	19	3.9	-5.7	0	4.62	158
4/15/13	9	335	10	3.3	2.2	0	3.18	0
9/23/13	14	139	28	5.3	15.2	0	0.22	188
11/12/13	11	172	4	7.3	-2.4	0	4.47	159
11/12/13	13	145	46	5.6	-1.4	0	3.15	160
11/12/13	15	130	40	3.8	-0.2	0	1.72	162
11/26/13	7	144	6	8.2	-10.6	0	3.30	146
11/30/13	10	154	15	5.8	-5.5	0	3.80	155
12/29/13	9				-30.7	0	3.68	150
12/30/13	11	273	16	3.1	-33.9	0	7.10	195

Table B4: Meteorological Parameters for Mildred Lake on Complaint Days.

Incident Date	Incident Time	WIND DIR	WIND SDEV	WIND SPEED	PRECIP	LOWER CAMP TOWER	
						DELTA	WIND DIR (100 m)
1/24/13	16	146	5	11.3	0	-1.2	147
4/18/13	8				0	0.8	127
5/5/13	22	325	21	19.8	0	-1.3	331
5/9/13	7	359	4	7.3	0	0.6	28
5/9/13	16	288	48	7.7	0	-1.9	302
5/15/13	8	167	29	5.1	0	1.2	173
5/15/13	16	188	60	9.9	0	-1.7	202
5/24/13	3	123	10	11.3	0	0.3	142
6/5/13	16	164	45	11.7	0.76	-1.2	163
6/6/13	17	296	8	17.2	0	-2.0	302
6/22/13	19	155	50	9.1	0	-1.2	145
7/15/13	20	330	5	16.9	0	-1.2	338
7/16/13	1	341	9	12.7	0	-0.6	349
8/19/13	8	240	3	14.5	0	-0.9	244
8/22/13	8	165	12	9.1	0	0.0	156
8/26/13	13	154	86	4.5	0	-0.8	
9/4/13	8	150	2	9.5	0	2.2	157
9/4/13	18	200	36	12.6	0	-1.0	204
9/11/13	8	171	40	3.9	0	2.4	179
9/25/13	17	27	36	6.3	0	-1.6	4
9/30/13	8	4	7	11.5	0.25	-0.7	0
9/30/13	16	12	3	15.6	1.02	-1.0	12
10/7/13	8	121	20	8.0	0	-0.8	135
10/15/13	15	297	18	19.3	0	-1.2	290
10/16/13	15	283	25	11.3	0	-1.5	278

Table B5: Meteorological Parameters for Patricia McInnes and Athabasca Valley on COMP Complaint Days.

DATE	HOUR	WIND DIR		WIND SDEV		WIND SPEED		TEMP	PRECIP	Lower Camp Tower	
		AMS6	AMS7	AMS6	AMS7	AMS6	AMS7			DELTA	WIND DIR
9/29/13	11	105	78	29	20	6.4	3.6	9.9	0	4.9	100
9/29/13	13	100	52	48	50	8.1	4.6	13.7	0	3.2	9
9/11/13	6	237	103	41	31	4.3	3.4	5.6	0	2.3	125
6/19/13	6	325	301	8	33	8.6	4.4	14.1	0	1.9	354
6/21/13	10	177	118	40	18	3.4	4.0	22.7	0	1.7	149
6/19/13	7	326	304	9	37	8.3	5.3	15.2	0	1.7	351
6/23/13	9	185	150	24	14	4.1	4.7	14.7	0	1.6	170
8/23/13	8	243	98	41	30	3.2	2.6	13.8	0	1.5	288
8/23/13	9	250	90	37	29	3.4	2.5	16	0	1.4	313
8/25/13	10	167	139	45	21	3.2	4.9	15.3	0	1.3	166
7/21/13	8	256	131	75	5	3.4	6.1	15.7	0	1.2	216
8/23/13	10	254	89	33	28	2.8	2.2	18.3	0	1.2	342
8/26/13	4	205	121	37	10	3.3	3.7	9.9	0	0.9	181
6/21/13	11	163	106	42	22	3.7	4.4	24.9	0	0.9	137
7/5/13	5	330	207	61	86	6.0	5.2	15.6	0	0.8	111
8/26/13	3	212	129	31	31	3.0	2.8	10.6	0	0.8	168
7/5/13	6	325	220	60	76	5.0	4.5	15.9	0	0.7	78
11/29/13	7	220	193	6	39	15.1	8.3	-2.2	0	0.7	218
8/5/13	11	294	112	48	77	5.1	2.7	21.1	0	0.7	333
7/4/13	10	192	124	21	51	6.8	4.3	24.5	0	0.7	238
8/1/13	6	323	328	9	23	8.8	5.6	11.9	0	0.6	356
8/1/13	1	327	328	18	17	9.6	7.5	14.7	0	0.5	12
7/24/13	5	305	272	13	29	7.5	5.5	13.7	0	0.5	346
10/19/13	8	251	215	80	59	3.1	2.0	2	0	0.5	158
8/7/13	11	11	32	36	44	4.2	2.3	17.7	0	0.4	28
9/13/13	11	348	346	4	5	13.8	8.7	17.8	0	0.3	356
7/24/13	6	308	277	14	38	8.2	6.3	13.2	0	0.3	340
8/22/13	21	270	275	76	69	11.4	8.8	19.8	0	0.2	263
7/30/13	6	264	183	28	49	6.4	3.1	10	0	0.1	294
7/5/13	9	265	243	45	51	6.4	5.4	16.4	0	0.1	341
8/29/13	2	307	322	24	52	7.2	4.8	16	0	0.1	350
6/21/13	12	149	95	34	25	4.1	4.5	24.2	0	0.0	134
8/29/13	1	294	303	32	66	7.6	5.6	16.7	0	-0.1	351
8/27/13	2	300	289	14	21	7.1	6.3	14.9	0	-0.1	357
8/27/13	1	305	293	21	31	7.2	5.5	15.5	0	-0.1	6
8/27/13	3	304	293	19	28	6.9	6.6	14.6	0	-0.2	348
11/13/13	7	294	295	15	33	19.8	16.9	-1.4	0	-0.2	331
8/28/13	10	226	158	5	31	11.0	4.0	19	0	-0.2	255
6/20/13	12	17	340	27	65	4.3	2.8	23.3	0	-0.3	335
8/25/13	13	9	33	86	96	6.6	5.7	17.3	1.02	-0.3	302
7/28/13	5	42	28	22	32	7.4	3.2	14.3	1.27	-0.3	38
8/5/13	13	337	16	34	70	10.1	5.9	22.7	0	-0.3	357
7/23/13	6	28	51	58	45	7.0	3.5	15.1	0	-0.4	49

7/28/13	4	46	41	18	34	7.6	3.2	14.2	3.56	-0.4	53
7/23/13	7	6	38	59	56	7.2	3.8	15.1	0	-0.4	25
DATE	HOUR	WIND DIR		WIND SDEV		WIND SPEED		TEMP	PRECIP	Lower Camp Tower	
		AMS6	**AMS7**	**AMS6**	**AMS7**	**AMS6**	**AMS7**			**DELTA**	**WIND DIR**
8/27/13	4	310	306	13	24	6.5	6.4	14.4	0	-0.4	344
9/13/13	12	349	346	4	5	13.9	9.7	19	0	-0.4	354
9/13/13	12	349	346	4	5	13.9	9.7	19	0	-0.4	354
6/26/13	7	115	147	8	22	7.6	2.9	17.4	0	-0.4	130
6/26/13	7	115	147	8	22	7.6	2.9	17.4	0	-0.4	130
8/30/13	6	327	337	7	5	8.1	7.4	13.8	0	-0.5	1
8/30/13	6	327	337	7	5	8.1	7.4	13.8	0	-0.5	1
10/31/13	15	210	73	100	67	6.1	4.9	5.4	0	-0.5	288
8/29/13	24	343	339	8	1	12.0	11.1	15.3	0	-0.5	4
8/27/13	5	306	322	16	38	5.5	6.0	14.3	0	-0.5	345
7/29/13	6	294	291	4	10	16.1	20.0	11.4	0	-0.6	316
7/28/13	8	359	347	28	23	7.5	4.2	14.4	0	-0.6	24
6/15/13	7	319	331	5	5	15.6	11.5	13.9	0	-0.6	338
8/24/13	14	150	121	12	54	6.5	6.1	23.8	0	-0.6	151
7/29/13	7	293	287	4	8	16.0	20.2	11.7	0	-0.6	315
6/1/13	9	125	147	18	11	7.3	7.2	15.3	0	-0.6	143
8/29/13	23	347	339	9	1	12.9	11.7	15.9	0	-0.7	8
8/28/13	11	232	172	14	38	9.9	4.1	20.6	0	-0.7	259
8/30/13	7	332	339	11	5	8.0	7.5	13.8	0	-0.7	1
7/29/13	8	292	285	3	6	16.3	19.8	11.8	0	-0.7	315
8/5/13	14	357	27	28	45	12.4	7.5	21.3	0	-0.7	21
8/30/13	8	334	338	10	5	8.5	7.9	14	0	-0.7	3
7/28/13	15	280	271	20	25	9.7	10.0	15.6	2.29	-0.8	354
7/23/13	10	332	338	15	16	10.7	6.8	17.2	0	-0.8	
11/18/13	6	341	352	7	3	7.4	6.8	-16	0	-0.8	0
7/3/13	5	208	140	20	29	11.2	5.7	18.6	0	-0.8	242
8/29/13	22	349	338	8	1	13.6	12.5	16.6	0	-0.8	10
6/11/13	6	334	329	9	7	13.3	11.7	9.5	0.25	-0.8	357
8/5/13	15	15	25	30	40	14.4	8.7	21.4	0	-0.9	49
8/5/13	15	15	25	30	40	14.4	8.7	21.4	0	-0.9	49
6/11/13	7	335	328	10	7	12.9	10.5	9.4	0.25	-0.9	358
7/5/13	13	178	177	31	30	5.7	4.9	16.2	0	-0.9	60
6/9/13	8	322	324	6	4	19.9	18.3	9.9	3.56	-0.9	342
11/18/13	7	340	352	7	3	7.8	6.8	-16.3	0	-0.9	359
11/18/13	7	340	352	7	3	7.8	6.8	-16.3	0	-0.9	359
7/16/13	7	322	334	16	17	9.3	10.3	11.8	0	-0.9	344
10/2/13	4	348	342	5	14	8.8	7.1	6.3	0	-0.9	6
6/9/13	10	320	323	4	3	20.5	19.2	9.9	1.78	-0.9	346
6/9/13	4	341	338	8	7	21.8	18.8	9.6	1.02	-1.0	356
10/8/13	13	293	250	47	62	8.8	6.1	7.4	0	-1.0	22
9/26/13	11	316	323	9	7	7.3	6.7	9.8	0	-1.0	345
7/5/13	14	172	167	28	27	5.7	4.5	16.2	0	-1.1	111
6/30/13	13	174	161	14	28	13.4	9.5	27.6	0	-1.1	170
6/9/13	12	325	326	7	6	23.5	23.2	9.9	1.02	-1.1	353
8/26/13	15	60	13	63	59	8.1	8.7	19	0	-1.1	355
9/13/13	20		338		40		7.6	16.3	0	-1.2	4

7/5/13	15	164	151	14	25	4.6	3.8	16.1	0	-1.2	145
6/19/13	12	1	352	13	11	9.7	7.5	24	0	-1.2	348
DATE	HOUR	WIND DIR		WIND SDEV		WIND SPEED		TEMP	PRECIP	Lower Camp Tower	
		AMS6	**AMS7**	**AMS6**	**AMS7**	**AMS6**	**AMS7**			**DELTA**	**WIND DIR**
6/25/13	16	102	172	18	89	7.8	5.7	25.7	0	-1.2	144
6/15/13	17	1	5	13	18	15.7	9.4	15.2	0	-1.2	19
8/26/13	16	37	356	43	35	9.8	10.2	19.6	0	-1.3	358
7/4/13	20	297	301	30	55	6.5	5.5	23.8	0	-1.3	347
7/7/13	14	100	41	35	81	4.5	2.8	17.2	0	-1.3	348
8/29/13	9	351	342	5	12	12.9	11.6	15	0	-1.3	19
8/30/13	14	338	342	5	2	10.6	9.0	20	0	-1.3	356
9/9/13	15	316	358	6	35	14.3	7.8	24.1	0	-1.4	330
9/26/13	20	1	348	23	15	8.8	6.1	10.2	0	-1.4	32
8/28/13	16	269	323	7	66	9.5	5.8	23.9	0	-1.4	356
9/25/13	18	30	355	8	5	14.0	9.2	13.7	0	-1.5	9
6/19/13	18	39	84	23	9	12.8	10.6	25.5	0	-1.5	46
9/13/13	18		342		10		10.5	21.2	0	-1.5	359
6/29/13	16	150	311	67	67	5.4	3.4	24.7	1.27	-1.6	132
7/23/13	16	357	339	11	3	16.0	13.7	22.3	0	-1.6	3
7/18/13	18	348	359	21	10	11.5	8.4	25.1	0	-1.6	355
7/4/13	14	277	43	71	64	8.9	4.6	26.8	0	-1.7	257
8/29/13	18	348	342	7	4	12.2	12.4	20.2	0	-1.7	357
8/29/13	15	345	339	5	7	11.8	12.5	21.4	0	-1.8	4
7/21/13	13	4	7	34	64	5.7	5.5	23.1	0	-1.8	330
7/4/13	15	292	17	48	66	9.5	5.3	27	0	-1.8	278
8/1/13	14	4	344	12	4	10.7	8.8	19.5	0	-1.8	349
7/4/13	16	302	353	10	58	9.3	5.6	27.6	0	-1.9	275
7/4/13	17	309	348	10	31	9.8	6.6	26.9	0	-1.9	285
7/21/13	15	358	338	18	11	7.6	7.9	23.8	0	-2.2	334